

Transportation systems in buildings

CIBSE Guide D: 2015



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Note from the publisher

This publication is primarily intended to provide guidance to those responsible for the design, installation, commissioning, operation and maintenance of building services. It is not intended to be exhaustive or definitive and it will be necessary for users of the guidance given to exercise their own professional judgement when deciding whether to abide by or depart from it.

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Foreword to the fifth edition

This fifth edition of CIBSE Guide D: *Transportation systems in buildings* is the result of extensive review and revision by a dedicated and enthusiastic team comprising lift and escalator specialists and building service engineers.

It is very significant that this work was undertaken on an entirely voluntary basis. Both the time and resources generously provided by those involved, including their companies, were very considerable.

This latest edition of the Guide is very comprehensive covering the whole spectrum of interior circulation, planning and design, selection of equipment and performance, computer programmes, types of systems, legislation, fire and safety, requirements for persons with disabilities, lift components, lift traffic controls, escalators and moving walkways (passenger conveyors), energy consumption, electrical systems and environmental conditions.

Since its inception Guide D has become the *de facto* reference for many people involved in the broad and varied world of vertical transportation. The Guide provides the reader with a wealth of information and recommendations on key issues relating to vertical transportation systems. The Guide is not only a key source of information for those who work within the vertical transportation industry but is also a valuable source of information for architects, developers and those involved in the management of estates and individual buildings.

It is important that people, goods and equipment are moved safely and efficiently. I believe that this latest edition of CIBSE Guide D: *Transportation systems in buildings* will help meet those objectives.

Finally, I wish to acknowledge the very valuable assistance of the staff of the CIBSE Publications Department, the CIBSE Lifts Group and the members of the Guide D Steering Committee.

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Important note

Note that BS EN 81-1: 1998: *Safety rules for the construction and installation of lifts. Electric lifts* and BS EN 81-2: 1998: *Safety rules for the construction and installation of lifts. Hydraulic lifts* will be withdrawn from 31 August 2017 and replaced by BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transportation of persons and goods. Passenger and goods passenger lifts* and BS EN 81-50: 2014: *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components*.

For up-to-date information on British Standards and other developments within the lifts and escalator industry, refer to the CIBSE Lifts Group website (<http://www.cibseliftsgroup.org>).

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1 Introduction

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1 Introduction

1.1 Purpose of Guide D

The purpose of CIBSE Guide D is to provide guidance to practitioners involved in such systems. The Guide should also be of interest to architects and developers, along with facilities and building managers who may not be directly concerned with the design and installation of lifts and escalators but need to understand the advice offered to them by specialists. Not least, the Guide should be of value to students embarking on a career in mechanical, electrical or building services engineering and those already practising in these disciplines who wish to enhance their knowledge through a programme of continuing professional development.

1.2 Recent developments

During recent years we have seen the machine-room-less lift (MRL) become firmly established in the global marketplace with an ever broadening range of applications, speeds and duty loads. Now, for many buildings, the MRL lift is an appropriate provision offering significant benefits in terms of reduced space and capital cost. The machine-room-less range of traction drive lifts also includes a counterweight less lift. The MRL installation is not without its disadvantages to lift maintenance personnel and others who are now required to carry out their activities on public landings with the consequential risks so resulting. The lack of the machine room also removes from the lift practitioner the actual observation of machines, brakes and ropes, etc.

One of the key items restricting the length of travel for a conventional lift is the weight of the hoisting ropes, which effectively limited travel to some 500 m. After several years of development a carbon-fibre rope covered in a friction-proof coating is now available which could potentially permit a travel distance of 1 km.

Looking forward the next major step in lift technology could be lifts powered by linear drives, which could permit lifts to move horizontally as well as vertically. This technology was first demonstrated in 1996 in a system known as Odyssey and was installed in Disney World's 'The Twilight Zone Tower of Terror'TM in Florida. The proposed prototype system has no ropes and allows several lifts to operate in the same shaft moving horizontally and vertically on the circular principle first seen in paternoster lifts. This move away from conventional roped systems will be followed with interest, as will the response from the other major international manufacturers. The use of ropeless magnetic levitation lifts was predicted by Dr Gina Barney as far back as 1985 (Barney and dos Santos, 1985) and it appears that this idea has now come to fruition.

Destination control technology ('hall call allocation') has also continued to establish itself in the marketplace, especially in 'high-end' office developments where its benefits are typically of most value. There has been a recognised perception that whilst providing benefits for uppeak performance they may not be as efficient at handling two-way and inter-floor traffic. This has resulted in some manufacturers offering hybrid group systems whereby destination control is used to dispatch lifts from the main lobby but uses a conventional two button system to call lifts on the upper floors, with active car call buttons to select the destination floor. This prevalence of destination control systems has in turn catalysed debate on traffic planning and the need for revised design criteria to acknowledge the characteristics and capabilities of such systems. The use of a hall call allocation system was also predicated by Dr Barney (Barney and dos Santos, 1985) and these systems are now widely in use in various types of buildings.

The most recent developments in terms of standards has come with the publication of BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transportation of persons and goods. Passenger and goods passenger lifts* (BSI, 2014a) and BS EN 81-50: 2014: *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components* (BSI, 2014b). These two standards will replace BS EN 81-1: 1998: *Safety rules for the construction and installation of lifts. Electric Lifts* (BSI, 1998a) and BS EN 81-2: 1998: *Safety rules for the construction and installation of lifts. Hydraulic Lifts* (BSI, 1998b). BS EN 81-1 and BS EN 81-2 will coexist with BS EN 81-20 and BS EN 81-50 until BS EN 81-1/2 are withdrawn in July 2017; from 31st August 2017 all new lift installations must meet the requirements of BS EN 81-20 and BS EN 81-50. The introduction of these two new standards will require the revision of a substantial number of other standards and documents that contain reference to BS EN 81-1 and BS EN 81-2. The introduction of the new standards will present some challenges in the coming years and it will interesting to see how the vertical transportation industry deals with these.

The gradual adoption of EN 81-1/2 throughout the world has led to the exciting prospect of a truly global lift safety standard. In December 2017 it is proposed that ISO adopts and amends EN 81-20/50 to create 'ISO X' and 'ISO Y', with an 'ISO Z', to deal with regional variations for Japan and North America. In December 2020 these amendments may be complete and ISO would then take the lead and provide regular revisions every three years, commencing in 2023. EN 81-20/50 would then be withdrawn. Lift practitioners and suppliers working outside the CEN ambit will then be working to a common set of standards. This proposal is at an early stage and although there is support agreement is some way off and indeed it may never happen.

1.3 Contents of Guide D

The design of any lift or escalator system must commence with a consideration of the traffic flows through the building for which the system is intended. The relevant factors, along with guidance on the location and arrangement of lifts, escalators and moving walks within buildings, are discussed in chapter 2, which considers a range of building types along with some additional guidance principles for disabled circulation.

The assessment of demand and fundamental principles of traffic planning and selection of lift equipment are considered in chapter 3. Guidance tables have been updated to align with current thinking, particularly the trend towards simulation, and to link with the twelve building types considered in chapters 2 and 5. The chapter also includes a number of very useful design tips.

Chapter 4 covers advanced planning techniques and the use of computer simulation. This chapter has been extensively revised and includes comparisons between conventional control systems and destination control systems. The findings of recent surveys into actual passenger demand in buildings are presented along with new demand templates for use in computer simulations. The value of simulation in assessing potential benefits of modernisation is also discussed. An outline of the principles of lift kinematics, supporting chapter 4, is provided in Appendix A2.

Chapter 5 should be considered a pivotal chapter as it gives a thorough review of various types of vertical transportation systems. It should be the first port of call for new entrants into the industry as not only does it describe in detail the various types of lifting systems it also provides advice on planning and design principles. The chapter examines the standard traction drive and hydraulic drive lifts, including machine-room-less lifts and the appendix provides guidance on structural well sizing and links with the twelve building types considered in chapters 2 and 3.

Firefighting lifts and escape lifts for people with disabilities are particularly important categories. For this reason these are treated separately in chapter 6, which explains the basic requirements for lifts that are intended to be used in fire and emergency situations. This chapter has been updated to include the recommendations of BS 9991: *Fire safety in the design, management and use of residential buildings. Code of practice* (BSI, 2011a), BS 9999: *Code of practice for fire safety in the design, management and use of buildings* (BSI, 2008) and BS EN 81-72: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Firefighters lifts* (BSI, 2015). Comment and guidance is also provided on the use of lifts for general evacuation.

The principal components of lifts, including the main elements of both electric traction and hydraulic drives, are described in chapter 7. It also includes a section covering uncontrolled movement away from a landing with the lift doors open.

Lift drive and control techniques are considered in chapter 8. It provides a detailed guide to controls and drives to allow a better understanding of the various systems and products currently available. This should provide users and specifiers with the necessary information to ensure they select the correct system for their particular application.

Comment on programmable electronic systems in safety related applications for lifts (PESSRAL) is also considered.

Lift traffic control is outlined in chapter 9 and identifies the history of early lift control systems and the need to have lift traffic control. It provides guidance on the traffic control of single lifts, and for groups of lifts through legacy systems, based on relay logic, to modern day systems, utilising microcomputers. Several case studies support the guidance.

Chapter 10 discusses escalators and moving walks, including their safety considerations. The chapter details the different escalator applications which range from low-rise installations to accommodate a small change in level within a story of a building to long travel installations in deep underground stations. Inclined walkways and horizontal moving walkways are also considered. The chapter also includes a number of very useful design tips.

Transportation systems in buildings should provide independent and equal access for everyone. Chapter 11 has been updated to include recently published standards and provides guidance on the types of disability and design issues that need to be considered along with the standards and regulations that are applicable (and the forthcoming revision of BS EN 81-70). There are also illustrations of the most common types of lifting platforms in use today.

Electrical systems and environmental conditions supplies are discussed in chapter 12. This chapter examines the provision of power supplies for the whole building and guidance on key environment conditions, which should be considered during the design process.

Lift, escalator and moving walk energy efficiency and power consumption issues are discussed in chapter 13, which addresses how energy consumption can be minimised through good design, selection and control of the transportation equipment. The ISO classification system is referenced along with guidance on the current requirements of the BREEAM building classification system.

Chapter 14 offers some guidelines on remote alarms and remote monitoring and identifies the different systems currently in use. The chapter also suggests ways in which the resulting data can be used to improve the efficiency of vertical transportation systems and their interface with other systems within the building.

The proper commissioning, thorough examination, inspection and preventive maintenance of lifts escalators and moving walks is critical to ensure that the safety and capital value of these assets are maintained. These important issues are dealt with in chapter 15. The chapter also includes a number of very useful design tips.

Chapter 16 deals with the upgrading of safety, performance and equipment of existing lifts. It examines the reasons for upgrading, which can range from improving the reliability of the lift, its aesthetic appearance or obsolescence of key components. The performance can be in terms of the system's traffic handling, ride quality or energy consumption to improving the safety of the equipment. This chapter also includes easy to read tables for upgrading existing traction and hydraulic drive lifts and includes guidance on accessibility and vandal resistance considerations.

Appendix A1 provides an extensive glossary of terms. This is not limited to the terms used within this Guide but also includes definitions of many of the terms likely to be encountered when dealing with lift, escalator and moving walk systems. The CIBSE is indebted to GBA Publications for permission to reproduce this valuable glossary.

As mentioned earlier, Appendix A2 deals with lift kinematics, which supports chapter 4.

It is fortunate that safety rules for the construction and installation of lifts and escalators, specifications, codes of practice, commissioning recommendations and safe working are all covered by an extensive range of British, European and international standards and codes. Chapter 17 provides an overview of some of these important documents. The chapter is supported by a comprehensive and up-to-date (at the time of publication) list of legislation, standards, codes of practice etc. in Appendix A3.

Finally, a comprehensive index is provided.

1.4 Other sources of information

It is hoped that this fifth edition of CIBSE Guide D: *Transportation systems in buildings* will provide an invaluable reference source for those involved in the design, installation, commissioning, operation and maintenance of transportation systems in buildings. However it cannot be, and does not claim to be, exhaustive. The various chapters contain extensive references to other sources of information,

particularly British Standards and associated standards and codes of practice (see Appendix A3), which should be carefully consulted in conjunction with this Guide, together with relevant trade and professional publications.

References

Barney GC and dos Santos SM (1985) *Elevator Traffic Analysis Design and Control* 2nd edn. (London: Peter Peregrinus)

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BSI (1998b) BS EN 81-2: 1998: *Safety rules for the construction and installation of lifts. Hydraulic lifts* (London: British Standards Institution)

BSI (2011a) BS 9991: 2011: *Fire safety in the design, management and use of residential buildings. Code of practice* (London: British Standards Institution)

BSI (2011b) BS 9999: 2008: *Code of practice for fire safety in the design, management and use of buildings* (London: British Standards Institution)

BSI (2014a) BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transportation of persons and goods. Passenger and goods passenger lifts* (London: British Standards Institution)

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2 Interior circulation

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2 Interior circulation

2.1 General

2.1.1 Cautions

This chapter provides general guidance regarding the movement of people in buildings. Because it deals with people, many of the recommendations are based on empirical data acquired by observation and the experience gained in their application. Much of what follows cannot be proved theoretically and many of the conclusions have been drawn from the observations made. Reasons are given for the conclusions so that if new evidence comes to hand (or opinions change) the results can be modified. National and local regulations may also affect the circulation design, such as Fire and Safety codes and these should be taken into account. Readers are referred to Barney (2015) and Fruin (1971) for fuller expositions and case studies.



Caution: whilst the reader may apply the guidance given here, specialist design assistance may be needed for complex or unusual situations.



Note: throughout the chapter people are called 'pedestrians' when on foot, and 'passengers' when being mechanically transported.



Caution: all the tables in this chapter give empirical values and should be considered to be average values only.

2.1.2 Basic factors

The circulation of people in the interior of buildings is a complicated activity (Dober, 1969) and is affected by a number of basic factors:

- Mode (horizontal and vertical movement): people generally move horizontally, except where they are using inclined moving walks, they then change to vertical movement to reach a higher or lower level. To change mode they can use stairs, escalators or lifts.
- Movement type (natural or mechanically assisted): people are moving naturally when walking along corridors and through portals and are mechanically assisted when using escalators, moving walks and lifts.
- Complications (human behaviour): the movement of people around a building is complex because people are complex. Individuals have:
 - their concepts of route
 - their purpose for travel
 - their level of urgency

- their personal characteristics of age, gender, culture, handicaps etc.

There is always unpredictability in human behaviour.

2.1.3 Design factors

The design of circulation in buildings is to ensure the free flow of people, goods and vehicles. The levels of occupancy and density of usage should be such as to permit the free movement of people and goods. The efficiency of interior circulation is very dependent on building shape. Tall/slender and low/squat buildings are generally inefficient. The ideal shape is 'compact'.

A number of factors affect the effective and efficient design of the interior circulation in a building:

- Consider all circulation routes: these include principal and secondary circulation areas, escape routes, service routes and areas.
- Provide clear and obvious routes: pedestrians should be able to see the route to take and be assisted by good signage and open vistas. For example, to sign the location of lifts at the boarding points of escalators.
- Ensure that the circulation patterns are rational: an example is the avoidance of pedestrians passing through a lift lobby, where other persons are waiting. Consider the importance of the journey undertaken (e.g. hospital theatre traffic)
- Ensure that incompatible types of circulation do not coincide: this would apply to pushing goods trolleys across a pedestrian mall in a shopping centre and a consideration is the requirement to provide space for the movement of shopping trolleys, wheelchairs, mobility aids and carts. The separation of different traffic types (e.g. clean or dirty) in a hotel or hospital. In offices, it may be necessary to make provision for the occasional movement of equipment, plant and refurbishment materials.
- Minimise the movement of people and goods: the relative location of rooms and the need to group some spaces together for related or associated activities is essential, e.g. sales, marketing, human resources and training in an office building.
- The design and location of portals, corridors, stairs and mechanical handling equipment (horizontal and inclined pedestrian conveyors, escalators, and lifts) should be coordinated.
- Bottlenecks and pinch points are prevented. A bottleneck or pinch point reduces the free movement of people and goods.

- Sizing of circulation elements: it is important to size each circulation element. The handling capacities of corridors, which lead to stairs, which in turn lead to a lift should be adequately sized for their anticipated demand. The relationship of major spaces with entrances and mechanical people handling equipment. The conflict of vertical and horizontal circulation modes.



Note: the term ‘handling capacity’ is used here for passive (i.e. non-mechanical) building elements in the same way as it is applied to the mechanical elements and the term ‘demand’ is used to indicate the level of usage.

2.2 Symbols and definitions

2.2.1 Symbols

C_c	corridor handling capacity (person/minute)
C_e	escalator handling capacity (person/minute)
C_s	stairway handling capacity (person/minute)
v	average pedestrian speed (m/s)
D	average pedestrian density (person/m ²)
k	average density of people (person/escalator step)
V	speed along the incline (m/s)
W_c	effective corridor width (m)
W_s	effective stair width (m)

2.2.2 Some definitions

Throughout this chapter people are called ‘pedestrians’ when on foot, and ‘passengers’ when being mechanically transported.

Portals are defined as: entrances, doorways, gates, etc.

The term ‘handling capacity’ is used here for passive (non-mechanical) building elements in the same way as it is applied to the mechanical elements and the term ‘demand’ is used to indicate the level of usage.

2.3 Signing convention

In this and other chapters, icons have been adopted to signify warnings, cautions, design tips and notes. These are as follows:



Warning: this sign indicates something that should be avoided.



Caution: this sign alerts the designer to an important consideration.



Design tip: This icon identifies a useful design opportunity.



Note: draws attention to important text

2.4 Human factors

2.4.1 Human physical dimensions

The physical dimensions of the human body vary widely. Females are generally smaller than males. The space an individual occupies depends on the clothing worn and what they might be carrying. Regional and cultural factors also play a part. To allow for all these factors and other circumstances, particularly body sway, it is recommended that the typical occupancy template be considered to be an ellipse of dimensions 600 mm by 450 mm and ‘covering’ an area of 0.21 m², see Figure 2.1.

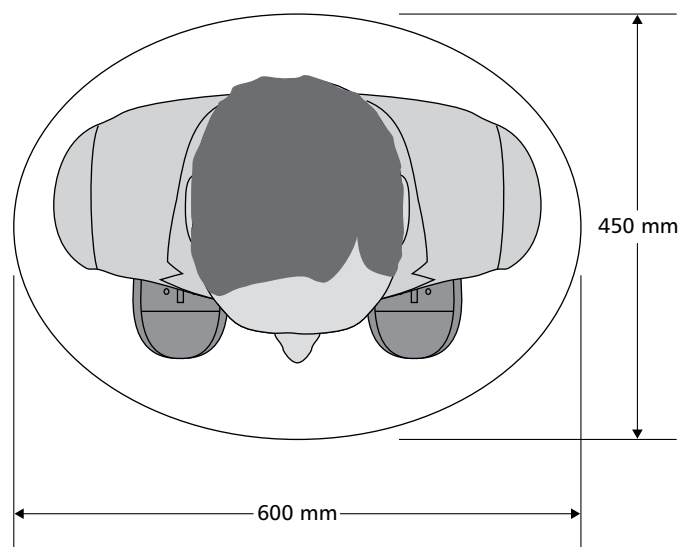


Figure 2.1 A typical occupancy ellipse (showing male subject)



Note: The actual body template of the individual does not fill the ellipse.

If the typical occupancy template is used to represent the average individual, then the larger males and females may be compensated for by smaller males and the females who may be present.

The template shown in Figure 2.1 is a typical value, which is mainly specific to European and North American people. There is growing evidence that over the last few decades more European and North American people have become bigger and taller. Some have become overweight, obese and clinically obese as evidenced by changes in their body mass index (BMI). The average used in this chapter follows Figure 2.1 with the average (European/North American) person considered to weigh 75 kg.



Design tip: in other parts of the world people are different sizes. For guidance, a 65 kg person may occupy 0.18 m², a 68 kg person may occupy 0.19 m² and an 80 kg person may occupy 0.22 m². These sizes need to be considered when designing outside Europe/North America (see Table 3.1).

2.4.2 Human personal space

Humans value personal space (Hall, 1966). This is measured by a personal buffer zone around each individual. The actual size of the buffer zone varies according to an individual's culture, age, status, gender, handicaps etc. It has been observed that individual female subjects are comfortable with a personal buffer zone of 0.5 m² (circle of 0.8 m diameter) and individual male subjects with a personal buffer zone of 0.8 m² (circle of 1.0 m diameter). To visualise these sizes a woman's umbrella occupies an area of approximately 0.5 m² and a man's umbrella occupies approximately 0.9 m².



Design tip: Table 2.1 can be used:

- when designing pedestrian waiting areas, e.g. where people are waiting for an event.
- where pedestrians or passengers are standing in a less confined space, such as a bar.

When considering linear queues (waiting in line) for a service, assume two persons per metre length of space. Where a queue is unrestrained it is necessary to assume that they occupy a width of at least 1.5 m width. A control barrier, which should be at least 600 mm in width, can be used to restrain the queue width.

Table 2.1 Occupancy levels in waiting areas (Barney, 2003)

Level of occupancy	Density (persons/m ²)	Characteristics
Desirable	0.4	Allows individuals to walk freely or to stand without any interference from other individuals.
Comfortable	1.0	Allows individuals to walk freely with some diversions necessary and for individuals to stand without any interference from other individuals.
Dense	2.0	Individuals who are walking now take care not to collide with other persons and persons waiting are aware that other individuals are present.
Crowding	3.0	It is only possible to walk at a shuffle, with care, at the average rate of the crowd. There is no or little chance of a contraflow. Individuals waiting are very aware of other individuals.
Crowded	4.0	Walking is almost impossible. Individuals waiting are unhappy to be so close to other individuals. This density is only possible, where persons are placed in a confined space, such as a lift car, or a rapid transit train.

2.5 Circulation elements

The discussion in this section is mainly applicable to office buildings, where a number of factors affect pedestrian movement including:

- pedestrian dimensions
- pedestrian velocities
- unidirectional/bidirectional flow
- cross flows
- patterns of waiting
- site and environmental conditions
- statutory requirements.

2.5.1 Corridor capacity

The term 'corridor' is defined here to include passageways, walkways, subways etc; i.e. areas whose main function is to provide a connection between major spaces and operational areas. They do not include areas where waiting can occur, such as shopping malls. These are dealt with in section 2.6.11.

The capacity of a straight corridor can be given as:

$$C_c = 60 v D W_c \quad (2.1)$$

where C_c is the corridor handling capacity (persons/minute), v is average pedestrian speed (m/s), D is the average pedestrian density (persons/m²) and W_c is the effective corridor width (m).

Equation 2.1 is an empirical relationship with a number of qualifications. Pedestrian speed and density are not independent of each other. For densities below 0.3 persons per square metre pedestrians can walk freely, called free flow design. When densities increase above 0.5 persons per square metre there is an approximately linear decrease of average walking speed up to a density of about 3.0 persons per square metre, when walking is reduced to a shuffle. The throughput peaks at densities of about 1.4 persons per square metre, called full flow design. Walking speeds vary systematically (statistically) with type of population (age, gender, grouping, purpose), ability (fitness, handicap), gradient, flow direction, air temperature, floor finish etc. Within each group there can be variations in average speed. Table 2.3 indicates the empirically derived average values, as guidance.



Caution: equation 2.1 allows for the flow rate to increase/decrease as the corridor width increases/decreases. The corridor width should be at least 900 mm. This factor should thus be used with great care as small changes in corridor width can have little or no effect.

Table 2.3 below shows the possible horizontal pedestrian flows in persons per minute and persons per hour, and typical pedestrian speeds in metres per second (m/s) for a free flow design density of 0.3 person/m² and a full flow design density of 1.4 person/m².

Table 2.4 below presents the minimum straight widths of corridors that have been found to be suitable for different

Table 2.3 Possible pedestrian flow rates with grouping

Type of traffic	Pedestrian design density					
	0.3 person/m ²			1.4 person/m ²		
	Speed (m/s)	Flow rate		Speed (m/s)	Flow rate	
		Person/min.	Person/hour		Person/min.	Person/hour
Commuters, working persons	1.5	27	1620	1.0	84	5040
Individual shoppers	1.3	23	1380	0.8	67	4020
Family groups, tourists	1.0	18	1080	0.6	50	3000
School children	1.1–1.8	18–32	1080–1920	0.7–1.1	59–92	3540–5520

Note: the flow rates assume a corridor width of one metre

purposes and shows the minimum width of corridors to accommodate various types of traffic. Some compensation can be allowed for mixed two-way traffic situations, e.g. a 3.0 metre wide corridor would allow most traffic types to be accommodated.

Traffic can only flow freely along unrestricted routes. Corridors are rarely free of obstructions. For example, a row of seated persons reduces the effective width of a corridor by 1.0 m. Table 2.5 indicates the effect of a number of obstructions. The table shows the reduction in metres of the effective corridor width caused by obstructions.

Table 2.4 Minimum corridor widths

Usage	Minimum width (m)
One-way traffic flow	1.0
Two-way traffic flow	2.0
Two men abreast	1.2
Man with bag	1.0
Porter with trolley	1.0
Woman with pram	0.8
Woman with pram (child alongside)	1.2
Man on crutches	0.9
Wheelchair	0.8*

* Wheeled vehicles require extra corridor width in order to turn at junctions, especially if they are very long, e.g. hospital trolleys.

Table 2.5 Reductions in corridor widths

Obstruction	Reduction (m)
Ordered single queue	0.6
Un-ordered single queue	1.2–1.5
Row of seated persons	1.0
Coin operated machine:	
— one person	0.6
— with queue	1.0
Person waiting with bag	0.6
Window shoppers	0.5–0.8
Small fire appliance	0.2–0.4
Wall mounted radiator	0.2
Rough/dirty surface	0.2

2.5.2 Stairway capacity

Stairway handling capacity is 83% of that for a corridor, i.e:

$$C_s = 0.83 (60 v D W_s) \quad (2.2)$$

where C_s is the stairway handling capacity (persons/minute), v is average pedestrian speed (m/s), D is the average pedestrian density (persons/m²) and W_s is the effective stairway width (m).

Table 2.6 shows the possible pedestrian flow rates in persons per minute and persons per hour, and typical pedestrian stairway speeds along the slope in metres per second (m/s) for a free flow design density of 0.6 persons per square metre and a full flow design density of 2.0 persons per square metre for each one metre width of stairway.



Note: stairways impose a more stylised and disciplined form of movement on pedestrians. Thus free flow design is possible at a density of 0.6 persons per square metre and full flow design is possible at a density of 2.0 persons per square metre.



Design tip: to enable comfortable walking on a stair a rule of thumb has been suggested to match the average adult stride (on a stairway) of about 600 mm with the sum of twice the riser (rise) height plus the tread (going) depth. This results in a range of riser heights of 100–180 mm and treads of 360–280 mm. A domestic stair often has a rise of 180 mm and a going of 240 mm. An efficient inclination has been found to be 27°.

2.5.3 Portal capacities

Portals, which are known by various names (gate, door, entrance, turnstile etc.) form a division between two areas, for reasons of privacy, security, access control etc. They represent a special restriction in corridor width. Their main effect is to reduce pedestrian flow rates. Table 2.7 indicates probable flow rates for a possible range of pedestrian flows in persons per minute and persons per hour through an opening of one metre.



Note: Table 2.7 indicates flows through a portal of one metre in width. Most domestic doors are less than this (approximately 750 mm) and the flow rates are likely to be lower. Doors in non-domestic buildings may be slightly wider than one metre and would permit the higher values to be possible.

Table 2.6 Likely stairway pedestrian flow rates

Type of traffic	Pedestrian design density					
	0.6 person/m ²			2.0 person/m ²		
	Speed (m/s)	Flow rate		Speed (m/s)	Flow rate	
		Person/min.	Person/hour		Person/min.	Person/hour
Young/middle aged men	0.9	27	1620	0.6	84	5040
Young/middle aged women	0.7	21	1260	0.6	60	3600
Elderly people/family groups	0.5	15	900	0.4	40	2400

Table 2.7 Possible portal flow rates

Portal type	Flow rate	
	Person/min.	Person/hour
Gateway	60–110	3600–6600
Clear opening	60–110	3600–6600
Swing door	40–60	2400–3600
Swing door (fastened back)	60–90	3600–5400
Revolving door	25–35	1500–2100
Waist high turnstile:		
— free admission	40–60	2400–3600
— with cashier	12–18	720–1080
— single coin operation	25–50	1500–3000
— card/detector operation	20–30	1200–1800

2.5.4 Escalator handling capacity

Escalators provide a mechanical means of continuously transporting pedestrians from one level to another. Except for deep underground systems escalators provide for short range movement. They are found in offices, stores, shopping centres, railway stations, hospitals, museums, etc. Speed, step widths, inclination and the size of boarding and alighting areas are factors that affect their handling capacity.

Escalators should be specified against an anticipated duty. The definitions of duty are given in BS 5656-2 (BSI, 2004) and are shown in Table 2.8.

The inclination of an escalator is usually 30°, but can be 35° provided the maximum speed is 0.5 m/s and it serves a maximum rise of 6 m.

Table 2.8 Escalator duty categories

Duty category	Typical usage (passengers per day)	Typical locations
Light	Up to 3000	Shops, museums, libraries and leisure facilities
Medium	Up to 10 000	Department stores, shopping centres, regional airports and regional railway stations
Heavy	Up to 20 000	Major railway and metro stations, major international airports and critical locations such as underground railway systems
Intensive	Over 20 000	Ditto

Table 2.9 Practical escalator handling capacity (BS 5656-2: 2004)

Speed	Step width					
	600 mm		800 mm		1000 mm	
	Person/min.	Person/hour	Person/min.	Person/hour	Person/min.	Person/hour
0.50	37	2250	57	3375	75	4500
0.65	49	2925	73	4388	97	5850
0.75	57	3375	85	5063	113	6750

The most common rated speed of escalators is 0.5 m/s, although speeds of 0.65 m/s and 0.75 m/s are available. Most escalators run at one speed only, although some escalators can switch to the higher speed during heavy traffic.

Step widths of 600 mm, 800 mm and 1000 mm for escalators are available, the latter allowing two columns of passengers to be carried.

The handling capacity of a standard escalator with a step depth of 400 mm is:

$$C_e = 150 V k \quad (2.3)$$

where C_e is the escalator handling capacity (persons/minute), V is the speed along the incline (m/s) and k is the average density of people (person/escalator step).

The density factor k considers the step occupancy levels and experience has shown this depends on step width. Practical values for k that have been found satisfactory are:

- for 1000 mm steps: $k = 1.0$ (i.e. one person per 1000 mm step)
- for 800 mm steps: $k = 0.75$ (i.e. one and one half persons per two 800 mm steps)
- for 600 mm steps: $k = 0.5$ (one person per two 600 mm steps).

Table 2.9 gives guidance to the practical escalator handling capacities based on the above assumed densities in persons per minute and persons per hour and horizontal speeds in metres per second (m/s).



Note: BS EN 115-1: 2008 + A1: 2010 (BSI, 2008) suggests other informative values, which are slightly larger.

The practice in the UK of one stationary column and one walking column does not increase an escalator's mechanical handling capacity, but does increase the passenger flow rate and decrease an individual passenger's travelling time.

2.5.5 Moving walk handling capacity

Moving walks can either be horizontal or inclined. Horizontal moving walks are typically used for medium/long range travel in airports, exhibition centres and railway stations. Inclined moving walks are typically used for short range travel in shopping centres, stores and railway stations.

Inclinations range from 6° to 12°, although the safest maximum inclination is generally considered to be 10°. The running speeds for horizontal moving walks are 0.5 m/s, 0.65 m/s and 0.75 m/s. The permitted running speed for an inclined moving walk is 0.5 m/s. The speed is again measured in the direction of movement of the pallets.

Nominal widths for moving walks up to an inclination of 6° are 800 mm, 1000 mm and 1400 mm and above 6° are 800 mm and 1000 mm. A width of 1400 mm allows two columns of passengers and the possibility for some passengers to walk along the moving walk.

It is likely that the maximum occupation density of a moving walk may be about 2.0 person/m² (i.e. Table 2.1, dense level of occupancy). Table 2.10 indicates practical maximum handling capacities in persons per minute and persons per hour assuming a density of 2.0 person/m² using equation 2.1, but substituting the equipment speed for pedestrian speed.

2.5.6 Handling capacity of lifts

Lifts cannot handle the traffic volumes handled by other facilities and have a considerable throttling effect on pedestrian movement. For example, the most efficient 8 car group comprising 21-person capacity cars serving 14 office floors can only provide a handling capacity of 50 person/min. (3000 person/hour). This is less than a flight of stairs can provide. And a 3-car group comprising 10-person cars serving 8 floors can only manage 16 person/min. (960 person/hour). Thus the recommendation to use escalators in bulk transit systems is proven. Fortunately the high volumes

found in bulk transit systems do not occur when populating or emptying a building. Considerable care should be taken in sizing a lift system to accommodate the worst passenger demands. The method of sizing a lift is given in chapter 3 and is not discussed further here.

2.6 Circulation in particular types of buildings



Important note: this section is concerned with the circulation of people in twelve different types of buildings. Reference should be made to the corresponding subsections of section 3.14, which deal with the selection of equipment and those subsections of chapter 5, which deal with the application of different types of lifts, should also be consulted.

2.6.1 Airports

Many airports are arranged on two main levels with the arrival level below the departure level. There may then be other levels above and below providing various services (e.g. baggage handling, catering etc.) and facilities (offices). Another common characteristic is an adjacent, underground or elevated railway station. As with shopping centres, the movement of baggage carts/trolleys from one level should be catered for. A solution is to install inclined moving walks and this greatly improves circulation. Lifts, however, are the main means of vertical movement for persons with limited mobility.

Passengers at airports, with any significant baggage use the trolleys provided. Most airports have sufficiently large halls and corridors and no problems should arise when they are used on one level. However, when the passenger requires to move from one level to another, e.g. to reach a railway station, then difficulties can arise.

Generally each baggage trolley may be attended by two persons plus their baggage. The weight of the baggage is generally restrained by the 20 kg allowance most (economy) passengers are allowed, plus some 5 kg of hand luggage. Thus a loaded trolley can weigh some 75 kg (including its own weight), i.e. equivalent to one person. However, it occupies the space taken by three or four persons. Thus the total weight of two passengers and their trolley can be some 225 kg and occupy the space of some 5 people. This space

Table 2.10 Practical handling capacities of moving walks and ramps (source: BS 5656-2 (BSI, 2004))

Inclination (degree)	Speed (m/s)	Nominal width					
		800 mm		1000 mm		1400 mm	
		Person/min.	Person/hour	Person/min.	Person/hour	Person/min.	Person/hour
Horizontal moving walks:							
0	0.50	48	2880	60	3600	84	5040
0	0.65	62	3648	78	4560	106	6350
0	0.75	72	4320	90	5400	126	7560
Inclined moving walks:							
6	0.50	48	2880	60	3600	84	5040
10	0.50	48	2880	60	3600	—	—
12	0.50	48	2880	60	3600	—	—

requirement should be considered, when designing the circulation.

It becomes particularly awkward when considering the part lifts play in circulation. Consider a nominal 50-person rated capacity lift (rated load 3750 kg). According to Table 64 of BS EN 81-20 (BSI, 2014), the maximum available car area for an electric traction lift should then be 7.0 m². According to the body template (Figure 2.1) only 33.3 passengers can be accommodated. They may together weigh only 2500 kg, some 67% of the rated load.

If each pair of passengers and their baggage trolley occupy 1.05 m² (i.e. 5 human spaces) then the nominal 50-person lift can accommodate 13.4 passengers and 6.7 trolleys. The total load may be 1500 kg. This is 40% of the rated load. In these circumstances the lifts are unlikely to be overloaded.

If the lift were to be a nominal 50-person rated capacity (3750 kg rated load) hydraulic lift, then the platform area from Table 6 of BS EN 81-20 would be exactly the same. However Table 7 of this standard, which can be used, allows a maximum area of 9.64 m². It is then possible to accommodate 18 passengers and 9 trolleys. This is a load of 2025 kg, which is some 54% of rated load. This would indicate that hydraulic lifts may be the most suitable for large passenger/baggage carrying lifts, where their poorer dynamic performance would not be a significant disadvantage. For smaller rated loads electric traction lifts are more suitable owing to their ability to deal with intense traffic levels.

2.6.2 Car parks

Car parks can be attached to shopping centres, offices, airports, railway stations etc. They are often multi-storey, although those at shopping centres and out-of-town railway stations may be a single or at most two levels. The circulation requirements are more likely to be constrained by the car park entry and exit ramp handling capacities.

For offices the peak demand is often in the evening when occupants are attempting to reach their vehicles. The office lifts, which may not serve the car parking levels, can bring large numbers of people to the lobby. Those with vehicles can make a significant demand on any lifts serving the car park levels. Once the occupants have reached their vehicles they may then spend some time before reaching the exit. Another factor is the vehicle occupancy, which for offices is likely to be about 1.2 persons per vehicle, unless car pools are in operation. The car park lifts should be designed to meet the demand efficiently.

For shopping centres the vehicle occupancy can be much higher with at least 2.0 persons per vehicle. Large lifts should be installed in shopping centres where a large food store is situated in order to provide an adequate service, as considerable numbers of shoppers will take their trolleys in the lifts. This follows a similar argument to that given regarding airport passenger/baggage lifts.

2.6.3 Department stores

This category applies to large departmental and chain stores. These stores may have many entrances, some of which may open to a main street whilst others open into the mall areas of shopping centres. The opportunity therefore

exists for 'leakage' into and out of shopping centres. Many stores own the lifts and escalators inside their demise. These facilities may be used by shopping centre shoppers to move between mall areas. Thus store facilities enhance those provided by a centre to the mutual advantage of both.

2.6.4 Entertainment centres, cinemas, theatres, sports centres, stadia and concert halls

This category of building types often accommodates large numbers of people attending public events. Large theatres have many levels and their circulation should be designed to permit the rapid build-up of patrons prior to performances. Usually these entry routes are not large enough for a rapid departure, but this is not usually a problem.

Other buildings in this category are generally lower rise although stadiums can also have many levels and accommodate many tens of thousands of attendees.

Circulation in these buildings needs to be properly considered at the design stage to ensure that entrances are wide enough and of sufficient number to permit entry and exit. Corridors, stairs and any vertical transportation in addition to that provided for people with disabilities should be sized adequately.

With the increased expectation of access for all into all areas of public buildings the requirements for access and more onerously for emergency egress for persons with limited mobility must be considered. Also to keep the numbers of evacuation lifts to reasonable numbers may require the provision of large safe havens to accommodate wheelchair bound and other mobility limited persons until they can be evacuated.

2.6.5 Hospitals

These are mainly designed in Britain on the 2–3 storey low rise principle, although many city hospitals have high rise elements. In the main the principal corridors are sized to accommodate bed and trolley movements and therefore present no difficulties when handling pedestrian movements. Lifts are provided mainly as a means of moving bed-bound patients from floor to floor. The use of lifts as a primary circulation element in high rise hospitals is vital, particularly for theatre traffic, where special arrangements should be made. NHS Health Building Note 00-04 (DoH, 2013) may be consulted for additional information on circulation and Health Technical Memorandum HTM 08-02 (DoH, 2010) for advice on the provision of lifts.

2.6.6 Hotels

Lifts play an important part in the circulation of guests and service staff in a hotel. It is recommended that there should be at least one passenger lift per 100 guests in a medium quality hotel and at least one service/goods lift per two passenger lifts. Ideally there should be at least two service lifts to each floor in large hotels. Escalators should be employed for short range movements, e.g. to connect function levels with the lobby.

For security reasons it is normal practice that the above-ground guest lifts do not serve underground car parks

directly. Guests should cross the main lobby in the sight of the hotel staff to access the car park lifts.

2.6.7 Offices

There are significant numbers of lifts installed in offices and without them most office buildings would be untenable. Some locations may also include escalators. The guidance of section 2.2 should be followed and some is repeated here.

The interior circulation in a building should be designed to consider all principal and secondary circulation areas, escape routes, service routes and service areas. Pedestrians should be able to see the route to take, assisted by good signage. Circulation patterns should be rational, e.g. avoid pedestrians passing through a lift lobby, where other persons are waiting. Ensure that incompatible types of circulation do not coincide, e.g. tenants and goods traffic. Minimise the movement of people and goods by locating similar activities close to each other, e.g. sales and marketing, and personnel (human resources) and training.

Consider the levels of occupancy and density of usage so as to permit the free movement of people and goods. Prevent bottlenecks. Consider the relationship of major spaces, e.g. meeting and seminar rooms, with entrances and the people handling equipment. Consider the importance of the journey undertaken, e.g. rapid access to trading floors.

The capability of the various circulation elements is given in detail in section 2.4 and their location is given in section 2.7.

2.6.8 Railway stations

Railway stations may be served mainly by stairs, although the deeper ones use escalators. The main demand occurs as a train arrives, when many hundreds of people can alight. Obviously it would be expensive to install vertical transportation equipment to serve this peak demand. Thus the demand should be spread out in some way. A method of achieving this is to place the stairs/escalators at one end of the platform thus producing a more even demand on the facility. Distractions can be provided along the way such as shops and kiosks, etc. The width of the platform may be determined more by safety rather than circulation requirements and thus should be adequately sized for its purpose.

Railway stations suffer from the same problems as airports with respect to baggage trolleys (see section 2.6.1). Inclined moving walks may be installed to assist these movements.

In the future all new stations should provide access for limited mobility persons. This may prove challenging to incorporate the necessary shafts.

2.6.9 Residential buildings

Residential buildings include flats (housing association and private), university, college and hospital residencies. Circulation is not normally a problem except in high rise flats, where sufficient lifts should be installed.

2.6.10 Residential care homes and nursing homes

Residential care homes and nursing homes do not usually present any circulation problems as they are not densely populated and do not experience peak traffic conditions.

2.6.11 Shopping centres

2.6.11.1 General considerations

A shopping centre is unlike the old-fashioned high street, where shops line each side of the road, with shoppers on pavements at the sides and vehicular traffic passing along the middle of the street. A shopping centre is usually a purpose-built building, where all shoppers are protected from the weather in a climatically controlled environment and segregated from vehicular traffic. The shops line each side of the malls with several floors of malls above and below. No two shopping centres have the same structure, population or circulation patterns. In the UK shopping centres are generally on one, two or three floors, although in Asian countries shopping centres often have 7 or 8 mall levels. Two floors are generally considered as much as the average UK shopper is prepared to contemplate. Centres with three floors often have food courts at the upper or lower floors to form an attraction and a contrast to the main sales areas. There are places set aside for rest, sustenance and amusement.

Readers should consult chapter 2 of Barney (2015) for a detailed discussion of good practice and design.

Shoppers do not populate a shopping centre to the high levels (in density terms) found in other public places, e.g. railway stations. Two traffic conditions can be observed: a low level of shopper occupancy (uncrowded–free flow), and a peak value of shopper occupancy (crowded–full flow). Also although the walking speeds vary widely, they are generally less than the natural (comfortable) speed of 1.3 m/s (3 mph). Contrast these values with those given in section 2.4.

2.6.11.2 Practical levels of shopper movements

Entrances

Walking speeds reduce to 0.7 m/s, when shoppers pass through entrances, otherwise the shopper flows remain similar to those given in Table 2.6.

Malls

The density of shoppers in uncrowded conditions is 0.2 person/m² and 0.45 person/m² during crowded conditions. The density can increase to 1.0 person/m² at pinch points (areas where the mall size is inadequate, e.g. at a food court).

The walking speed of shoppers in uncrowded conditions is generally 1.3 m/s and in crowded conditions is generally 1.0 m/s.

Pedestrian flow rates are given in Table 2.10.

Table 2.10 Actual mall pedestrian flows rates (per metre width of mall)

Traffic type	Uncrowded (0.2 person/m ²)		Crowded (0.45 person/m ²)	
	Speed (m/s)	Flow rate (person/hour)	Speed (m/s)	Flow rate (person/hour)
All shoppers	1.3	936	1.0	1620

Counter-flows reduce mall capacity by 15% compared to unidirectional flows.

The effective mall width (equal to actual mall width minus street furniture and window shoppers) reduces as the condition changes from uncrowded to crowded. This results from more stationary shoppers looking into shop windows.

Mall widths should be of the order of 68 m wide as a compromise between too wide to cross and too narrow to pass along.

Stairs

Uncrowded density on stairs is found to be approximately 0.4 person/m² and crowded density on stairs reaches 0.8 person/m².

Shoppers' speeds when using stairs varies according to traffic type.

The stair capacity under uncrowded conditions and under crowded conditions varies according to traffic type, see Table 2.11.

Table 2.11 Stairway (handling) capacity (per metre width of stair)

Traffic type	Speed (m/s)	Uncrowded (0.4 person/m ²)	Crowded (0.8 person/m ²)
Men	0.8	960	1920
Women	0.7	840	1680
Elderly men	0.5	600	1200
Elderly women	0.6	720	1440
Children	0.8	960	1920
Push chairs	0.5	600	1200

There is a tendency for more down traffic than up traffic in the ratio 60:40.

A minor contraflow can reduce a major flow by effectively reducing the stairway width by some 750 mm.

Escalators and moving walks

About 80% of shoppers may use the escalators to quickly reach other floors in a shopping centre, as they rarely have to wait.

The 800 mm step width escalators (commonly used in stores) have a theoretical step utilisation of $k = 0.75$. However, shopping centre escalators are observed to load to only $k = 0.5$ step utilization under uncrowded conditions and to $k = 1.0$ step utilisation under very crowded

conditions. The width of an 800 mm step is not large enough to accommodate two adult people side by side. To achieve this, an escalator with a step width of 1000 mm (commonly used in malls) is required, when a higher step utilisation can be achieved.

Table 2.12 Actual escalator handling capacity

Speed (m/s)	Handling capacity (person/hour) for step width 800 mm	
	Uncrowded	Crowded
0.50	2250	4500

In some shops only an up travelling escalator is provided with stairs alongside for downward circulation.

There is a tendency for stores and shopping centres to install inclined moving walks, which allows shoppers to keep their purchases with them in trolleys as they circulate. For safety, any trolley intended for use on moving walks should be designed for that purpose.

Lifts

Observation (scenic) lifts, lifts for the transportation of 'prams', car park lifts and other lifts are provided in shopping centres, but not in sufficient quantities to serve more than a fraction of the shoppers. They are mainly used by elderly, infirm and disabled people, mothers with children and push chairs, and people with heavy packages. Observation lifts are sometimes installed as a feature to provide a visual impact in retail complexes. They do contribute to the circulation aspects of a shopping centre, but cannot be considered as a major handling capacity provider as passengers often use one simply for the ride.

2.6.12 Universities and other education buildings

Most university buildings can be classified as institutional buildings, where the occupants receive a service. A university campus often has a mixed collection of lecture blocks, office type buildings, halls of residence, catering services and factory like units containing teaching and research equipment (reactors, high voltage laboratories, telescopes). Where universities occupy city sites many have tall buildings (10–20 stories) and even those on out-of-town sites follow suit in order to reduce land use and keep a compact campus. The office type buildings can be treated in the same way as detailed earlier in this section 2.4. The halls of residence can be treated in a similar way to hotels, although perhaps at lower levels of demand and performance. The catering services can be attached to either the office-type buildings or halls of residence and should be treated as office facilities or hotel facilities. The factory-like buildings may be low rise and may be subject to special movement provisions associated with the equipment installed, e.g. barriers to radioactive areas.

The main feature of the university campus is the lecture changeover periods. There are hourly cycles of 10 minutes of demand after each 50 minute lecture, tutorial or seminar finishes. In between the peaks the activity levels are low. To install lifts in a tall building to suit this demand is not cost effective (and universities do not have large capital budgets). A better solution is to try to re-arrange the activities in the

building to reduce the load on the lifts. An example in Adler (1999) illustrates the relationship chart in a small firm. A set of relationships can be formed for a university building. It would be possible to reduce the demands made for 10 minutes every hour by the following:

- Lecture facilities can be placed in the lower levels, say basement, ground and three to four floors above the entrance level. Students can be encouraged to use stairs if they are wide, well lit and visible.
- Laboratory, bulk service facilities (‘cyber’ cafes, libraries) and student administration (registrars, bursars, careers advisory etc.) can be placed from the fourth floor upwards. These are either used for periods longer than one hour (laboratories), shorter than one hour (administration) or randomly (libraries).
- Offices should be placed at the top of the building. Their occupants generally use the lifts on a more random basis.

2.7 Location and arrangement of transportation facilities

2.7.1 General

Having discussed the various passive circulation elements (corridors, stairs, portals etc.) and the active circulation elements (moving walks, escalators and lifts) in the previous sections it is now necessary to consider their location and arrangement, which should take account of:

- the location of entrances and stairs
- the location of lifts, escalators and moving walks
- the distribution of the occupants in the building
- safe circulation
- car parks with minimum or no facilities at ground level.

The main principles, given in section 2.2, to bear in mind here are:

- to minimise the movements of people
- to minimise the movements of goods
- to prevent clashes between people and goods
- to prevent bottlenecks.

Ideally all circulation activities should be centralised in a main core of a building. This is clearly not always possible when access into a building is considered. Sometimes the main lobby is close to the main entrance and sometimes the main lobby is some distance into the building. This latter case requires occupants and visitors to walk some distance in order to reach the transportation facilities. However, it may be better for occupants to walk to the centre of a building to access stairs and lifts, since their central location during the day may outweigh the comparative inconvenience during arrival and departure. Generally the maximum distance to a lift or stair from an occupant’s work place should not exceed 60 metres with a distance of less than 45 metres being preferred. Emergency escape routes are

usually closer, but do not necessarily form part of the normally used circulatory routes.

2.7.2 Stairs

Stairs should not lead directly off corridors, but be accessed from landing and lobby areas, where people may congregate without obstructing a circulation route. Thus the vertical and horizontal modes of circulation can be allowed to merge smoothly. If it is the intention to encourage the use of stairs for short journeys to/from adjacent floors (interfloor movement), then the stairs should be of sufficient size, clearly visible, adequately signed and encountered before reaching the lifts.

The provision of well signed and positioned stairs can considerably lessen the demands made on the lifts. In general lifts may be used for travel over a large number of floors and stairs for travel over a small number of floors. A judgement is made by the passenger with respect to the waiting time for a lift versus the walking time (and walking effort) with respect to stairs. In office environments they can be a advantageous where (say) heavily populated trading floors need to be accessed. They are also very useful for access to car parks, relieving the lifts of travelling below the main terminal, and may be used for access to double deck lifts.

Table 3.11 (chapter 3) provides guidance to stair usage. Table 2.13 summarises the division of passenger demand between lifts and stairs. Although stairs are an always-available facility, their attraction diminishes with the number of floors a person need to travel. Designers should take these factors into account.

Table 2.13 Comparison of stair and lift usage

Floors travelled	Up (%)		Down (%)	
	Stair	Lift	Stair	Lift
1	10	90	15	85
2	5	95	10	90

2.7.3 Escalators and moving walks

Escalators are typically used for short range movement between adjacent floors (except in underground railway systems). They are found in offices between principal levels, in shops between trading floors, in shopping centres between malls and elsewhere such as railway stations, hospitals, museums etc. They are usually sited in an obvious circulation path, making it easy for pedestrians to board them.

Escalators and moving walks should only be accessed from adjacent corridors/walkways, landing and lobby areas, where people do not obstruct other pedestrian circulation routes. Space should be available to accommodate queuing at the boarding point. Again the intention is to ensure that the vertical and horizontal modes of circulation can merge smoothly.

In order to provide a safe area for passengers to board and alight, it is especially important that the boarding and alighting areas adjacent to an escalator or moving walk are not part of another circulation route. This obligation is

required by Annex A.2.5 of BS EN 115-1: 2008 + A1: 2010 (BSI, 2008), which requires a sufficient unrestricted area be available to accommodate passengers at the landings. The area of this space is defined as the distance between the outer edges of the handrails plus 160 mm, multiplied by a depth of 2.5 metres. Alternatively the depth can be reduced to 2.0 metres if the width of the space is defined as twice the distance between the outer edges of the handrails plus 160 mm.

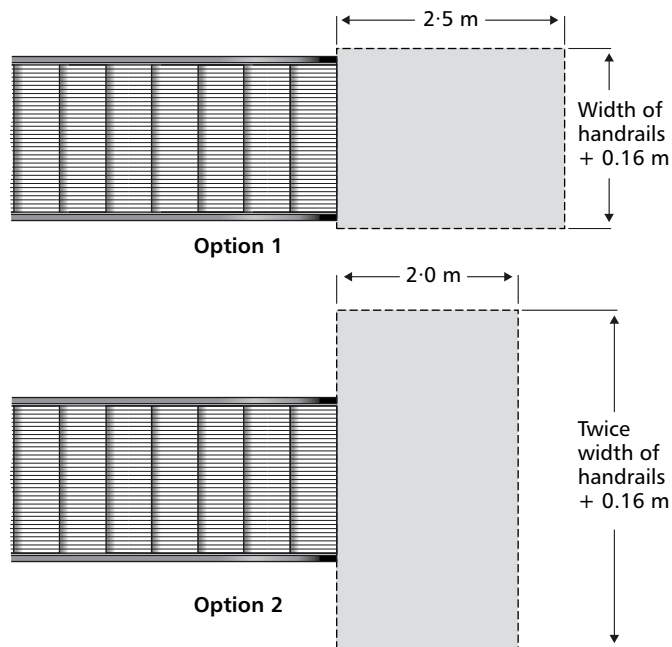


Figure 2.2 Illustration of unrestricted free space according to BS EN 115-1: 2008 + A1: 2010 (BSI, 2008)

Figure 2.2 illustrates clause A.2.5 with Option 1 being a 2.5 m landing depth and Option 2 being a 2.0 m landing depth. Where successive units (BSI, 2004) are installed each successive escalator, or moving walk, should have its own individual unrestricted area.

Escalators occupy more space than stairs in order to accommodate their inclination. There are several standard escalator arrangements as shown in Figure 2.3. Types (a) and (b) provide efficient circulation by providing the shortest transition path and time from one escalator and the next. Type (b) requires a larger structural opening than types (a) and (c) and presents users with a higher risk of falling into the void. Type (c) is typical of a store as it allows the store to lengthen the circulation route past goods for sale. This configuration also takes up less space.

Some baggage/trolley manufacturers can adapt trolleys for use on moving walks. In these cases the unrestricted area at the landings should be increased to at least five metres and the number of flat/horizontal steps at the boarding and alighting points increased. The most significant effect is the increased footprint required for the equipment. Shopping/baggage trolleys are not permitted on escalators.

In order to encourage pedestrian confidence and to assist the efficient and safe boarding and alighting of escalators, the start and end of the escalator should present a number of horizontal (flat) steps. BS EN 115-1: 2008 + A1: 2010 (BSI, 2008) specifies that at least two flat steps are provided for escalator speeds up to 0.5 m/s, at least three flat steps for speeds above 0.5 m/s and up to 0.65 m/s, and at least four

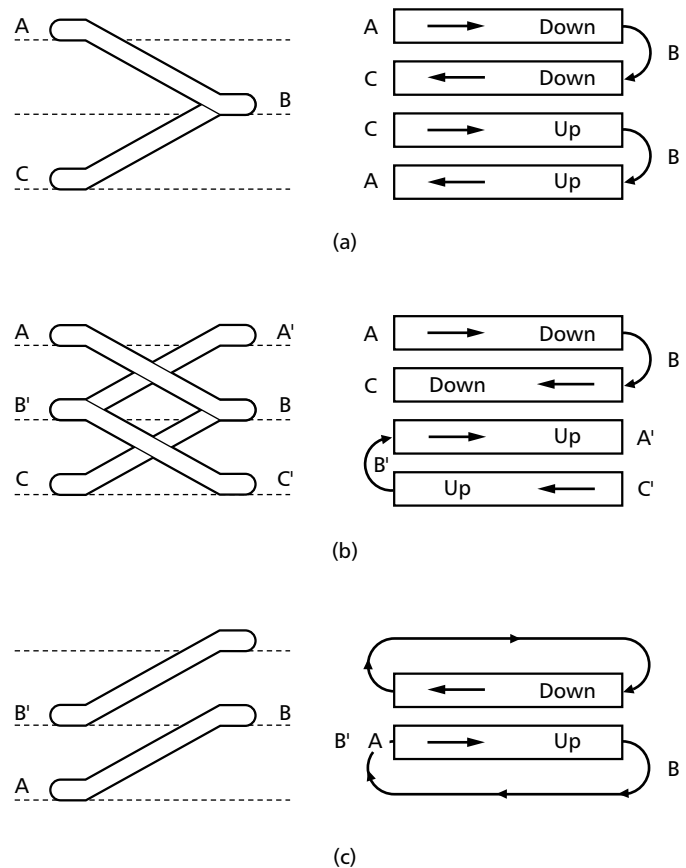


Figure 2.3 Escalator configurations (a) parallel (b) cross-over (c) walk round

flat steps for speeds above 0.65 m/s. In locations where it is anticipated that the escalators may be used by persons with impaired mobility additional flat steps should be considered.

2.7.4 Lifts

The grouping of passenger lifts is particularly important where they provide the main means of vertical transportation within a building. Lifts should always be placed together rather than distributed around a building. This provides a better service (shorter intervals), mitigates the failure of one car (availability of adjacent cars) and leads to improved traffic control (group systems). Eight lifts are the recommended maximum number of lifts that should be grouped together, using conventional landing call stations*, especially if large lifts are used (>2000 kg). This allows passengers to determine when a lift arrives (from the lantern and gong signals), to walk to the car (across the lobby) and to enter it before the lift doors start to close.

The distance across a lobby is usually 1½ to 2 times the depth of the deepest car. According to BS ISO 4190-1 (BSI, 2010), where lifts are placed side by side this distance should not be less than 2400 mm and when facing not more than 4500 mm. If the lift lobby is too large, passengers have too far to walk and the closure of the car doors has to be delayed (increased door dwell time) to accommodate the increased walking time.

* If hall call allocation signalling is used more than eight lifts may be grouped together giving additional freedom to lobby design. The application of hall call allocation group control often causes large numbers of persons to congregate in front of individual cars and this may affect lobby sizes and shape.

Lift lobbies should not be part of a through circulation route, either to other lifts, or other areas in the building. Lobbies should be provided that are dedicated to passengers waiting for the lifts. The ideal lobby size would be one which could accommodate one full car load of passengers waiting and permit the simultaneous disembarkation of one full car load of arriving passengers. This area can be calculated using the density information given in section 2.2.2 at between ‘comfortable’ and ‘dense’ (say 1.4 person/m²).

The shape of lobbies is most important. For example, a group of lifts whose doors are fitted to a convex shaped lobby would be most inefficient, whereas if the doors were fitted to a concave shaped lobby the lobby design would be nearly perfect. Zoning a building requires more lobby space at the main terminal level. The positioning of the groups is very important. Adequate signs should be provided to quickly and simply direct the passengers to the correct group.

Some buildings may be designed with their main entry points at more than one level. The presence of more than one main terminal level for the lift system does not lead to efficient circulation and, where possible, buildings should not be designed in this way. Means should be provided to bring the two entrance routes together at a single lift lobby. Except in special cases it is recommended that the main terminal floor should be used as an interchange for the different circulation modes.

BS 5655-6 BSI, 2002) gives recommended layouts and limitations for groups of lifts. The preferred arrangements of between two and four lifts arranged in line are given in Figure 2.4 and between two and eight lifts arranged opposite each other are shown in Figure 2.5. Note all the lobbies (indicated ‘L’) are waiting areas with no through circulation.

It is suggested that the position of any central lift core should be towards the centre of the building in order to reduce the walking distances from any point in the building.

Some floor plates are very large. Ideally all circulation activities should be centralised in a main core of a building. This is not always possible when access into a building is considered. Sometimes the main lobby is close to the main entrance; sometimes the building design places the main lobby some distance into the building. This latter case involves occupants and visitors in a long walk to reach the transportation facilities. However it may be better for occupants to walk to the centre of a building to access stairs and lifts, since their usage during the day may outweigh the comparative inconvenience during arrival and departure.

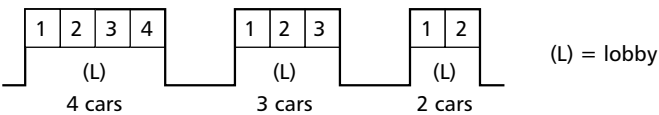


Figure 2.4 Preferred arrangement for 2 to 4 lifts (in line)

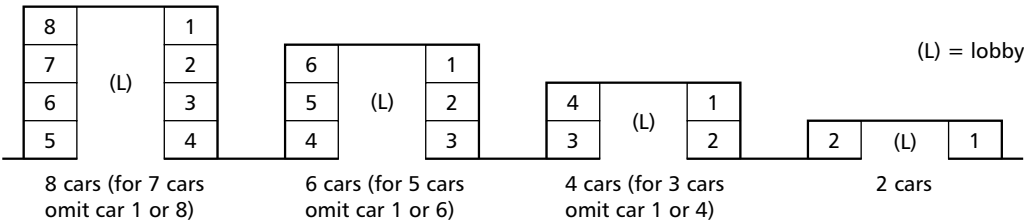


Figure 2.5 Preferred arrangement for 2 to 8 lifts (facing)

Generally the maximum distance to a lift or stair from an occupant’s work place should not exceed 60 m, with a distance of less than 45 m being preferred. Emergency escape routes are usually closer but do not necessarily form part of the normally used circulation routes.

Where a building layout cannot accommodate these arrangements, the following factors should be considered to optimise the accessibility and visual links to all lifts within a group to the passengers:

- lobby size
- location of push buttons
- location and type of landing indicators
- walking distances to lift entrances in a lift lobby
- additional structural costs of fragmented lift cores.

2.7.5 Lifts versus escalators

In general lifts are used for travel over a large number of floors and escalators for travel over a small number of floors. A judgement is made by the passenger with respect to the waiting time for a lift versus the length of time walking (and walking effort) with respect to escalators.

Low rise structure such as shopping centres, sports complexes, conference and exhibition centres, railway stations, airports, hospitals, etc. are good examples of buildings where the provision of escalators considerably aids circulation (and is used by the passengers).

In office environments the usefulness of escalators is lessened, although they can be advantageous where (say) a heavily populated trading floor(s) need to be accessed. They are also very useful for access to car parks, relieving the lifts of travelling below the main terminal, and may be used for access to double-deck lifts. Table 2.14 indicates some guidance as to the division of traffic between lifts and escalators.

Table 2.14 Likely division of traffic between lifts and escalators

Floors travelled	Escalator (%)	Lift (%)
1	90%	10%
2	75%	25%
3	50%	50%
4	25%	75%
5	10%	90%

2.8 Facilities for persons with disabilities

The discussion so far has assumed that all persons circulating in a building are fully able bodied. However, a significant proportion of the population are disadvantaged in some way. BS EN 81-70 (BSI, 2003) categorises disabilities into physical, sensory and intellectual. BS 8300 (2009) gives some guidance for facilities within buildings. The Equality Act 2010 (TSO, 2010) lays down various provisions, regulations and penalties for non-conformance. Building Regulations Approved Document M (NBS, 2004) provides guidance to compliance in the UK.

Generally, arrangements made to allow persons with disabilities to make use of circulation elements assist the able-bodied and should be implemented wherever possible. Chapter 11 of this Guide discusses lifting facilities for people with disabilities.

2.9 Pedestrian movement modelling

More advanced pedestrian movement studies might be carried out using pedestrian modelling software such as 'Oasys' (Arup), 'Steps' (Mott Macdonald) and 'Exodus' (Fire Safety Engineering Group). Such studies are beyond the scope of this Guide.

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3 Fundamental traffic planning and selection of equipment

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3 Fundamental traffic planning and selection of equipment

3.1 Introduction

This chapter provides a general guide to UK and European practice, which may differ from North American practice (Strakosch, 2010). It is recommended that Barney (2003) be consulted for the detailed theory and a source of the primary references. Other references readers may like to consult are BS 5655-6 (BSI, 2011), the British Council of Offices' *BCO Guide to specification 2014* (BCO, 2014) (referred throughout this chapter as *BCO Guide*) and ISO 4190-6 (ISO, 1984) for residential buildings.

The various terms used in this chapter are defined in section 3.2, and other definitions may be found in the Glossary (Appendix A1 to this Guide).

The transportation capacity of the lift group in a building is a major factor in the success or failure of a building as a place to work, to live or to receive a service. Building occupants expect lifts to be available and easy to use without a second thought. Unfortunately this is not always the case. For example, a speculative building often results in the installation of an inadequate lift system for the eventual occupants.

The planning and selection of transportation equipment is a very involved subject. Although the basic calculations are relatively simple, the theory on which they are based is complex. The results obtained should always be tempered with a great deal of working experience of existing buildings, in order to ensure a satisfactory design results.

The difficulty in planning a lift installation is not in calculating its probable performance, but in estimating the passenger demand that is likely to occur. Quite often the building has yet to be built and estimates have to be based on the experience gained with previous similar structures. Existing buildings can be surveyed, by observation, or by means of an attached data logger, to determine the current activity. However, even this is prone to error, as the building's population may have adapted to a poor (or good) lift performance.

It is essential, therefore, that all the parties involved in the planning of a lift installation should have a clear understanding of the basis for the planning. The architect or planner should establish the lift system required at a very early stage in consultation with a lift specialist and not after the rest of the building has been designed, as often has happened in the past.

A design, which is tightly planned, may prove inadequate once a new building becomes fully occupied. It is important to remember that the distribution and size of the population of any large building can alter regularly, for example, as tenants change. To understand the effect of any of these changes on a building, it is essential to document the design

criteria and the reasons for decisions taken at all stages of a design.

Two key factors affect the demand that a building's occupants may make on a lift system: the quantity of service and the quality of service required. The quantity of service factor—how many people might use the lift system over a defined period of time—is represented by the handling capacity. The quality of service factor—how well the lift system deals with its passengers—is represented by passenger waiting time and lobby queuing. Both factors are interrelated and depend, amongst other things, on the type of building and its use, and on the type of occupier. This makes the design task very difficult for buildings of a speculative nature.

Two models can be used for lift traffic design and analysis:

- The first model uses a calculation method based on mathematical formulae. This classical model has been used for nearly 80 years and results in a satisfactory solution for the majority of designs. The pure uppeak traffic condition (i.e. only incoming traffic) is used for this method as it provides a well-defined, simple traffic pattern, amenable to mathematical analysis. These calculations can be carried out by hand, using a program, a spreadsheet or a simulation program. The fastest method is a spreadsheet based method, an example of which is used to illustrate this chapter, see Appendix 3.A2. It provides instant results to each change of input.
- The second model, which has been used for over 40 years, is based on a discrete digital simulation of the movement of lifts in a building and the passenger dynamics. This simulation model allows very complex situations to be analysed. Simulations are very slow to carry out at the present time (especially if ten simulations are run to obtain good statistical data) compared to the instant answers provided using a spreadsheet.

It is recommended that calculations should always be carried out, in order to refine a design and obtain an understanding of the various, sometimes, conflicting factors. A simulation may then be performed, if the system being considered has any unusual aspects or to offer information not provided by the calculation method, e.g. passenger queues etc.

This chapter deals with the classical model based on calculation; chapter 4 deals with the simulation model.

The two most frequently asked questions, when sizing a lift system are:

- *Question 1:* What is the handling capacity of my lift? (Quantity of service.)

— *Question 2: How good is my lift system? (Quality of service.)*

These questions are answered in following sections.

3.2 Symbols

A_d	Average down peak passenger arrival rate (person/5-minutes)
A_i	Average interfloor passenger arrival rate (person/5-minutes)
A_r	Average uppeak passenger arrival rate (person/5-minutes)
AJT	Passenger average journey time (s)
ATTD	Passenger average time to destination (s)
ATT	Passenger average transit time to destination (s)
AWT	Upppeak passenger average waiting time (s)
CA	Car area (m ²)
CF	Capacity factor
%CF	Percentage car capacity factor
DT	Distance between terminal floors (m)
d_f	Average interfloor height (m)
H	Average highest reversal floor
H_m	Average lowest basement reversal floor
INT	Average interval with defined car load (s)
k	Hall call allocation look ahead factor
L	Number of lifts
m	Number of served floors below the main terminal
n	Number of served floors above the main terminal
NIA	Net internal area (m ²)
NUA	Net usable area (m ²)
P	Average number of passengers (persons)
PC	Probable capacity (persons)
%POP	Percentage population
RTT	Average round trip time (s)
RL	Rated load (kg)
S	Average number of stops
S_m	Average number of basement stops
SRT	System response time (s)
T	Floor to floor performance time (s)
T_m	Basement floor to floor performance time (s)
t_{ad}	Advance door opening time (s)
t_c	Door closing time (s)
t_{cyc}	Cycle time (s)
t_e	Main terminal to express zone terminal flight time (s)
$t_{f(1)}$	Single (1) floor flight time (s)
t_l	Average single passenger loading (entry) time (s)
t_o	Door opening time (s)
t_p	Average single passenger transfer time (entry or exit) (s)
t_{sd}	Start delay time (s)
t_u	Average single passenger unloading (exiting) time (s)
t_v	Time to travel between two standard pitch adjacent floors at rated speed (s)
t_{vm}	Time to travel between two adjacent basement floors at rated speed (s)
U	Effective building population (persons)
UPPHC	Average uppeak handling capacity (persons/5-minutes)
UPPINT	Average uppeak interval with 80% car load (s)
v	Rated speed (m/s)

3.3 Definitions

advanced door opening (t_{ad})

period of time saved by opening the lift doors during levelling

Note: This feature overlaps the levelling operation with the opening of the doors to reduce effective door opening time.

car area (CA)

accessible area in a lift car where passengers can stand

cycle time (t_{cyc})

period of time from the instant the car doors begin to close until the instant the car doors begin to close again at the next adjacent floor provided no passengers have crossed the threshold

door closing time (t_c)

period of time measured from the instant the car doors start to close until the doors are locked

door opening time (t_o)

period of time measured from the instant that the car doors start to open until they are 800 mm open

effective building population (U)

number of tenants, excluding visitors, expected to enter the building on a daily basis

Note: This is not the number of physical positions that can be occupied, but includes persons away on business, absences and 'hot desking'.

interval (INT)

period of time between successive car arrivals (or departures) at the main terminal with cars loaded to any value

performance time (T)

period between the instant the car doors start to close and the instant that the car doors are 800 mm open at the next adjacent floor

Note: Sometimes called 'door-to-door' time.

passenger arrival rate (A_r, A_d, A_i)

rate at which passengers arrive for service by a lift system (persons/5-minutes)

Note: Passenger demand is often given as a percentage of a building's population arriving in 5-minutes.

passenger average: (Barney et al., 2005)

— *journey time (AJT)* (see Figure 3.3)

period of time (in seconds) from when a passenger either registers a landing call, or joins a queue, until the passenger alights at the destination floor

Note: A passenger is deemed to have alighted, when any passenger detection device is interrupted or the passenger physically crosses the door sills.

- **standing time**
period of time from when a passenger is stationary in front of their allocated lift, until the allocated lift begins to open its doors
- **time to destination (ATTD)** (see Figure 3.3)
period of time from when a passenger either registers a landing call, or joins a queue, until the responding lift begins to open its doors at the destination floor
- **transfer time (t_p)**
period of time for a single passenger to enter or leave a lift car
Note: The passenger loading (entry) and unloading (exiting) times may not be the same value.
- **transit time (ATT)** (see Figure 3.3)
period of time from when a responding lift begins to open its doors at the boarding floor until the doors begin to open again at the destination floor
Note: The passenger transit time commences, if the responding lift doors are open, when a passenger arrives.
- **waiting time (AWT)** (see Figure 3.3)
period of time from when a passenger either registers a landing call, or joins a queue, until the responding lift begins to open its doors at the boarding floor
Note: The passenger waiting time continues if a passenger does not enter the responding lift, e.g. it is full.
Note: The passenger waiting time is zero, if the responding lift doors are open, when a passenger arrives.
Note: If a passenger registers a destination call before arriving at the lift lobby, waiting time may be divided into two components: walking time (time to reach the lobby) and standing time (time waiting in the lobby).
- **walking time**
period of time from when a passenger registers a destination call on a destination input device, until they stand stationary in front of the allocated lift

probable car capacity (PC)

maximum number of passengers a lift car is likely to be able to accommodate

rated load (RL)

load for which the lift has been built and at which it is designed to operate

rated speed (v)

speed for which the lift has been built and at which it is designed to operate

round trip time (RTT)

average period of time for a single lift car trip around a building, usually during uppeak traffic conditions, measured from the time the car doors open at the main

terminal, until the car doors reopen at the main terminal, when the car returns to the main terminal, after its trip around the building

single floor flight time ($t_f(1)$)

period of time measured from the instant that the car doors are locked until the lift is level at the next adjacent floor

system response time (SRT)

period of time that it takes a lift group to respond to the first registered landing call at a floor

Note: Sometimes taken as the period of time between a passenger registering a call at a landing and the subsequent cancellation of that call by the traffic controller

transfer floor

floor which is served by more than one lift or group of lifts for the purpose of passenger transfer between building zones

uppeak handling capacity (UPPHC)

number of passengers that a lift system can theoretically transport during the uppeak traffic condition with a car occupancy of 80% of the probable capacity

Note: This is calculated by determining the number of trips made by the lifts, which occur over the worst five minute (300 seconds) period and then multiplying it by the average number of passengers (P) carried in that five minutes.

uppeak interval (UPPINT)

average time between successive car arrivals (or departures) at the main terminal (or other defined) floor with cars assumed to be loaded to 80% of probable capacity during the uppeak traffic condition

3.4 Signing convention

In this chapter, icons have been adopted to signify warnings, cautions, design tips and notes. These are as follows:



Warning: this sign indicates something that should be avoided.



Caution: this sign alerts the designer to an important consideration.



Design tip: This icon identifies a useful design opportunity.



Note: draws attention to important text.

3.5 Traffic patterns

A building will experience a number of traffic patterns, i.e. passenger arrivals, departures, boarding at floors and disembarking at floors. To illustrate these patterns consider Figure 3.1, which shows a classical traffic pattern of passenger demand in an office building as it would be observed from the main terminal, or main access, floor. It shows the number of up landing calls and down landing calls registered during the working day. Today this pattern is rarely observed, as many occupying organisations have adopted a staggered arrival or a 'flexitime' attendance

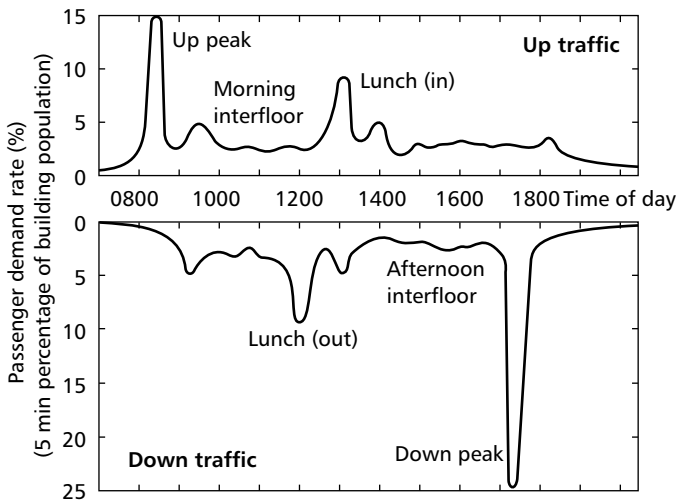


Figure 3.1 Passenger demand pattern showing four distinct classical passenger demands

regime. However, this pattern does serve as a generally agreed model for discussion.

Figure 3.1 shows four distinct classical passenger demands:

- At the start of the day there are a larger than average number of up landing calls. This demand is due to the building's occupants arriving to start work. This traffic pattern is called the morning uppeak. Industry practice is to size a lift installation to handle the number of passengers requesting service during the heaviest five minutes of the uppeak traffic condition. This is a sound recommendation. To size the lift system to handle the actual peak would require too large a system, which would be very expensive and much of the equipment would be under utilised during large periods of the working day. The duration of the classical uppeak traffic condition is typically five minutes.
- Late in the day there is a larger than average number of down landing calls. This demand is due to the building's population leaving at the end of the working day. This traffic pattern is called the evening down peak. The profile of the down peak traffic is larger in size and longer in duration than the uppeak profile. Fortunately a lift system inherently possesses about 60% more handling capacity, during down peak, than during uppeak. This is due to lifts filling to capacity at three to five floors and then making an express run to the main terminal. This reduction in the number of stops allows the lift to serve other waiting passengers more quickly. The duration of the classical down peak condition is typically 10 minutes.
- In the middle of the day there may be a number of uppeaks and down peaks. This represents a situation where the occupants of the building take their midday breaks. This pattern is called midday traffic (sometimes called lunch time traffic). Today this traffic pattern can be very intense and is often more demanding than, either the uppeak, or the down peak, with strong patterns of simultaneous up and down traffic together with some interfloor traffic. This traffic condition may typically exist for one to two hours dependent on the arrangements for the midday break.

During the rest of the day the numbers of up and down landing calls are much smaller than during the peak periods. They have similar up and down demand values and over a period of time they balance out. This traffic pattern is called interfloor traffic, sometimes qualified as balanced interfloor traffic. Interfloor traffic exists for most of the working day and is a very important traffic demand.

Generally, if the lift system, which uses a conventional (two button) landing call system (i.e. *not* hall call allocation signalling systems) is sized correctly for the uppeak traffic pattern, all other traffic patterns should be adequately served. There are exceptions to this comment. These include: hotels, where meal times clash with check-in/check-out, hospitals at visiting times, buildings with trading floors (insurance and stock markets) that open at specified times, buildings where restaurants are high in the building, and residential buildings.

The uppeak traffic condition can be easily mathematically analysed.

3.6 Four important equations

To answer Question 1 (see page 3-1) it is necessary to consider how a lift moves around a building during uppeak traffic.

Figure 3.2 shows a lift making a round trip in a building during the uppeak traffic condition. It is characterised by passengers arriving at the main terminal for transportation to the upper floors. The lift travels around the building making stops to allow passengers to alight eventually reaching the highest requested floor when the lift reverses direction and then travels non-stop back to the main terminal floor.

The calculation method, to size a given lift installation, requires the determination of the round trip (RTT) time, in seconds, that it takes for a single lift to make a round trip around a building during the uppeak traffic condition, such as that shown in Figure 3.2.

The round trip time of a single lift during uppeak traffic (Barney and dos Santos, 1975) is given by:

$$RTT = 2Ht_v + (S + 1)(T - t_v) + 2Pt_p \quad (3.1)$$

Using the value obtained for RTT, the uppeak interval (UPPINT) can be calculated by dividing it by the number of lifts (L) in the installation. In a system of L cars the uppeak interval is given by equation 3.2:

$$UPPINT = \frac{RTT}{L} \quad (3.2)$$



Note: in an installation of only one car the uppeak interval (UPPINT) is equal to the round trip time (RTT).

The uppeak handling capacity (UPPHC) is calculated for the worst five-minute period during uppeak traffic. It can be calculated using the average car occupancy of (P) passengers.

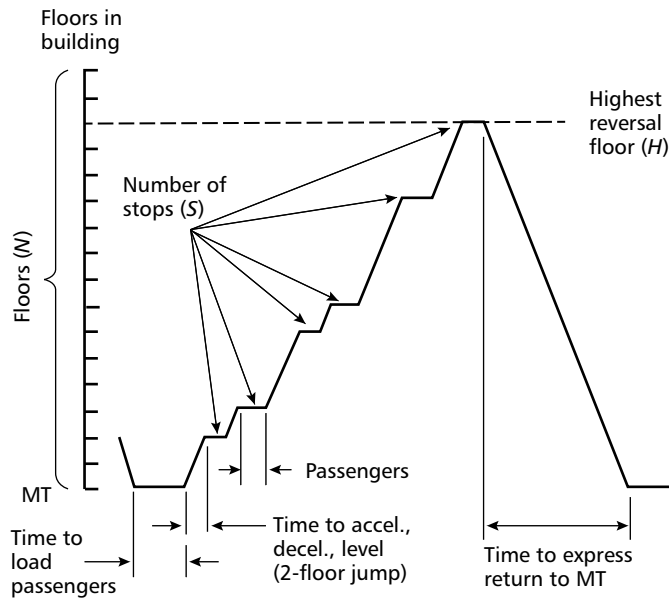


Figure 3.2 The elements of a round trip (see section 3.2 for definitions of symbols)

The uppeak handling capacity (UPPHC) is given by equation 3.3:

$$\text{UPPHC} = \frac{300 P}{\text{UPPINT}} \quad (3.3)$$

The percentage of building population that can be handled (%POP) is obtained by dividing the UPPHC value by the building's effective population (U). The percentage population (%POP) handled is given by equation 3.4:

$$\% \text{POP} = \frac{\text{UPPHC} \times 100}{U} \quad (3.4)$$

3.7 Quality of service: the handling capacity of a lift installation

To determine the handling capacity of a lift installation the component parts of equation 3.1 need to be determined.

There are six parameters: H, S, P, t_v, T, t_p .

3.7.1 Values for H and S

The values for H were derived by Schroeder (1955) and for S by Bassett (1923) and are given by equations 3.5 and 3.6:

$$H = N - \sum_{i=1}^{N-1} \left(\frac{i}{N} \right)^P \quad (3.5)$$

$$S = N \left[1 - \left(1 - \frac{1}{N} \right)^P \right] \quad (3.6)$$

The evaluation of H and S requires values for the number of floors above the main terminal (N) and the average number of passengers in the car (P).



Design tip: values for H and S have been tabulated in Appendix 3.A1 for a range of values for N and P .

3.7.2 Value for number of floors (N)

The number of floors above the main terminal is a known value. However, not all floors may be served and the value for N selected should be for the number of floors actually served.

3.7.3 Value for average number of passengers (P)

The average number of passengers in the car (P) should be taken as 80% of the maximum probable car capacity (PC).

$$P = 0.8 \times PC \quad (3.7)$$

ISO 4190-1 (ISO, 2010) gives the maximum car platform sizes (Table 3.1, column 2) for a range of standardised rated loads (Table 3.1, column 1). Lifts installed to European Standard BS EN 81-20 (BSI, 2014a) assume that an average passenger weighs 75 kg. It is accepted that on average a 75 kg person occupies an area of 0.21 m². The *BCO Guide* (BCO, 2014) states:

'For all traffic conditions the average car loading in any five minutes (including scenic lifts) should not exceed 80%, allowing 0.21 m² per person'.

Table 3.1, column 3 shows the maximum probable capacity (PC) in persons and Table 3.1, column 4 shows the value for P to be used to evaluate equation 3.7 for 75 kg passengers.



Note: average values for H, S and P are often not integer numbers.



Note: the value given for P produces a comfortable experience for passengers as the area of occupancy per person increases to 0.21 m² for a 75 kg person (other weights similarly).

For safety reasons, lifts are required by BS EN 81-20 (BSI, 2014a) to be sized to carry a specified rated load in kg. A value for the safe nominal number of passengers that a lift may carry can be found by dividing the rated load by a figure representing the average weight of persons in the region where the lift is to be installed. For European traffic designs, see columns 3 and 4 of Table 3.1 for persons assumed to weigh 75 kg (shown shaded in Table 3.1).

Table 3.1 also shows the probable capacity and the design value for P for other assumed passenger weights. For example: 65 kg is often used in Singapore, 68 kg is often used in Australia and 80 kg is often used in Russia. For other parts of the world BS EN 81-12 (BSI, 2014b) should be consulted.

Table 3.1 Car capacity

(1)	(2)	(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)
Rated load (RL) (kg)	Max. area (CA) (m ²)	Passenger weight = 75 kg Occupancy = 0.21 m ²		Passenger weight = 65 kg Occupancy = 0.18 m ²		Passenger weight = 68 kg Occupancy = 0.19 m ²		Passenger weight = 68 kg Occupancy = 0.19 m ²		Passenger weight = 68 kg Occupancy = 0.19 m ²		Passenger weight = 80 kg Occupancy = 0.22 m ²		Passenger weight = 80 kg Occupancy = 0.22 m ²		
		Actual capacity (AC) (person)	Value of <i>P</i> for calcs.	Actual capacity (AC) (person)	Value of <i>P</i> for calcs.	Actual capacity (AC) (person)	Value of <i>P</i> for calcs.	Actual capacity (AC) (person)	Value of <i>P</i> for calcs.	Actual capacity (AC) (person)	Value of <i>P</i> for calcs.	Actual capacity (AC) (person)	Value of <i>P</i> for calcs.	Actual capacity (AC) (person)	Value of <i>P</i> for calcs.	
450	1.30	6.2	4.9	7.2	5.8	6.8	5.5	5.9	4.7							
630	1.66	7.9	6.3	9.2	7.4	8.7	7.0	7.5	6.0							
800	2.00	9.5	7.6	11.1	8.9	10.5	8.4	9.1	7.3							
1000	2.40	11.4	9.1	13.3	10.7	12.6	10.1	10.9	8.7							
1275	2.95	13.8	11.0	16.1	12.9	15.3	12.2	13.2	10.5							
1600	3.56	16.9	13.6	19.8	15.8	18.7	15.0	16.2	12.9							
1800	3.92	18.7	14.9	21.8	17.4	20.6	16.5	17.8	14.3							
2000	4.20	20.0	16.0	23.3	18.7	22.1	17.7	19.1	15.3							
2500	5.00	23.8	19.1	27.8	22.2	26.3	21.1	22.7	18.2							

Notes: col. 1: rated load (RL) range from BS ISO 4190-1 (BSI, 2010); col. 2: maximum car area (CA) values taken from BS EN 81-1/2 (BSI, 1998); cols. 3/5/7/9: actual capacity (AC) calculated by dividing car area (CA) by indicated passenger weight; cols. 4/6/8/10: value for *P* is 80% of AC for indicated passenger weight

3.7.4 Value for rated speed (*v*)

This may be provided by the lift installer, in which case see section 3.7.5.

A generally accepted rule of thumb for offices is that a lift should be able to travel the distance between terminal floors (DT) in 20 seconds for prestige class buildings or 30 seconds for speculative buildings.

For offices, Table 3.2 indicates maximum suggested travels for the ISO 4190-1 (ISO, 2010) range of rated speeds. Values for other building types are given in Table 3.3.



Caution: the evaluation of the round trip time assumes that the rated speed is reached in the distance of a single floor jump. In approximate terms this is given by *v*² metres of travel. Lifts with rated speeds over 1.6 m/s may not reach the rated speed over a typical floor height, see 3.10.5.

Table 3.2 Recommended maximum travel distance for various rated speeds

Rated speed (m/s)	Maximum travel (m) for 20 s travel time	Maximum travel (m) for 30 s travel time
1.00	20	30
1.60	32	48
2.50	50	75
3.50	70	105
5.00	100	150
6.00	120	180
10.00	200	300

Table 3.3 Travel times for building types other than offices

Building type	Travel time (s)
Large hotels	20
Small hotels	30
Hospitals, nursing/residential homes, etc.	24
Residential buildings	20–30
Factories, warehouses, shops, etc.	24–40

3.7.5 Value for adjacent floor transit time (*t_v*)

This is given by equation 3.8. To provide a value the average interfloor distance (*d_f*) is required and the rated speed (*v*) of the lift.

$$t_v = \frac{d_f}{v} \tag{3.8}$$

The average interfloor distance can be obtained by dividing the total travel from the main terminal to the highest served floor (DT) by the number of served floors.

$$d_f = \frac{DT}{v} \tag{3.9}$$



Caution: the average interfloor distance may contain significantly different non-standard floor heights, e.g. main terminal, conference floors, technical floors, etc. Where this is the case the value obtained for *t_v* may need to be revised.

3.7.6 Value for performance time (*T*)

The variable *T* may be provided by the lift installer. If *T* is known go to section 3.7.7.



Caution: some lift companies state the performance time (*T*) to be the time from the instant the doors start to close until the instant the doors start to open even if the lift is still moving.

The variable (*T*) is composed of a number of independent time values:

$$T = t_f(1) + t_{sd} + t_c + t_o - t_{ad} \tag{3.10}$$

and can be easily measured (see definitions) on actual installations.



Warning: *T* is made up of five terms. When any measurements are made on existing installations each term is subject to a measurement error. Their

subsequent summation can lead to significant inaccuracies. Although it is important to know their nominal values, a much more accurate value can be obtained by measuring T directly from the time the doors start to close until they are 800 mm at the adjacent landing.



Design tip: of the three terms in the round trip time equation 3.1, the central term is the most influential and the saving of one second on the value of T can increase the handling capacity by about 5%.

A value for single floor flight time ($t_f(1)$) may be provided by the lift installer. Otherwise, Table 3.4 indicates some possible values for the indicated values of acceleration/deceleration, jerk and interfloor distances.

Table 3.4 Single floor flight times

Rated speed (m/s)	Acceleration (m/s ²)	Jerk (m/s ³)	Single floor flight time (s) for stated average interfloor distance		
			3.6 m	4.5 m	5.5 m
1.00	0.4–0.7	0.75	6.1	7.1	8.1
1.60	0.7–0.8	0.9	5.2	5.8	6.4
2.50	0.8–0.9	1.0	5.0	5.5	6.0
3.00	1.0	1.25	4.6	5.1	5.6
5.00	1.2	1.5	4.3	4.8	5.2
6.00	1.2	1.8	4.1	4.6	5.0



Design tip: the relationships between distance travelled, velocity, acceleration and jerk are complex and are given in detail in Appendix A2. Using the equations of motion given in Appendix A2, flight times for any distance or number of floors travelled can be obtained by calculation or by using a spreadsheet.

The value for start delay (t_{sd}) may be provided by the lift installer. Otherwise assume 0.5 seconds.



Caution: the start delay on some installations can be very long and has a significant effect on the value of T and may need to be measured.

The values for door closing (t_c) and door opening (t_o) times may be provided by the lift installer. Otherwise some suitable values for an initial design are shown in Table 3.5. More detailed times are given in chapter 7, Table 7.1.

Value for advance door opening time (t_{ad}) may be provided by the lift installer. Otherwise assume 0.5 s. Also known as pre-opening time.

Table 3.5 Door times

Door type	Door time (s) for stated door width (mm)			
	800	1100	800	1100
	Closing time		Opening time	
Side	3.0	4.0	2.5	3.0
Centre	2.0	3.0	2.0	2.5

3.7.7 Value for average one-way single passenger transfer time (t_p)

The passenger transfer time can vary considerably and is affected by:

- the shape of the car
- the size and type of car entrance
- the environment (i.e. commercial, institutional, residential)
- the type of passenger (i.e. age, gender, agility, purpose, culture)
- the existing car loading.

The value for this time requires judgement. General rules can be suggested. If the car door width is 1000 mm, or less, assume passengers enter or exit in single file. For door widths of 1100 mm and wider assume the first six passengers enter or exit in single file and the remainder in double file. For offices consider 1.2 s to be the one-way single passenger transfer time. Where passengers are elderly, or have no reason to rush, the transfer times should be increased to about 2.0 s.



Design tip: the value to be assigned to t_p is the average for all passengers that are transferring. For example, a 2000 kg lift may load 16 passengers. Each passenger may have a transfer time of 1.2 s. The first six passengers take 6×1.2 s, i.e. 7.2 s, but the next 10 passengers exit in pairs, i.e. in 6.0 s. Therefore the total transfer time for all passengers is 13.2 s, and the average transfer time (t_p) is:

$$t_p = 13.2/16 = 0.83 \text{ s.}$$

This is the figure to be entered in equation 3.1 for t_p .

Table 3.6 gives suggested average passenger transfer times (t_p) for offices, taking into account door width and car capacity. Note that it has been observed that the time taken for passengers to exit lift cars (t_u) is often shorter than the time taken to enter (t_l). This effect can be accounted for by averaging, see equation 3.11.

$$t_p = \frac{t_l + t_u}{2} \quad (3.11)$$

Table 3.6 Average passenger transfer times (t_p) for offices

Rated load (kg)	t_p (s)	Typical door width (mm)
320–800	1.2	800
1000	1.0	900
1275	0.9	1100
1600–2500	0.8	>1100

Example 3.1

A facility manager has been asked the handling capacity of a group of lifts installed in an office building with an effective population (U) of 731 occupants. The following information is known:

- Number of floors (N): 10
- Number of lifts (L): 4
- Rated speed (v): 1.6 m/s
- Rated load (RL): 1000 kg
- Interfloor distance (d_f): 3.6 m
- Single floor flight time: 5.2 s
- Door close time: 3.0 s
- Door open time: 2.5 s
- Advance door opening: 0.5 s
- Start delay: 0.5 s

What is the handling capacity of the lift installation?

Equation 3.1 needs to be solved, i.e:

$$RTT = 2 H t_v + (S + 1) (T - t_v) + 2 P t_p$$

The value for P can be found from Table 3.1, column 4:

$$P = 9.1 \text{ persons.}$$

From Appendix 3.A1, for $N = 10$:

$$S = 6.2 \text{ and } H = 9.4.$$

The floor transit time (t_v) is obtained from equation 3.8:

$$t_v = 3.6/1.6 = 2.25 \text{ s}$$

The performance time (T) is obtained from equation 3.10:

$$T = 5.2 + 0.5 + 3.0 + 2.5 - 0.5 = 10.7 \text{ s}$$

Assume the value for passenger transfer time (t_p) for a rated load of 1000 kg from Table 3.6:

$$t_p = 1.0 \text{ s.}$$

Hence, from equation 3.1:

$$\begin{aligned} RTT &= 2 (9.4 \times 2.25) + (7.2 \times 8.45) + 2 (9.1 \times 1.0) \\ &= 121.3 \text{ s} \end{aligned}$$

From equation 3.2:

$$UPPINT = 121.3/4 = 30.3 \text{ s}$$

From equation 3.3:

$$UPPHC = (300 \times 9.1)/32.9 = 90.1 \text{ person/5-minutes}$$

From equation 3.4:

$$\%POP = (90.1 \times 100)/731 = 12.3 \%$$

3.8 Sizing of office lift installations

The method described below sizes a lift system to serve the demands of an office building's occupants by matching the

passenger demands for transportation with the handling capacity of the installed lift system for the worst five minute period during the morning uppeak traffic condition. The method provides the means of calculation and analysis for the planning and selection* of lifts mainly for office buildings. The 'matching' can be expressed as:

$$A_r = UPPHC \quad (3.12)$$

where A_r is the uppeak passenger arrival rate (person/5-minutes).

The size of the demand may be measured, in terms of the arrival rate of either, a specified number of persons/5-minutes (A_r), or a specified percentage of the building population (%POP) assumed to arrive in the peak 5-minutes. The traffic design should select a lift system to meet these quantity of service criteria.

3.8.1 Estimation of office building population

Passenger demand is dependent on the population of a building.

The size of the intended population should be obtained, either from the building owner, or from the proposed occupier, or may be known for an existing building. If the population value is available, go to section 3.8.4.



Warning: the building population may change over time.

3.8.2 Estimating office building floor area

If the population numbers are not available for a new building, or a speculative office building, or an existing building then an estimation should be made using floor areas (ANSI/BOMA, 1996, 2010).



Note: If the floor area is known go to section 3.8.3.

Most estimates start from a knowledge of the net usable area (NUA), that is, the area which can be usefully occupied. If gross floor area (GFA) is used this can lead to inaccuracies.

The NUA excludes circulation space (stairs, corridors, waiting areas, escape routes), structural intrusions (steel-work, space heating, architectural features, ductwork), and facilities (training rooms, smoking rooms, kitchens, toilets, cleaners' areas, etc.).

The net internal area (NIA), sometimes called the rentable area, is larger than the usable area as it includes tenant's facilities such as: kitchens and cleaners' cupboards and some of the circulation space.

The ratio of usable area (NUA) to rentable area (NIA) might be 80–85%.

* See also *BCO Guide* (BCO, 2014) for other specifications for offices.



Warning: the method of determining the NUA is not universally agreed. For example, ANSI/BOMA (1996) and ANSI/BOMA (2010) offer different, sometimes conflicting, proposals. A coalition of worldwide organizations and bodies involved in property management called the International Property Measurements Standards Coalition (IPMS) was formed in May 2013. It includes the British Property Federation and the Royal Institution of Chartered Surveyors (RICS). In November 2014, IPMS published *International Property Measurement Standards: Office Buildings* (IPMSC, 2014). Although the document has yet to receive worldwide acceptance it does represent a step forward in building measurement methods.

3.8.3 Estimating office building population from floor area

The occupancy density of a building should be obtained for a new building from the owner or developer and for an existing building from the occupant.



Note: if the occupancy density is known go to section 3.8.4.

The number of people occupying the usable area can vary according to the quality of the accommodation (i.e. prestigious, standard or speculative) and the type of occupancy (i.e. single, sector† or mixed tenancy).

Buildings based on open plan layouts have higher populations than those with cellular offices.

For cellular offices, occupancy can range from 10 m² to 14 m² per person of NIA. As a starting point assume an occupancy of 12 m² per person, then:

- for prestigious buildings add 2 m² per person
- for speculative buildings deduct 2 m² per person.

For open plan offices, occupancy can range from 8 m² to 12 m² of NIA. As a starting point assume an occupancy of 10 m² per person, then:

- for prestigious buildings add 2 m² per person
- for speculative buildings deduct 2 m² per person.

For some task-based activities (e.g. trading desks and call-centre workstations), the space per person may range from 4 m² to 6 m².

For 'VIP' floors the occupancy density can extend to 25 m² per person.

Mixed arrangements would require separate consideration to obtain a total occupancy value.



Design tip: various studies have shown that in many buildings it is unlikely that all the total population is present on any one day. Where this is known to be the case the total building population can be reduced by 10–20% to account for persons working

† Sector occupancy refers to tenants engaged in the same activity, e.g. stockbrokers.

at home, on holiday, on sick leave, persons away on company business, vacant posts, hot desking etc.



Caution: work by BCO (2013) indicates that the occupier densities in some office buildings is increasing (i.e. less space per person) suggesting that high density offices may be 10 m² per person.

3.8.4 Estimating passenger arrival rate

The passenger arrival rate should be obtained, either from the building owner, or from the proposed occupier.



Note: if the value for the passenger arrival rate is known, go to section 3.8.5.

The five minute uppeak arrival rate can vary depending on the type of building occupancy (i.e. different business interests or single tenant), the starting regime (i.e. unified or flexitime), and the distance to bulk transit facilities such as buses and trains.

The apparent morning arrival rate may appear to be low, but during the peak period the lifts are generally serving other interfloor and down travelling traffic. The design arrival rate might range from 10% to 14%.

As suggested in the *BCO Guide* (BCO, 2014), assume as a starting point a pure uppeak arrival rate of 12%, then:

- for single tenancy add 1%
- for mixed tenancy deduct 1%
- for prestigious buildings add 1%
- for speculative buildings deduct 1%.

The value obtained for the passenger arrival rate should be used as the target handling capacity of the installed lift system.

3.8.5 Quality of service

The quality of service criterion is different to the quantity of service criterion and is represented by the average passenger waiting time.

For most office buildings this can range from 25 s to 30 s. Unfortunately, average passenger waiting times cannot be easily measured, owing to the difficulty of determining the exact arrival instant for each passenger. The time the lift system takes to respond to the landing call registered by the first arriving passenger can be measured. During uppeak traffic this time is called the interval and is the average period of time between successive arrivals of the lift, or lifts, at the main terminal. Table 3.7 indicates an intuitive relationship between quality of service and interval.

Table 3.7 Probable quality of service in office buildings

Interval (s)	Quality of service
<20	Excellent
25	Above average
30	Average
40	Below average
>50	Unsatisfactory

These values are similar to those given in BS 5655-6 (BSI, 2011).

A target value for the average interval may be provided by either the building owner or the developer.



Caution: when using the interval as a quality indicator, passenger waiting time depends on car occupancy, i.e. the number of passengers in the lift. In general, an average passenger waiting time is less than the calculated interval, when the average car occupancy is less than 80% of probable capacity. When average passenger capacity factor exceeds 80% (for a sufficiently long time), the average passenger waiting time increases substantially and it rapidly becomes unacceptable. The lift system becomes saturated and the lobby queues increase uncontrollably, because the lifts cannot cope with the passenger demand. See section 3.10.

Simulation can be used to obtain more definitive values for average passenger waiting (see chapter 4).



Design tip: a useful rule of thumb for the general level of service provided by a single lift serving several floors is:

- excellent service: one lift per 3 floors
- average service: one lift per 4 floors
- below average service: one lift per 5 floors.

The performance time (T) has the most effect on the round trip time, equation 3.1. Reducing the value of T by one second can increase the handling capacity of a lift installation by about 5%. Quality of service may be judged by the value selected for T . For a 3.6 m interfloor height, Table 3.8 gives the values of T that can indicate the probable performance of an installed lift system.

The above two rules of thumb may need to be ignored in order to achieve, for example, either a specified interval, or a specified handling capacity.

Table 3.8 The performance time (T) as a quality of service indicator

Value of T (s)	Comment
8.0–9.0	Excellent system
9.0–10.0	Good system
10.0–11.0	Average system
11.0–12.0	Poor system
>12.0	Consider system replacement

3.9 Worked example of design calculations

Example 3.2

A 10-floor (above the main terminal) office building with a net usable area of 8125 m² for a single speculative tenant with open plan accommodation is to be built. The interfloor distance is 3.6 m. Design a suitable lift installation.

Note: this example is typical of an initial enquiry. Little is known, except the number of floors, interfloor distance, net usable floor area, type of accommodation.

Net internal area (NIA) = 8125 m²

Using section 3.8.2 assume 80% utilisation:

$$\text{Net usable area (NUA)} = 8125 \times 0.8 = 6500 \text{ m}^2$$

Using section 3.8.3 assume 8 m² per person, hence:

$$\text{Maximum population} = 6500/8 = 813 \text{ persons}$$

Assume 10% absenteeism (section 3.8.3):

$$\text{Actual population} = 813 \times 0.9 = 731 \text{ persons}$$

Using section 3.8.4 assume 12% arrival rate (multiply by 0.12):

$$\text{Arrival rate} = 731 \times 0.12 = 88 \text{ person/5-minutes}$$

Using section 3.8.5 assume interval is 30 s (average system).

Thus the lift system requirements are to provide a handling capacity of 88 persons/5-minutes (12%) with a 30-second interval.

In simple terms, there will be 10 trips in five minutes at an interval of 30 s. To transport 88 persons in 10 trips requires an average car occupancy of 8.8 persons. Table 3.1 shows a lift with a rated load of 1000 kg can accommodate 9.1 persons (by area).

Equation 3.1 needs to be solved:

$$\text{RTT} = 2 H t_v + (S + 1)(T - t_v) + 2 P t_p$$

Values for H and S can be obtained from Appendix 3.A1. Hence, for $N = 10$ and $P = 8.8$:

$$H = 9.4 \text{ and } S = 6.0$$

The total travel is 36 m and a value for v is obtained from Table 3.2 as 1.6 m/s. This gives:

$$t_v = 3.6/1.6 = 2.25 \text{ s}$$

A value for T is obtained from equation 3.10:

$$T = t_f(1) + t_{sd} + t_c + t_o - t_{ad}$$

Table 3.4 indicates a suitable value for $t_f(1)$ as 5.2 s and Table 3.5 indicates suitable door operating times for a 1100 mm centre opening doors as $t_c = 3.0$ s and $t_o = 2.5$ s.

From section 3.7.6 assume the start delay is 0.5 s and the advance opening is 0.5 s. Thus:

$$T = 5.2 + 0.5 + 3.0 + 2.5 - 0.5 = 10.7 \text{ s}$$

From Table 3.6 assume $t_p = 1.0$ s.

The data determined for the lift system are:

- Number of floors (N): 10
- Rated speed (v): 1.6 m/s

- Rated load (RL): 1000 kg
- Interfloor distance (d_f): 3.6 m
- Single floor flight time: 5.2 s
- Door close time: 3.0 s
- Door open time: 2.5 s
- Advance door opening: 0.5 s
- Start delay: 0.5 s

The data for equation 3.1 are:

- $H = 9.4$
- $S = 6.0$
- $P = 8.8$
- $t_v = 2.25$ s
- $T = 10.7$ s
- $t_p = 1.0$ s

The calculations are as follows:

$$\begin{aligned}
 \text{RTT} &= 2 \times 9.4 \times 2.25 + (7.0 \times 8.6) + 2 \times 8.8 \times 1.0 \\
 &= 42.3 + 60.2 + 17.6 \\
 &= 120.1 \text{ s}
 \end{aligned}$$

To achieve an average system (Table 3.7), i.e. a 30-second interval, then four lifts would need to be installed.

$$\text{UPPINT} = 30.0 \text{ s}$$

$$\% \text{POP} = 12\%$$

$$\text{UPPHC} = 88 \text{ persons/5-minutes}$$

These values meet the design criteria.

3.10 Frequently asked questions in the evaluation of RTT

A number of assumptions are made in order to derive the round trip time equation (equation 3.1). These can place limits on the validity of the method. It is important for a designer to be aware of these limitations, especially when using computerised design methods, in order to ensure a realistic design.

(a) Do passengers arrive uniformly in time?

The derivation of the round trip time equation assumes that passengers arrived at a lift system for transportation, according to a rectangular probability distribution function (PDF). However, it is more likely that the arrival processes can be according to a Poisson PDF.

It has been shown (Barney, 2003) that values for S and H derived using the Poisson PDF are always smaller than with a rectangular PDF. Thus the use of formulae based on the rectangular PDF produces slightly more conservative

designs when compared to designs using formulae derived from other PDFs.

(b) Can the rated load be used to determine the number of passengers a lift car can accommodate?

The nominal capacity in persons based on BS EN 81-20 (BSI, 2014a) is the rated load divided by 75. This is not the probable capacity (PC). As discussed in section 3.7.3, the nominal passenger carrying capacity of lifts presented in safety standards should not be used for traffic planning. To determine the maximum practical loading of the car, consider area only.

(c) Why should lifts load to 80% of probable capacity?

In the round trip time calculation the lifts are assumed to fill to 80% of the probable capacity (PC), see Table 3.1. This has been shown (Barney, 2003) to be a reasonable statistical assumption and allows some lifts to fill to capacity and others to lower values, giving an average of 80%. The number of passengers as a percentage of the probable capacity is called the percentage capacity factor (%CF) and is given by equation 3.13.

$$\% \text{CF} = \frac{P}{AC} \times 100 \quad (3.13)$$



Note: lifts cannot load to a greater value than 100% of probable capacity.

(d) What happens if all floors are not equally populated?

Generally the floors of a building are not equally populated. It is possible (Barney, 2003) to derive quite complex formulae for S and H . If calculations are carried out for a building where most of the population occupies the higher floors then it is found that the value for H rises and the value for S falls. Conversely, if most of a building's population occupies the lower floors of a building the value for H falls significantly and the value for S also falls. The effect in both cases, compared to a building with each floor being equally populated, is that the value for the round trip time reduces. Therefore the effect of an unequal population is generally favourable to the conservative sizing of a lift system.

(e) What happens if the rated speed is not reached in a single floor jump and if the interfloor heights are not equal?

These two assumptions are related. For lifts with speeds greater than 1.6 m/s the first assumption is usually not valid. Most buildings have irregular interfloor distances (e.g. main entrance floors, service floors, conference floors), making the second assumption incorrect. It has been found (Barney, 2003) that if the flight time to travel the average interfloor distance is determined and this time is used as $t_f(1)$ in the round trip time calculation, then an error in the calculation of only a few percent occurs. Peters (1997) has provided formulae for the 'corrections' recommended in the 1993 edition of this Guide.

(f) *What are landing and car call dwell times?*

Some door control systems cause the lift doors to open for a fixed length of time (dwell) after a lift arrives at a floor. Passengers can then leave a lift (for a car call) or board a lift (for a landing call), without the doors closing on them.

Typical office building door dwell times are: 2.0–3.0 seconds for a car call stop and 3.0–4.0 seconds for a landing call stop. The longer landing call dwell times allow waiting passengers to walk across a large lobby to the waiting lift. Where passenger detection systems are fitted to the car doors (BS 5655-6 (BSI, 2011), these times can be automatically shortened to 0.5 seconds once the first passenger crosses the threshold. This is called differential door timing (or door closing dwell time). The lift doors can then close when the threshold is clear of passengers.

Where mobility impaired/disabled access is required the dwell time is set at 5.0 seconds as a minimum. In residential buildings it is common to set dwell times to 7.0 seconds to allow for prams and bicycles to be manoeuvred into and out of the lift. Good control systems should reduce the dwell times when a car call is registered or re-registered, or when the door close button is operated.

Where differential door timing is not fitted the round trip time equation needs to be adjusted when a door dwell time is longer than the calculated passenger transfer time. This can occur when only one passenger enters/leaves at a landing and the door dwell time is longer than a passenger transfer time. This introduces the concept of a lift system cycle time (t_{cyc}). The cycle time includes any door dwell times when no passenger transfers occur. The cycle time can be applied to the round trip time equation by deleting the term $(2 P t_p)$ and adding the value of the dwell time to the value of the performance time (T).



Caution: where passenger movements are complex a simulation study may need to be carried out to verify the calculated design.

(g) *What are lobby loading times?*

Many control systems operate a lobby loading time at the main terminal floor during periods of dominant up travelling traffic. This prevents the lift closing its doors and moving away with only one passenger in the car after that passenger has entered and registered a car call. The lobby loading time should be set to be equal to the time for a reasonable number of passengers to board the car, this can be taken as 60% probable car loading. There may then be no effect on the round trip time calculation due to the lobby loading time.



Caution: if the lobby loading time does not reduce to a standard dwell time values during off peak periods, passenger service times may increase.

(h) *Is the traffic controller ideal?*

The traffic control system (dispatcher) is assumed to be ideal. On older scheduled (timed) systems, it is possible for the wrong control algorithm to be switched on for the prevailing traffic pattern: for example, the down peak program during uppeak. Modern on-call traffic controllers utilise load and direction detection systems to determine

the prevailing traffic pattern. Some designers increase the value of the round trip time by 5% or 10% to account for losses due to controller inefficiency. This value must be made known to all parties to a design.



Caution: the overuse of this assumption may result in an over lifted solution.

Uppeak performance can be boosted by traffic control techniques (Barney, 2003) such as uppeak zoning, uppeak sectoring, landing call allocation and landing call allocation with uppeak sub zoning (see section 9.7). Formulae for H and S that may be used in the calculation of the round trip time when a hall call allocation traffic control is employed are:

$$S = \frac{N}{k} \left(1 - \left(\frac{N-1}{N} \right)^{kP} \right) \quad (3.14)$$

$$H = N - \sum_{i=1}^{N-1} \left(\frac{i}{N} \right)^S \quad (3.15)$$

where k is the system look ahead.



Note: in a hall call allocation system calls are assigned to a certain number of cars ahead of the next arriving car. Thus k usually has a value of 2 or 3.

(i) *Are all the adjustments described in (a) to (h) necessary?*

Lift traffic design is not a precise science, but rather an art. The uppeak traffic pattern is mathematically defined absolutely. It will always give absolute values, which may not happen in practice. Real morning arrivals are never as precise. In general a satisfactory design can be obtained without making any of these adjustments. But an experienced designer might consider some adjustments of significance. For example, where differential door timing was not fitted.

(j) *How can the calculation deal with transfer floors?*

Tall buildings (or even some lower ones) may provide some means to travel between zones or building rises. A served floor (other than the main terminal or upper lobby) is important where there are common facilities to be accessed, e.g. restaurant, travel bureau, sports facilities, post room, reprographics, etc.

The effect on traffic handling can be disruptive. In general it is important to restrict access to such floors during uppeak and down peak, although the object of such a floor would be defeated at other times, i.e. at the midday break or during interfloor traffic.



Design tip: during up or down peak traffic, the transfer floor should be either included in the zone below or the zone above, whichever produces similar interval times at the main terminal floor.



Caution: it is difficult to calculate the effect of a transfer floor and simulation techniques should be used, see chapter 4.

(k) *How does lift function, building form and building function affect the calculations?*

See sections 3.13, 3.14 and 3.15.

(l) *Will the RTT value obtained by calculation be the same as that obtained by simulation?*

It is possible, but unlikely, for several reasons, such as the following:

- The calculation method uses a rectangular probability distribution function to describe passenger arrivals, whereas a simulation often uses a Poisson probability distribution function as it is simple to generate in a digital computer and closer to the real world.
- As the calculation can use non-integer values for the variables, e.g. $P = 8.8$, a simulation can only use integer value for each passenger (although the results can be averaged to non-integer values).
- The destinations in a calculation are statistically derived whereas in a simulation they may be generated by a pseudo random binary sequence (PRBS), of a specified length and feedback, which is easy to generate in a digital computer and closer to the real world.
- Statistical generation methods in a simulation cannot always provide the specified demand exactly, e.g. in a calculation the arrival may be defined as 100 persons/5-minutes whereas the simulation might present a range from 95 to 105 persons/5-minutes, so the comparison is not like for like.
- A simulation can deal with the conflict between the number of passenger transfer times and the effect of the door dwell times exactly, whereas in a calculation an assumption has to be made.
- A simulation can deal with dwell times almost exactly, calculation can only estimate their effect.

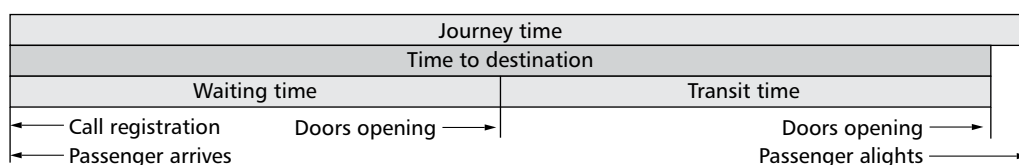
Also see section 4.3.



Design tip: in general the use of the calculation method to size a lift system will result in a slightly over lifted installation.

3.11 Passenger times during uppeak traffic demand

The quality of service relates to the passenger experience. Its primary measure is how long a passenger waits to board a lift, known as the passenger average waiting time (AWT). The second metric is the time it then takes for the passenger to reach the destination, known as the passenger average transit time (ATT). These relationships are illustrated in Figure 3.3.



The passenger average waiting time and the passenger average transit time can be combined to give the average passenger time to destination (ATTD). Finally there is the passenger average journey time (AJT). This time includes the additional time from the time the lift car doors open until the passenger alights onto the landing.

The definitions of these times have been agreed internationally (Barney et al., 2005) and these definitions are shown in section 3.3.

With the increasing installation of hall call allocation and adaptive call allocation traffic control systems the passenger waiting, transit, journey times and time to destination do not start with call registration, as they do with a conventional two button call station, as shown in Figure 3.3. The arriving passenger registers a call on call stations, which may be placed in the conventional locations, but are now often located some distance from the lobby or even activated by turnstile entry systems. In these cases the passenger has to walk and then stand in front of their allocated lift car. This walking time has an assumed value. The various passenger times are then measured from the end of the assumed walking time, i.e. when the passenger arrives as shown in Figure 3.3.



Caution: the time assumed will be accurate provided the passenger walks direct to the allocated car and is not distracted by coffee kiosks or social interactions.

Passenger average waiting times, transit times and times to destination cannot be easily calculated and their accurate estimation requires simulation. However, the equations below may be used to estimate these times.



Caution: all the formulae below are based on a mathematical model. To determine more accurate time values a simulation study should be carried out, see chapter 4.

Equation 3.16 can be used to provide a value for the passenger average waiting time (AWT). For car loads from 50% to 80% the AWT is given by:

$$AWT = [0.4 + (1.8 \times PC/100 - 0.77)^2] \times INT \quad (3.16)$$

For car loads less than 50% the AWT is 40% of the interval (INT). Car loads above 80% are not considered. On the spreadsheets in Appendix 3.A2 a value of AWT is presented in cell B39 for Examples 3.1 and 3.2.



Caution: many lift companies state AWT as half the interval. Others state incorrectly that the time for the lift to respond to a first landing call registered, sometimes called 'system response time' (SRT), is the average passenger waiting time. These times can be very inaccurate as some lift companies cancel the call registration as much as eight seconds before the lift actually starts to open its doors at a landing.

Figure 3.3 Illustration of passenger time relationships

Equation 3.17 can be used to provide a value for the passenger average transit time (ATT):

$$ATT = 0.5 H t_v + 0.5 S (T - t_v) + 1.5 P t_p \quad (3.17)$$

This estimate is based on how long it takes the average passenger to reach their destination, who is assumed to travel to the midpoint of the local travel for any group of lifts. This implies a travel for a distance of $H/2$ with the number of stops being $S/2$ and a transfer of P passengers boarding the lift and $P/2$ passengers alighting before the average passenger alights.

Equation 3.18 can be used to provide a value for the passenger average travel time to destination (ATTD).

$$ATTD = 0.5 H t_v + 0.5 S (T - t_v) + 1.5 P t_p + AWT \quad (3.18)$$

This average time is obtained by adding the primary metric of average passenger waiting time (AWT) to the secondary metric of average passenger transit time (ATT).

Equation 3.19 can be used to provide a value for the average passenger journey time (AJT):

$$AJT = ATTD + t_o + t_p \quad (3.19)$$

This is longer than the average passenger travel time to destination (ATTD) by the time required to open the lift doors and the passenger to cross the threshold.



Caution: the times AWT, ATT and ATTD are all subjective and related to passenger psychology. An acceptable time for waiting in an office building when accompanied and when alone may be different. Acceptable times in a residential building may not be acceptable in a hotel.

To achieve satisfactory passenger experiences target times given in Table 3.9 are recommended for office buildings.

Table 3.9 Target average passenger times for office buildings

Time	Target time (s)	Poor time (s)
AWT	< 25	> 30
ATT	< 60	> 70
AJT	< 80	> 90

The passenger average waiting time relates to a single floor in uppeak, i.e. the main terminal. The average transit time and journey time have a second dimension, i.e. the passenger destination. The values given in Table 3.9 relate to the average trip to the mid-point of travel. Thus some passengers with a destination low in the building will have shorter times whereas those travelling to the reversal floor will have longer time. Passenger psychology may allow a longer waiting time in exchange for a shorted transit time as long as the journey time is consistent.

The times indicated in Table 3.9 can be calculated as above, but more reliable values may be obtained by simulation.

The grade of service provided by an installed lift system in an office building can be expressed as either the percentage

of calls answered in specified time intervals, or the time to answer a specified percentage of calls.

Table 3.10 gives recommended target times values for several grades of service averaged over one hour of peak activity in an office building using system response time (SRT) as a quality indicator, see definitions (section 3.3). Although system response times cannot be calculated they may be obtained by simulation. Actual system response times can be measured easily using a stopwatch or the data logger on an installed lift system.

Table 3.10 Office building average system response time (SRT) performance

Grade of service	Percentage of calls (%) answered in stated time		Time to answer stated percentage of calls (s)	
	30 s	60 s	50%	90%
Excellent	>75	>98	20.0	45
Good	>70	>95	22.5	50
Fair	>65	>92	25.0	55
Poor/unacceptable	<65	<92	>25.0	>55



Caution: one hour of peak activity should be taken in order to obtain practical results.

It should be possible to obtain the grades of service indicated in the table during the worst hour of activity. This might occur during the midday break rather than during the intense, but shorter, uppeak and down peak periods at the beginning and end of the working day.



Design tip: during a shorter period of activity of (say) fifteen minutes, e.g. during down peak, the grade of service might fall one level and during an even shorter period of activity of (say) five minutes, e.g. during uppeak, the grade of service might fall two levels.

3.12 Traffic conditions other than uppeak

Alexandris et al. (1979) analysed traffic patterns other than uppeak, but they made a large number of assumptions. Peters (1990) developed the General Analysis method to overcome these problems, see chapter 4.

Simple formulae to calculate the other traffic conditions, such as down peak, midday and off peak can be obtained in the similar way to those obtained for uppeak. They can be used to estimate performance.



Caution: a much more accurate prediction of performance requires a study of all the circumstances by simulation (see chapter 4).

The down peak round trip time (RTT_d) can be obtained using:

$$RTT_d = N t_v + (0.5 S + 1) (T - t_v) + 2 P t_p \quad (3.20)$$

The underlying down peak handling capacity can then be calculated from the value of RTT_d .

The down peak average passenger waiting time (DNPAWT) in terms of the uppeak interval (UPPINT), uppeak handling capacity (UPPHC) and the number of passengers arriving during the down peak period (A_d) can be estimated using:

$$\text{DNPAWT} = 0.85 A_d \frac{\text{UPPINT}}{\text{UPPHC}} \quad (3.21)$$

On the spreadsheet for Example 3.2 (see Appendix 3.A2) a value of DNPHC is presented in cell B40.

The mid-day round trip time (RTT_m) can be obtained using:

$$\text{RTT}_m = 2 H t_v + 2 S (T - t_v) + 4 P t_p \quad (3.22)$$

The underlying midday handling capacity (MIDHC) can then be calculated from the value of RTT_m .

On the spreadsheet for Examples 3.2 (see Appendix 3.A2) a value of MIDHC is presented in cell B41.

An estimate of the average passenger waiting time (MIDAWT) can be made from:

$$\text{MIDAWT} = 0.85 \text{MIDINT} \quad (3.23)$$

The average passenger waiting time (IFAWT) in terms of the uppeak interval (UPPINT), uppeak handling capacity (UPPHC) and the number of passengers arriving during the interfloor period (A_i) can be obtained using:

$$\text{IFAWT} = \text{UPPINT} \left(0.22 + 1.78 \frac{A_i}{\text{UPPHC}} \right) \quad (3.24)$$

The passenger demands during off peak traffic periods are modest. These can be equivalent to a 5-minute demand as low as 3% of the building's population, which is well within the underlying capability of a properly designed lift system.

3.13 Selection of equipment with respect to lift function

3.13.1 Double deck lifts

Double deck lifts are used mainly in very tall buildings and comprise two passenger cabs one above the other connected to a single suspension/drive system. The upper and lower cabs can serve two adjacent floors simultaneously. During peak periods the cabs are often arranged to serve even and odd floors respectively with passengers guided into the appropriate cab for their destination. Special arrangements are made at the lobby for passengers to walk/travel up/down a half flight of stairs/escalators to reach the lower or upper main lobby.

The advantage for double deck lifts is that the shaft handling capacity is improved as effectively there are two lifts in each shaft. The disadvantage is for the passengers during off peak periods, when one cab may stop for a call with no call registered for the other cab. Special control systems are available, such as only using one deck during

off peak periods, where the traffic demand is low. The round trip time for double deck system can be obtained (Barney, 2003) using:

$$\text{RTT} = 2 H t_v + \left(S \left(2 - \frac{S}{N} \right) + 1 \right) (T - t_v) + P t_p + P \left(2 - \frac{S}{N} \right) t_p \quad (3.25)$$



Caution: the use of double deck lifts is rare in the UK and their traffic design is a specialised procedure requiring the use of simulation software (see chapter 4).

3.13.2 Firefighting lifts

Firefighting lifts are discussed in detail in chapter 6 and are usually single lifts situated around the floor plate. Their rated load is often only 630 kg and their rated speed sufficient only to reach the highest occupied floor in 60 s. Therefore their handling capacity is low.



Design tip: firefighting lifts provide a small, useful addition to the vertical transportation services of a building, especially those with large floor plates. However, do not factor their presence into the traffic handling provision.

Where a firefighting lift is part of a group, extra precautions are made to protect it, i.e. fire protected lobby/stairways, through-car doors, etc. These precautions may affect the traffic handling of these lifts and this should be taken into account when calculating the handling capacity of such a group.

3.13.3 Goods lifts

The need for goods lifts has increased substantially in recent years. Despite the computer revolution the amount of paper in and scrap paper out has increased. Also it is quite common to find in any type of building one or more floors under refurbishment, with the requirement to bring in equipment and to remove rubbish and debris. All buildings should be served by an adequate number of goods lifts of a suitable size. This should ensure that the passenger lifts are used for their designed purpose and not used as goods transporters to the detriment of the passenger service.

It is recommended that all office buildings contain at least one dedicated goods lift for usable floor areas up to 10 000 m². For larger buildings, an additional goods lift should be provided for each additional 20 000 m² gross floor area. Dedicated goods lifts should have a minimum rated capacity of 1600 kg. Consideration should be given to providing goods lifts with rated loads up to 2500 kg.



Caution: where passenger lifts are used as goods lifts, either generally, or in an emergency, the interiors should always be protected by suitable drapes.

3.13.4 Observation (glass/scenic) lifts

Observation lifts are often installed in hotels and shopping complexes to provide a feature or visual impact. They may

attract a large percentage of pleasure riders. They will be part of the vertical transportation system of a building. Generally they have longer flight and door times, which reduces their traffic handling performance.



Design tip: the car interiors are often shaped for aesthetic and viewing purposes rather than easy circulation in the car. They should be considered to be occupied at a reduced occupancy of (say) 60% in comparison to the 80% used for a conventional lift.

3.13.5 Shuttle lifts

Shuttle lifts generally serve two stops, such as at a railway station, underground station or in a tall building, which are divided into zones with service direct from the main lobby to an upper lobby. Calculation of their traffic performance is simple, as they only serve two floors, and is given by:

$$RTT = 2T + 2Pt_p \quad (3.26)$$

When installed in tall/very tall buildings shuttle lifts are usually large and fast and are an important transportation facility.



Design tip: the traffic design of shuttle lifts is a specialised procedure as they often transport passengers to/from a sky lobby, where further groups of lifts serve another section (zone) of the building.



Warning: very fast lifts (>10 m/s) travelling long distances (>250 m) may cause auditory discomfort to the passengers and special measures may need to be taken to alleviate this.

3.13.6 Lifts sharing a common well (shaft)

Here two independent lifts are installed in the same shaft. Usually the upper cab runs at a higher rated speed than the lower cab. Special precautions have to be adopted to ensure the two cabs do not collide. They are installed with the intention to reduce the number of shafts penetrating the total height of the building and thus release rentable space. For instance a 4-car group serving a low zone and a 4-car group serving a high zone might be reduced to four pairs in four shafts. The size of the wells is larger throughout the building.



Design tip: it may be found necessary to install an additional pair in a fifth shaft to achieve an equivalent performance to 8 single lifts, thus reducing the 'saved' space.



Caution: this type of installation is not easily analysed mathematically and traffic design needs to be carried out using simulation, see chapter 4.

3.14 Equipment selection with respect to building form

3.14.1 Basement service and floors served by only part of a lift group

Buildings are sometimes designed with car parks or with a service facility, such as restaurant or leisure area, below the main terminal at basement levels. Often not all floors below the main terminal floor are served by all lifts in a group. While this saves capital expenditure, it is not recommended as it violates the general rule that all lifts in a group should serve the same floors. Passengers may experience difficulty in selecting the correct lifts out of a group, which serve a basement, unless special signalling arrangements are made. In the event that only one lift out of a group serves all floors, the waiting time that passengers experience may be long.



Design tip: it may be better to provide basement service to the main terminal floor by a separate lift or lifts. This solution can avoid seriously affecting the traffic handling capabilities of the main lift group.

Serving floors below the main terminal has an effect on the uppeak, down peak and midday traffic patterns. One effect of service to the basement area is that during uppeak cars arrive at the main terminal already partly full, causing confusion. The time penalty to be added to the round trip time can be between 15 s to 30 s or more, depending on the number of basement stops. Designers should take account of these factors, when sizing an installation with served levels (M) below the main terminal.

A calculation of the basement probable stops (S_M) and basement reversal floor (H_M) can be carried out in a similar way to the upward service (Barney, 2003). The resulting additional time can then be added to the normal round trip time. The round trip (equation 3.1) is modified thus:

$$RTT = 2Ht_v + (S + 1)(T - t_v) + 2Pt_p + 2H_M t_{vM} + S_M(T_M - t_{vM}) \quad (3.27)$$

where the floor transit time (t_{vM}) and the performance time (T_M) are evaluated for the basement interfloor distance. Values for H_M and S_M can be calculated using equations 3.5 and 3.6 using the number of basement floors (M) for N .

3.14.2 Entrance bias

Some buildings have more than one main entrance (at a common or different level) and each entrance may be served by its own group of lifts. Or there may be a large lobby area with two groups of lifts on either side serving the same floors. The difficulty here is deciding whether the building population will use these entrances (and their associated group of lifts) on a 50/50 basis or not.



Design tip: in the absence of any guidance designers should assume an entrance bias of 60/60 and size the lift groups to meet this demand.

3.14.3 Stairs

Table 3.11 provides guidance to the division of passenger demand between lifts and stairs (Peters et al., 1996). Designers should take the stair usage factor into account.

Table 3.11 Stair usage

Floors travelled	Usage up (%)	Usage down (%)
1	80	90
2	50	80
3	20	50
4	10	20
5	5	5
6	0	0



Design tip: the provision of well signed and easily accessible stairs can considerably lessen the demands made on the lifts.

3.14.4 Attractive ('magnet') building facilities

There may be facilities in buildings which can distort traffic movements. Examples are restaurants (positioned at the top of the building, in the basement, even half way up the building); drinks and sandwich machines; leisure club facilities (swimming pools, gymnasia), facilities floors (bank, travel agent, shops), toilet facilities, post rooms, trading floors etc. These floors may provide a powerful attraction at different times of the day and should be considered in the traffic design. The effect of 'magnet' floors on lift performance may be studied using simulation, see chapter 4.

3.14.5 Lobby design

Lobby design (see section 2.7.4) can have an effect on the round trip equation. If lifts are served from large lobbies then the lobby door dwell time may need to be increased. Alternatively an increase in the passenger transfer time (t_p) used in equation 3.1 by 10% may be considered to account for any loading inefficiency. In severe situations some designers add 10% to the round trip time.

3.14.6 Tall buildings

Examination of Table 3.A1.1 (Appendix 3.A1) indicates that for a specified size of car the number of stops (S) increases as the number of served floors (N) increases. As the round trip time in equation 3.1 is dominated by the central term, which includes S , the effect is to increase the round trip time. This in turn increases the uppeak interval, the passenger waiting time and the passenger journey time. A similar deterioration of performance occurs for the other traffic conditions. The solution is to limit the number of floors served by the lifts.



Design tip: a rule of thumb is to serve a maximum of 15–16 floors with a lift or a group of lifts.

Limiting the number of floors served introduces the concept of zoning. Zoning is where a building is divided so that a lift or group of lifts is constrained to serve a designated

set of floors. There are two forms of zoning — interleaved and stacked:

- An interleaved zone is where the whole building is served by lifts, which serve, either even floors, or odd floors. This arrangement is not recommended today.
- A stacked zone building is where a tall building is divided into horizontal layers. This in effect stacks several buildings on top of each other, with a common footprint, in order to save ground level space. It is a common and recommended practice for office and institutional buildings. Each zone can be treated differently with regard to shared, or separate, lobby arrangements, grade of service, etc.

Where it is required that each zone receives the same grade of service, either the number of floors, or the number of lifts, in each zone can be adjusted to achieve this.



Design tip: it is usually easier to adjust the number of floors per zone, than the number of lifts per zone.

The number of floors in a zone, the number of lifts serving a zone and the length of the express jump all affect the round trip time. The round trip time equation can be adjusted by adding a time equal to the time (t_e) taken to pass the 'un-served' floors in both directions:

$$RTT = 2Ht_v + (S + 1)(T - t_v) + 2Pt_p + 2(t_e - t_f)(1) \quad (3.28)$$

where t_e is the flight time from the main terminal to the express zone terminal ('sky lobby').



Caution: an assumption of equation 3.28 is that the lift reaches full speed in its travel through the express zone. If this is not the case, the RTT calculation may be optimistic. A better approach would be to determine the actual flight time through the express zone, or to use simulation.

3.14.7 Very tall buildings

Very few very tall buildings (i.e. those over 40 stories high) are built in the UK. It is not proposed to discuss the traffic design of such buildings, as this is a very specialised procedure.

3.15 Equipment selection with respect to building function



Important note: this section is concerned with the selection of equipment for twelve different types of buildings. Reference to the corresponding subsections of chapter 2, which deals with the circulation of people, and those subsections of chapter 5, which deal with the application of different types of lifts, should also be consulted.

3.15.1 Airports

The movement of baggage carts/trolleys from one level to another is a significant demand. A solution is to install inclined moving walks and this greatly improves circulation. Lifts, however, are the main means of vertical movement.

Generally each baggage trolley might be attended by two persons plus their baggage. A trolley may weigh (including its own weight) some 75 kg, but occupy the space taken by three or four persons. Thus the total weight of two passengers and their trolley might be some 225 kg and occupy the space of some 5 people. This occupancy and loading requirement should be taken into account. In these circumstances lifts are very unlikely to become overloaded.

There are no changes required to equation 3.1.



Caution: care may need to be taken in the assumptions of lift car occupancy levels.



Design tip: as airport terminal buildings are low rise the selection of a hydraulic lift gives a concession regarding car platform size and rated load (BS EN 81-20 (BSI, 2014a)). This allows lifts of lower rated load to be installed for the same platform area and a possible cost saving.

3.15.2 Car parks

Car parks can be attached to shopping centres, offices, airports, railway stations, etc. They are often multistorey, although those at out of town shopping centres and railway stations may be at a single level. The pedestrian demand on the lifts is more likely to be constrained by the entry and exit ramp vehicle movement capacities. A factor is the vehicle occupancy, which can be considered to be 1.2 persons per car for office car parks and two persons per car elsewhere.

For offices the peak demand is often in the evening, when building occupants are attempting to reach their cars. The office lifts, which may not necessarily serve the car parking levels, can bring large numbers of people to the lobby. Those persons with cars can then make a significant demand on any lifts serving the car park levels. The demand on the car park lifts is similar to that experienced by the main lifts during the morning peak period, but this demand is downwards and to fewer floors.



Design tip: the traffic design should use equation 3.1 if the car park lifts are separate to the main lifts, and equation 3.19 if the lifts are part of a basement service.

3.15.3 Department stores

This category applies to large departmental and chain stores. These stores can have many entrances, some of which may open to a main street whilst others may open into shopping mall areas. The opportunity therefore exists for 'leakage' into and out of the shopping centre. Many stores own the lifts and escalators inside their occupancies. These facilities may be used by shopping centre pedestrians to move between mall levels.

3.15.4 Entertainment centres, cinemas, theatres, sports centres, stadia and concert halls

Buildings providing these functions can specialise in one of the activities or many of them. Many sports centres are low rise and do not require lifts, unless for disabled access. Town centre buildings such as cinema complexes, concert halls and theatres can be of higher rise. Such complexes generally use escalators as the main vertical transportation element.



Design tip: lifts provided in these circumstances do not have to meet a large passenger demand. They may only have to meet the requirements for the mobility impaired persons and firefighting.

There are no changes required to equation 3.1.

3.15.5 Hospitals

The building form is important, i.e. whether the building has a small footprint and is tall (US practice) or has a large footprint and is low rise (UK practice). In the former case, where lifts are used as a primary circulation element, their proper operation is vital, particularly when dealing with operating theatre emergencies. In Britain most hospitals are designed on a 2–3 storey low rise principle, although many city hospitals have high rise elements. Lifts are provided in UK low rise hospitals mainly as a means of moving bed bound patients and for service activities from floor to floor as staff and visitors use the stairs.

The traffic designer should understand the *modus operandi* of the hospital before finalising a design. Factors to be considered include: numbers of staff and shift patterns, numbers of visitors and visiting hours, location of theatres, X-ray, etc., distribution and deliveries of food, beverages, housekeeping supplies, waste disposal, patient emergency evacuation, porters, etc. For infection control purposes it may be necessary that patient bed lifts are separate from the visitor and staff lifts.

Demand estimation can be made by multiplying the number of beds by three, to allow for staff, visitors, etc. A suitable arrival rate can be taken as 8–10% with an interval of from 30–50 seconds.



Design tip: Health Technical Memorandum 08-02 (DoH, 2009) gives more specialised guidance.

There are no changes required to equation 3.1.

3.15.6 Hotels

Lifts play an important part in the circulation of guests and service staff in a hotel. Escalators should be employed for short range movements, e.g. to connect function levels with the lobby.

The average room occupancy is dependent on the type of hotel. For business hotels assume one person, for transit hotels 1.5 persons, and for holiday hotels two persons. These figures can be used to determine the likely demand.

The traffic patterns in hotels are complex, and are not comparable to the morning and afternoon peaks in an office building. The most demanding times are at check-out (08:00 to 10:00) and check-in (17:00 to 19:00). At these times heavy two-way traffic occurs with guests going to and from rooms, restaurants and in and out of the hotel. The arrival rate might change according to the star rating (*) of the hotel. Assume an arrival rate in the range of 10% (1*) to 15% (5*) and an interval range of 30 seconds (5*) to 50 seconds (1*).

Calculations should be made assuming equal numbers of up and down stops at these times.

At most other times lifts are unlikely to load to fill to more than 50%. However, the lift sizes should be at least 1275 kg, in order to accommodate luggage and provide guests with uncrowded and comfortable travel conditions.



Design tip: as a rule of thumb assume one lift for every 90–100 keys and there should be one passenger/goods lift for every two passenger lifts.



Caution: this rule should be used with care as it would not be suitable for a low rise hotel with 30% of its rooms at the entrance level. Neither would it be suitable for a high rise hotel with a small footprint. There are also differences between the operational needs of a 'transit' hotel near to airports, etc. where guests stay one night and hotels used by longer term and holiday guests.

There are no changes required to equation 3.1.

3.15.7 Offices

Much of this chapter is concerned with lifts in commercial office buildings. The British Council for Offices publishes general guidance.

3.15.8 Railway stations

Railway stations may be served mainly by stairs and pedestrian ramps, although some, particularly the deeper underground stations, use escalators. Generally railway stations, whether above or below ground, have poor provision of lifts. This may change as the requirements to assist persons with limited mobility are applied.

Passengers wishing to move from one level to another with hand baggage may find this difficult. When baggage trolleys are used these difficulties increase. As with shopping centres (section 3.15.11) a solution to this problem is to install inclined moving walks. This also greatly improves circulation.

There are no changes required to equation 3.1.

3.15.9 Residential buildings

The estimation of the population in a residential building is usually based on the number of bedrooms and the occupancy per bedroom. Suitable rules of thumb for the number of persons occupying a flat (apartment) are given in Table 3.12.

Table 3.12 Occupancy factors (persons) for residential buildings

Type	Luxury	Normal	Low income
Studio	1.0	1.5	2.0
1 bedroom	1.5	1.8	2.0
2 bedroom	2.0	3.0	4.0
3 bedroom	3.0	4.0	6.0

Table 3.12 does not include large luxury category residential buildings, but it is suggested that a four bedroom 'apartment' would have a population of four persons and a penthouse would have five persons.



Caution: some properties are bought as investments and are often unoccupied. This absenteeism may have an effect on passenger service.

The commonly used design period for a residential building is the afternoon, 5-minute, two-way traffic condition, which is considered the most demanding traffic period. During this period of time, people enter and leave the building. The lifts load passengers at the main lobby, distribute these passengers to various upper floors, reverse direction at the uppermost hall call, stopping in the down direction for additional passengers and transporting them to the main lobby. In low income housing (e.g. housing association), where many children and adults are leaving for school and work at the same time, the morning down peak may also be very heavy. Table 3.13 gives guidance.

Table 3.13 Design criteria: residential buildings (5-minute, two-way)

Type	Luxury	Normal	Low income
Interval (s)	45–50	50–60	50–70
Two-way handling capacity (%)	8	6–8	5–7



Caution: the value suggested for interval is nominal and should be calculated for an 80% occupied car.

In residential and low income flats one passenger lift should be large enough (say 1600 kg) to allow furniture movement, accommodate stretchers and to handle other service needs. Luxury flats may include a separate goods lift for furniture, trades-people and domestic help. These goods lifts should have rated loads of at least 2000 kg.

Each flat should have access to an alternative lift during maintenance or out of service conditions.

Penthouse apartments may require special considerations regarding occupancy and lift provision.

There are no changes required to equation 3.1.

3.15.10 Residential care homes and nursing homes

Homes generally have a low traffic requirement, which can be catered for by a single lift or lifting platform. Larger homes might acquire a second lift giving security of service in the event of break down or maintenance.

3.15.11 Shopping centres

Shopping centres are often built with two or three levels of retail and several levels of car parking above or below. Lifts do not play a major part in the pedestrian transportation arrangements, which are usually centred on escalators. Lifts should always be located in pairs and not singly in order to provide a reasonable interval of 40–60 s and security of service during breakdowns and maintenance. Often scenic lifts are provided not only for transportation, but as an enjoyable experience.



Design tip: in multi-level shopping complexes provision should be made for the movement of shopping trolleys, push chairs and persons with mobility problems from one level to another. A commonly applied solution to this problem is to install inclined moving walks. Where lifts are used it is unlikely that they fill to more than 50%.



Warning: escalators should never be considered for the transportation of shopping trolleys, push chairs and persons with mobility problems. Inclined moving walks should be limited to an inclination of 6 degrees. If shopping trolleys are to be transported these must be designed for the specific inclined walk.

The demand on lifts to access car parks is determined mainly by the maximum rate of entry/exit of vehicles and the average occupancy of each vehicle. These values may be determined from an associated (road) traffic study.

3.15.12 Universities and other education buildings

A university campus can have a variety of office type buildings, halls of residence, catering services and factory like units containing teaching and research equipment. Some buildings are mixed function: e.g. lecture rooms, laboratory and offices. Some buildings may specialise as lecture blocks only. Where universities occupy city sites many have tall buildings (10–20 stories) and even those on out of town sites follow suit in order to reduce land use and achieve a compact campus. There may be hourly cycles of 10 minutes of demand before and after each 50 minute lecture, tutorial or seminar session. These peaks can range from 15–25% with an interval of from 30–50 seconds. It is unlikely that an economic solution can be found to accommodate such high peaks requirements and heavy stair use can be expected. In between the peaks the activity levels are very low.



Design tips:

- The office type buildings can be treated as detailed elsewhere in this chapter.
- The halls of residence can be treated as hotels, although perhaps at lower levels of demand and performance.
- The catering services can be attached to either the office type buildings or halls of residence and should be treated similarly to those provided in office facilities or hotel facilities.

- The research buildings can be low rise and be subject to special movement provisions associated with the equipment installed.

3.16 Review of all traffic conditions

The primary traffic condition for design is pure uppeak. It is analytic and formulae can be easily derived. The uppeak design method provides a measure of the underlying handling capacity of a lift system. This in turn sets the performance of the three other major traffic conditions of down peak, interfloor and midday traffic. With the uppeak traffic condition considered to be unity, the underlying handling capacity ratios for the other conditions may generally be taken (Barney, 2003) as:

- uppeak: 1.0
- down peak: 1.6
- midday: 1.3
- interfloor: 1.4

For example, if a lift group has an uppeak handling capacity of 12% then it has a handling capacity of 19.2% during a down peak traffic demand.



Note: the underlying interfloor handling capacity is never utilised, as the typical demand is about one fifth of the uppeak demand.



Caution: it is important to obtain the correct uppeak sizing if the other traffic patterns are to be handled satisfactorily. If for example an installation is sized for uppeak using an uppeak booster, such as hall call allocation (see chapter 9) then the underlying handling capacity may be too small to meet the midday and down peak demands. Traffic conditions other than uppeak are best analysed by simulation.

3.17 Finally

All the calculations in this chapter are based on average values derived from mathematical models of experimental data. There can never be an 'average' system and therefore the results may not represent the performance gained from an actual installation.



Design tip: it is recommended that all uppeak calculations are 'pure' with no other traffic considered. Then the calculation can be used as a benchmark to compare different designs and different competitive offers in a tender situation.

The pure uppeak calculation gives a value for the underlying capability of the lift installation. It may be that a morning peak of only 10% of a building population is observed. There may, however, also be a further 5% of activity in the down direction and between floors.



Design tip: in this case a design for a 15% handling capacity would be justified.

In the majority of cases, calculations do provide a suitable traffic design. Where better evaluations are required a simulation should be carried out, but only after a thorough understanding of the possible designs have been obtained by calculation. Thus for unusual arrangements and a more accurate indication of performance, simulation techniques, see chapter 4.

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Appendix 3.A1: Table of values of H and S

Table 3.A1.1 Values of H and S with respect to number of passengers carried in car (P) (it may be necessary to use interpolation between given values of P)

(a) For 5 to 12 passengers per trip

Number of served floors, N , above MT	H and S values for stated average number of passengers per trip (P)															
	5		6		7		8		9		10		11		12	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
5	4.6	3.4	4.7	3.7	4.8	4.0	4.8	4.2	4.9	4.3	4.9	4.5	4.9	4.6	4.9	4.7
6	5.4	3.6	5.6	4.0	5.7	4.3	5.7	4.6	5.8	4.8	5.8	5.0	5.9	5.2	5.9	5.3
7	6.3	3.8	6.4	4.2	6.5	4.6	6.6	5.0	6.7	5.3	6.7	5.5	6.8	5.7	6.8	5.9
8	7.1	3.9	7.3	4.4	7.4	4.9	7.5	5.3	7.6	5.6	7.7	5.9	7.7	6.2	7.8	6.4
9	8.0	4.0	8.2	4.6	8.3	5.1	8.4	5.5	8.5	5.9	8.6	6.2	8.7	6.5	8.7	6.8
10	8.8	4.1	9.0	4.7	9.2	5.2	9.3	5.7	9.4	6.1	9.5	6.5	9.6	6.9	9.6	7.2
11	9.6	4.2	9.9	4.8	10.1	5.4	10.2	5.9	10.3	6.3	10.4	6.8	10.5	7.1	10.6	7.5
12	10.5	4.2	10.7	4.9	11.0	5.5	11.1	6.0	11.2	6.5	11.3	7.0	11.4	7.4	11.5	7.8
13	11.3	4.3	11.6	5.0	11.8	5.6	12.0	6.1	12.1	6.7	12.3	7.2	12.3	7.6	12.4	8.0
14	12.1	4.3	12.5	5.0	12.7	5.7	12.9	6.3	13.0	6.8	13.2	7.3	13.3	7.8	13.4	8.2
15	13.0	4.4	13.3	5.1	13.6	5.7	13.8	6.4	14.0	6.9	14.1	7.5	14.2	8.0	14.3	8.4
16	13.8	4.4	14.2	5.1	14.5	5.8	14.7	6.5	14.9	7.0	15.0	7.6	15.1	8.1	15.2	8.6
17	14.6	4.4	15.0	5.2	15.3	5.9	15.6	6.5	15.8	7.1	15.9	7.7	16.0	8.3	16.1	8.8
18	15.5	4.5	15.9	5.2	16.2	5.9	16.5	6.6	16.7	7.2	16.8	7.8	16.9	8.4	17.1	8.9
19	16.3	4.5	16.8	5.3	17.1	6.0	17.4	6.7	17.6	7.3	17.7	7.9	17.9	8.5	18.0	9.1
20	17.1	4.5	17.6	5.3	18.0	6.0	18.2	6.7	18.5	7.4	18.6	8.0	18.8	8.6	18.9	9.2
21	18.0	4.5	18.5	5.3	18.8	6.1	19.1	6.8	19.4	7.5	19.6	8.1	19.7	8.7	19.8	9.3
22	18.8	4.6	19.3	5.4	19.7	6.1	20.0	6.8	20.3	7.5	20.5	8.2	20.6	8.8	20.8	9.4
23	19.6	4.6	20.2	5.4	20.6	6.2	20.9	6.9	21.2	7.6	21.4	8.3	21.5	8.9	21.7	9.5
24	20.5	4.6	21.1	5.4	21.5	6.2	21.8	6.9	22.1	7.6	22.3	8.3	22.5	9.0	22.6	9.6

(b) For 13 to 20 passengers per trip

Number of served floors, N , above MT	H and S values for stated average number of passengers per trip (P)															
	13		14		15		16		17		18		19		20	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
5	4.9	4.7	5.0	4.8	5.0	4.8	5.0	4.9	5.0	4.9	5.0	4.9	5.0	4.9	5.0	4.9
6	5.9	5.4	5.9	5.5	5.9	5.6	5.9	5.7	6.0	5.7	6.0	5.8	6.0	5.8	6.0	5.8
7	6.9	6.1	6.9	6.2	6.9	6.3	6.9	6.4	6.9	6.5	6.9	6.6	6.9	6.6	7.0	6.7
8	7.8	6.6	7.8	6.8	7.9	6.9	7.9	7.1	7.9	7.2	7.9	7.3	7.9	7.4	7.9	7.4
9	8.7	7.1	8.8	7.3	8.8	7.5	8.8	7.6	8.8	7.8	8.9	7.9	8.9	8.0	8.9	8.1
10	9.7	7.5	9.7	7.7	9.8	7.9	9.8	8.1	9.8	8.3	9.8	8.5	9.8	8.6	9.9	8.8
11	10.6	7.8	10.7	8.1	10.7	8.4	10.7	8.6	10.8	8.8	10.8	9.0	10.8	9.2	10.8	9.4
12	11.6	8.1	11.6	8.5	11.6	8.7	11.7	9.0	11.7	9.3	11.7	9.5	11.8	9.7	11.8	9.9
13	12.5	8.4	12.5	8.8	12.6	9.1	12.6	9.4	12.7	9.7	12.7	9.9	12.7	10.2	12.8	10.4
14	13.4	8.7	13.5	9.0	13.5	9.4	13.6	9.7	13.6	10.0	13.7	10.3	13.7	10.6	13.7	10.8
15	14.4	8.9	14.4	9.3	14.5	9.7	14.5	10.0	14.6	10.4	14.6	10.7	14.6	11.0	14.7	11.2
16	15.3	9.1	15.4	9.5	15.4	9.9	15.5	10.3	15.5	10.7	15.6	11.0	15.6	11.3	15.6	11.6
17	16.2	9.3	16.3	9.7	16.4	10.2	16.4	10.6	16.5	10.9	16.5	11.3	16.6	11.6	16.6	11.9
18	17.2	9.4	17.2	9.9	17.3	10.4	17.4	10.8	17.4	11.2	17.5	11.6	17.5	11.9	17.6	12.3
19	18.1	9.6	18.2	10.1	18.2	10.6	18.3	11.0	18.4	11.4	18.4	11.8	18.5	12.2	18.5	12.6
20	19.0	9.7	19.1	10.2	19.2	10.7	19.3	11.2	19.3	11.6	19.4	12.1	19.4	12.5	19.5	12.8
21	19.9	9.9	20.0	10.4	20.1	10.9	20.2	11.4	20.3	11.8	20.3	12.3	20.4	12.7	20.4	13.1
22	20.9	10.0	21.0	10.5	21.1	11.1	21.1	11.5	21.2	12.0	21.3	12.5	21.3	12.9	21.4	13.3
23	21.8	10.1	21.9	10.7	22.0	11.2	22.1	11.7	22.2	12.2	22.2	12.7	22.3	13.1	22.3	13.5
24	22.7	10.2	22.9	10.8	22.9	11.3	23.0	11.9	23.1	12.4	23.2	12.8	23.2	13.3	23.3	13.8

Appendix 3.A2: Use of spreadsheets for calculation

In manual calculations of the round trip time using equation 3.1 it is assumed that cars load to 80% of the probable capacity (PC). The value obtained for UPPHC relies on the same assumption. But this is only correct if the arrival rate (A_p) exactly equals UPPHC. If too few, or too many, passengers arrive the car load may not be 80% and the values for S , H , RTT and the interval may alter.

This is so for Example 3.1 (see section 3.7.7). Here the maximum probable car capacity (PC) is 11.4 persons (Table 3.1) giving the 80% value (P) as 9.1 passengers. A calculation gives an interval of 30.3 s, a handling capacity of 90.1 persons/5-minutes, and a percentage population of 12.3%. In software, the calculation can be performed iteratively. If the calculated UPPHC is greater than the arrival rate, the number of passengers in the car can be changed using an iterative procedure until the UPPHC is equal to the required passenger demand.

The evaluation of the round trip time (equation 3.1) is relatively simple using a spreadsheet, see below.



Design tip: The evaluation of the highest reversal floor (H) requires the evaluation of the summation:

$$\sum_{i=1}^{N-1} \left(\frac{i}{N} \right)^P$$

This can be achieved by using a macro or simply calculating for (say) eight summations.

Example 3.2 evaluated using a spreadsheet

Using a spreadsheet to determine the underlying handling capacity, round trip time, etc.

(a) Given data (from section 3.9):

- Number of floors (N): 10
- Rated load (Q): 1000 kg
- Number of lifts (L): 4
- Rated speed (v): 1.6 m/s
- Building population (U): 731 persons
- Interfloor distance (d_f): 3.6 m
- Single floor flight time ($t_f(1)$): 5.2 s
- Door close time (t_c): 3.0 s
- Door open time (t_o): 2.5 s
- Advance door opening (t_{ad}): 0.5 s
- Start delay (t_{sd}): 0.5 s
- Passenger transfer time (t_p): 1.0 s

(b) Procedure:

- Enter given data into cells B12 to B27.
- Select the probable car capacity from Table 3.1 for a 1000 kg car (i.e. 11.4). Enter the estimated value for P (i.e. 8.8) and enter into input cells B14 and B15.
- Set input cells B20–B21 to zero, as there is no express jump.

(c) Derived data

The results are shown in cells B30–B38, i.e:

- B34: RTT = 119.4 s
- B35: UPPINT = 29.9 s
- B36: UPPHC = 88 persons/5-min.
- B37: %POP = 12.1%

Ignore results cells B39–B41, see sections 3.10 and 3.11.

Note: the values obtained are slightly different to those of the calculation shown in Example 3.1, as the spreadsheet does not round numbers.

	A	B
11	INPUT DATA	
12	Number of floors	10
13	Rated load	731
14	Probable car capacity	11.4
15	Number of passengers	8.8
16	Number of lifts	4
17	Rated speed	1.6
18	Building population	731
19	Interfloor distance	3.6
20	Express jump	0
21	Express additional time	0
22	Single floor flight time	5.2
23	Door close time	3
24	Door open time	2.5
25	Advance door opening	0.5
26	Start delay	0.5
27	Passenger transfer time	1
28		
29	RESULTS	Value
30	Number of passengers	8.8
31	Highest reversal floor	9.4
32	Number of stops	6.0
33	Performance time	10.7
34	Round trip time	119.4
35	Interval	29.9
36	Handling capacity	88
37	Percentage population	12.1
38	Capacity factor (%)	77
39	Upppeak average waiting time	23
40	Down peak handling capacity	143
41	Midday peak handling capacity	118

Figure 3.4 Example 3.3: spreadsheet output

4 Advanced planning techniques and computer programs

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4 Advanced planning techniques and computer programs

4.1 Introduction

Chapter 3 indicated the procedure to carry out a manual calculation of lift traffic performance. This chapter considers the application of advanced planning techniques that rely on computer software.

Using software, round trip calculations can be extended to account for traffic patterns other than uppeak, and to allow for multiple entrance floors. Simulation models the whole process of passengers arriving at the landings, registering their landing calls, boarding the lifts when they arrive, registering their car calls and then alighting at their destination.

Lift simulation is a very powerful tool. However it is good practice to start all design exercises with a round trip time (RTT) calculation. This is because:

- Historically, lift installations sized correctly with RTT calculations have worked. If a round trip analysis is done prior to a simulation analysis then any major differences between the two can be investigated and understood. If the simulation was done without the round trip analysis any discrepancy would not be noticed and explored.
- Simulation is complex and it is easy for less experienced practitioners to make mistakes, a round trip calculation may alert the practitioner of a possible error.
- RTT calculations are much faster than simulation. By using RTT calculations it is possible to establish what solutions are worth testing with simulation very quickly.

The use of computer methods greatly reduces the possibility of errors compared to manual methods. However, with any computer program, it is important that the input data and the output data are checked by experienced designers and not simply accepted without question. The method of calculation should also be examined very carefully if results differ significantly from those that would be obtained applying the calculation procedures discussed in this guide.

4.2 Advance round trip time calculations

4.2.1 Extending the uppeak calculation

RTT calculations are possible to complete by hand, sometimes supported by look up tables to determine H and S . However, most designers now use a spreadsheet or

software. Using software and extended formulae the basic uppeak RTT calculation can be extended to account for non-equal floor populations, interfloor heights, and lifts not reaching full speed in a single floor jump. Complete mathematical formulae recommended for implementation in software are given in Appendix 4.A1.

4.2.2 General Analysis

Alexandris et al. (1977) analysed traffic patterns other than uppeak, but they made a large number of assumptions. Peters (1990) developed the General Analysis method to overcome these problems; the mathematics is complex and so requires implementation in software.

General Analysis allows RTT calculations to be performed for any peak traffic flow. This overcomes most of the limitations associated with conventional uppeak calculations. For example, General Analysis allows assessment of:

- (1) office buildings with car parks and basements
- (2) hotel or residential buildings with two-way peak traffic
- (3) shopping centres with heavy interfloor traffic
- (4) offices with restaurants causing heavy peaks at lunch times
- (5) double deck lifts.

The General Analysis technique can be programmed into a computer. A full implementation of the General Analysis method allows individual floor populations to be considered and for the specification of differing passenger demand at all floors.

It is important to note, however, that all RTT calculations are designed to analyse 'peak' traffic situations, where there are traffic flows to and/or from the main entrance floor. If the traffic levels are low relative to the underlying handling capacity of the system being considered, the mathematical basis of the RTT calculation may be no longer valid. If this is the case, the calculated result for interval may be low or even zero. This is a limitation of all RTT calculations as non-peak traffic can only be analysed using simulation techniques.

General Analysis can be used to analyse uppeak, down peak and mid-day traffic as these are heavy traffic conditions. The method can provide improved results compared to the classical method described in chapter 3.

4.3 Simulation

Simulation has a number of advantages over RTT calculations:

- RTT calculations simplify the analysis exercise in order to be able to formulate the problem in mathematical terms. Results are extrapolated from an ‘average’ round trip of a single lift. With simulation, every lift trip is modelled, thereby avoiding the need to work with average trips.
- RTT calculations give results in terms of the system ‘interval’, which is period of time between successive car arrivals or departures at the main entrance (see section 3). Quality of service is better measured in terms of passenger waiting and transit times, which can be calculated by simulation. Although interval is often used as a quality metric that gives some indication of passenger waiting time, it is not directly related to passenger waiting time.
- Simulation is visibly closer to ‘real life’ and therefore more intuitive. For example, an overloaded system in simulation can show queues forming at landings.
- Simulation can model the lift control system. Simulation programs normally have a range of control systems available and sometimes have an option for users to add their own or a specified manufacturer’s traffic control algorithms. The choice of control system can significantly affect the results.
- The logic controlling door operation can be modelled, e.g. different dwell times at lobby floors, door re-opening, differential door timing.
- The output results can be displayed in a wide range of tables and graphs.

Simulation can be used to model scenarios that cannot normally be analysed with the RTT calculations, including:

- light (non-peak) traffic
- changing levels of traffic, e.g. the increasing levels of traffic as the work start time approaches in an office building
- mixed types of traffic, e.g. goods and passenger traffic using the same lifts
- lifts in the same group with different speeds and sizes.

Simulation is not always appropriate. If a designer’s brief is to select a lift installation for an office building using the traditional design benchmarks (see chapter 3), e.g. 12% uppeak handling capacity and 30 seconds uppeak interval, then the preferred approach would be to use an RTT calculation. Introducing simulation can otherwise complicate a simple exercise.

However, as stated in chapter 3, simulation is capable of better evaluations. This is most true when the actual traffic flow is known, or can be estimated with some certainty. Otherwise, a range of simulations with different traffic patterns may be performed so that it is clear to the client that how the building is used will affect recommended lift configurations.

4.4 Describing traffic

4.4.1 Preface

In order to apply advanced planning techniques such as simulation and General Analysis (Peters, 1990), an enhanced understanding of traffic in buildings is required.

4.4.2 Mixed traffic

Simple traffic is defined in terms of the percentage of the building population transported upwards or downwards in five minutes. Mixed traffic includes an element of people travelling to and from the entrance floors, plus an element of interfloor traffic. This can be described by specifying a total demand as a percentage of the building population over 5-minute periods. This total can then be separated into three parts as follows:

- (1) % *incoming*: the part of the total demand that corresponds to passengers arriving at the entrance floor(s), and travelling up the building, or down to any floors below the entrance floor(s). Sometimes called entrance traffic (Powell, 2001).
- (2) % *outgoing*: the part of the total demand that corresponds to passengers arriving at floors above (or below) the entrance floor(s), and travelling to the entrance floor(s). Sometimes called exit traffic (Powell, 2001).
- (3) % *interfloor*: the part of the total demand that corresponds to passengers travelling between floors other than the entrance floor(s).

This approach is particularly useful for defining heavy traffic at lunchtime. For example, the traffic in an office building may peak at 13% of the building population arriving over five minutes, with a traffic mix of 45% incoming, 45% outgoing and 10% interfloor.

For buildings with more than one entrance floor, an entrance level bias should also be defined. For example, in an office building with three below-ground car park levels and one main entrance, there may be an entrance level bias as shown in Table 4.1.

Table 4.1 Example entrance level bias

Floor	Entrance level bias (%)
Car park –3	10
Car park –2	20
Car park –1	20
Ground	50

The entrance level bias in Table 4.1 would be determined by making an assessment of the number of car park spaces and expected persons per car, in proportion to the number of people who occupy the building. Note that the entrance level bias may be different at different times of the day. For example, if people drive to work, but not to lunch, the car parks can have a higher bias at the beginning and end of each day.

Restaurant and other utility floors introduce further considerations. Figure 4.1 shows the results of a traffic

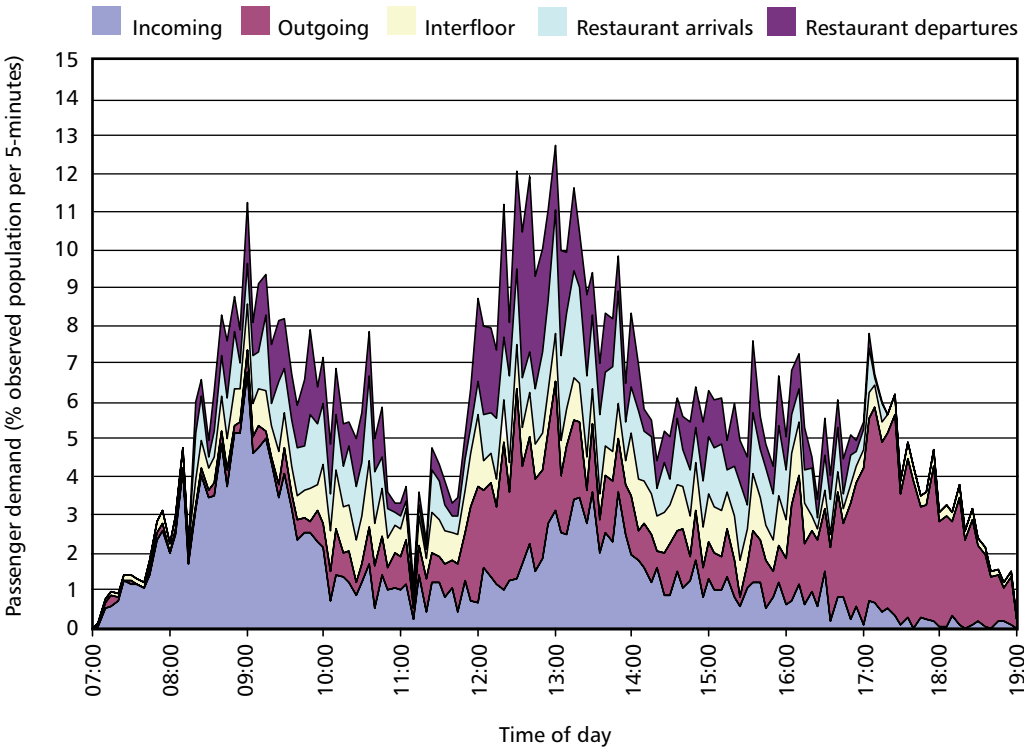


Figure 4.1 Example of mixed traffic in an office building with a restaurant at an upper level

survey in an office building with a restaurant. Passenger demand can be presented as a ‘stacked area’ graph, highlighting the contribution of each traffic component: incoming, outgoing, interfloor, restaurant arrivals and restaurant departures. The total peak demand (from all traffic types) at lunchtime is approximately 13% of the observed building population per five minutes.

The simplest way to model this building is to assume that the restaurant itself is an entrance floor, with an entrance bias.

If the restaurant in this building was removed, and it was assumed that people not eating in the restaurant would eat locally outside the building, the restaurant arrivals traffic would be added to the outgoing traffic component. Similarly, the restaurant departures traffic would be added to the incoming traffic component. This approach provides consistency when comparing results with offices without a restaurant or other utility floor. This is the assumption used in the presentation of survey results in section 4.5.

Some entrance floors are populated, which introduces further complexity. For example, in some buildings people

enter at a car park level and then take the lifts to their office on the ground floor. If traffic arising from people whose offices are on entrance floors is likely to be significant, specialist advice should be sought.

4.4.3 Complex traffic

For traffic flows that cannot be described in terms of mixed traffic, a more sophisticated measure is needed. Two terms are required:

- the passenger demand at floor i (defined for each floor at which passengers may arrive)
- the probability of the destination floor of passengers from floor i being the floor j (defined for all possible values of i and j).

Table 4.2 provides an example of traffic presented in this form. In this presentation of traffic, the demand is no longer simplified to be a function of the population.

Table 4.2 Example arrival rate and destination probability table

From/to	Arrival rate (persons per 5-minutes)	Destination probability / %							
		Ground	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Ground	25.2	0.0	14.3	14.3	14.3	14.3	14.3	14.3	14.3
Level 1	2.4	50.0	0.0	8.3	8.3	8.3	8.3	8.3	8.3
Level 2	2.4	50.0	8.3	0.0	8.3	8.3	8.3	8.3	8.3
Level 3	2.4	50.0	8.3	8.3	0.0	8.3	8.3	8.3	8.3
Level 4	2.4	50.0	8.3	8.3	8.3	0.0	8.3	8.3	8.3
Level 5	2.4	50.0	8.3	8.3	8.3	8.3	0.0	8.3	8.3
Level 6	2.4	50.0	8.3	8.3	8.3	8.3	8.3	0.0	8.3
Level 7	2.4	50.0	8.3	8.3	8.3	8.3	8.3	8.3	0.0
Total:	42.0								

4.5 Measuring traffic

4.5.1 Need for traffic surveys

All traffic analysis and simulation studies rely on an estimate of traffic demand.

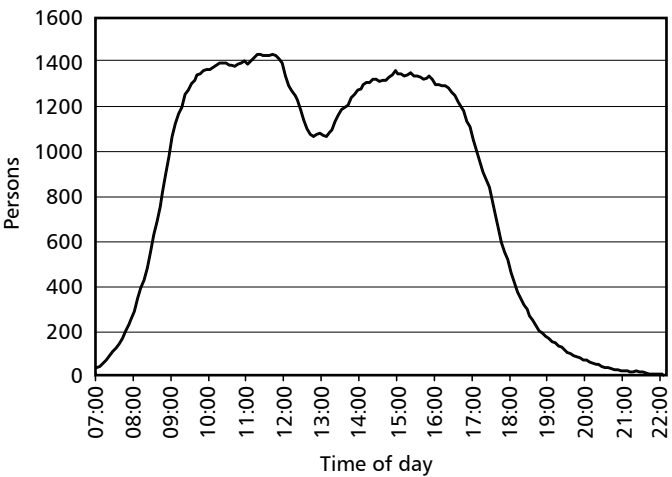
There is recognition that although uppeak calculations work, this is not because the assumed demand is realised, but because the combination of assumptions work together to provide a good ‘rule of thumb’.

The uppeak round trip calculation is accepted globally. However, if its application and assumptions are extended too far, errors can occur. For complex situations, more sophisticated models are required. However, without reliable estimates of passenger demand, results may still be questionable.

4.5.2 Manual passenger traffic surveys

In manual surveys, observers count passengers in and out of the lifts. A manual survey requires at least one person at each entrance floor and a person in at least one car. Peters and Evans (2008) provide a detailed discussion of how to undertake a survey. Figure 4.2 shows survey results from a single tenancy building in London. In this passenger demand plot, traffic up the building is shown in the top section, traffic down the building is shown in the lower section; this style of presentation mimics the classical plot in chapter 3. Interfloor traffic is included in the up and down plots.

In Figure 4.2 the percentage population per five minutes axis is based on the observed population on the day of the survey. This scales the results so that the passenger demand measured in different buildings can be compared. Figure 4.3 shows a maximum observed population of over 1400 people was reached during late morning. The occupancy of the building dropped over lunchtime; in this instance, not

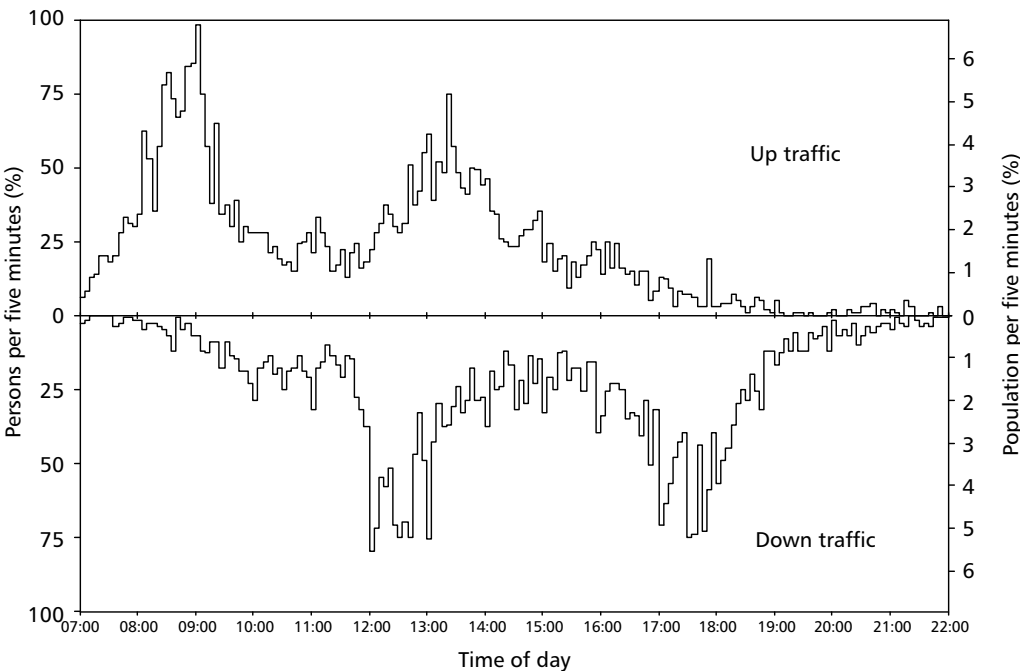


Observed building occupancy for sample traffic survey

everyone returned to the office after lunch. The observed population is often less than the nominal building population because many buildings are not fully occupied, and some occupants will be absent (see chapter 3).

For surveys to be credible a person experienced in lift systems and research should supervise them. Ideally the survey team should include someone who is able to identify faults and limitations in the existing system, for example:

- Wasted stops due to the absence or failure of the load bypass system.
- Unnecessary stops due to more than one hall call riser in the system — people register hall calls on both sets of buttons, resulting in two cars being sent to serve one person.
- Wasted car trips due to over active zoning systems continuously re-parking idle cars.
- Failure of systems to switch into an uppeak mode when there is predominant traffic from the entrance floor(s). This can result in one or more cars being idle at upper floors, while at the same time there are queues forming at the entrance floor(s).



Passenger demand for simple traffic survey

- Failure of systems to switch into a down peak mode. This can result in lower floors in the building receiving no or very poor service during down peaks.

Major faults can affect the observed passenger demand as sometimes people choose to travel at non-peak times or to use the stairs rather than to endure long waiting times. Performance metrics, e.g. average waiting time, will be negatively influenced.

4.5.3 Automated traffic analysers

Simple traffic analysers may be linked to the lift control system, and record the time every landing and car call is made and cleared. They analyse the data and provide a range of performance results and graphs. Modern control systems incorporate similar functionality. A range of traffic and performance measures can be determined, for example:

- average response time to landing calls by time of day
- distribution of response times
- distribution of landing and car calls by floor.

These traffic analysers can give an indication of a lift system's performance, but very limited information about the actual passenger traffic flow. In general, except when destination control (hall call allocation) is in use, the number of people associated with a given lift signal, e.g. a car or hall calls, is unknown.

For the building presented in Figure 4.2, the up and down hall calls counted by the control system was as presented in Figure 4.4. The hall call information gives no indication of the uppeak in the morning or at the end of lunch measured by observers counting people. This is because in uppeak traffic, a single hall call at the entrance level could correspond to a large group of passengers. At the same time,

a down call at upper floors may correspond to a single passenger. For this reason, it is of limited value to use simple traffic analyser results to assess the demand on an existing system, or to evaluate the benefits of modernisation. Instead, a count or estimate of the number of people transported should be made.

Some manufacturers have improved the estimate of actual demand by using information from passenger detection systems (light beams) and load weighing. Siikonen (2000) presents an example of this for a multi-tenant office building in Paris. The survey results measured and stored by the group control system are reproduced in Figure 4.5 (overleaf). Passenger demand is presented as a 'stacked area' graph, similar to Figure 4.1. It should be noted that this traffic data has been collected in 15-minute (as opposed to 5-minute) intervals and that results are averages based on daily statistics. On a single day during the busiest 5 minutes, measured peaks could be higher.

The increased application of destination control makes automatic data collection more straightforward as each passenger is required to register their own call for the system to operate optimally. This allows the origin and destination of the passenger for every call to be identified. Peters and Smith (2008) provide examples of data collected from an installation using destination control. Figure 4.6 (overleaf) plots the data of five working days in the same building. Plotting data for a whole week demonstrates a high level of consistency in passenger demand. Each installation has a recognisable passenger demand pattern or 'signature'. The assumption is made that one destination call corresponds to one person. This is reasonably reliable. Overestimates occur when waiting time is long and impatient passengers re-register their calls. Underestimates occur when passengers travelling together only register one call for the group, or when passengers tailgate into a car without registering a call.

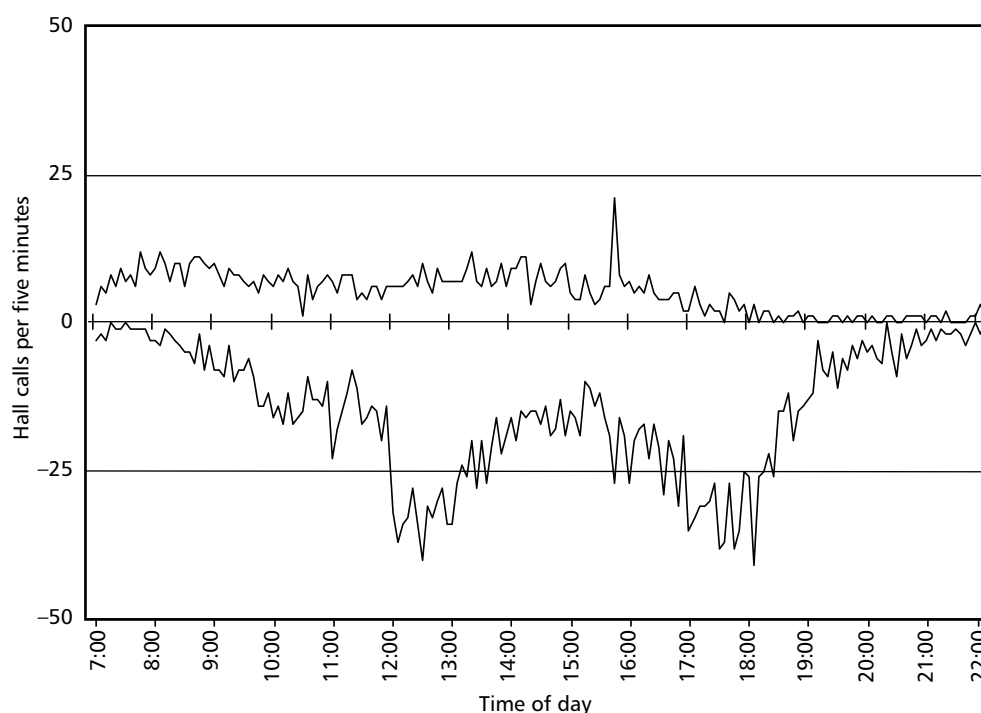


Figure 4.4 Plot of up and down hall calls per five minutes

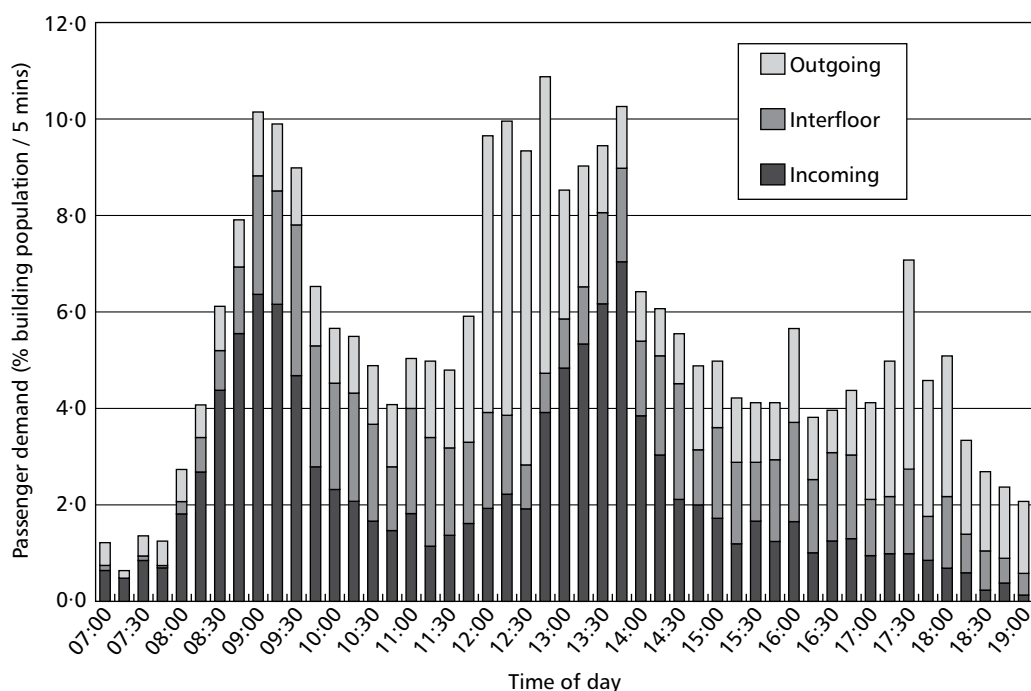


Figure 4.5 Example automatic traffic measurements for a multi-tenant office building

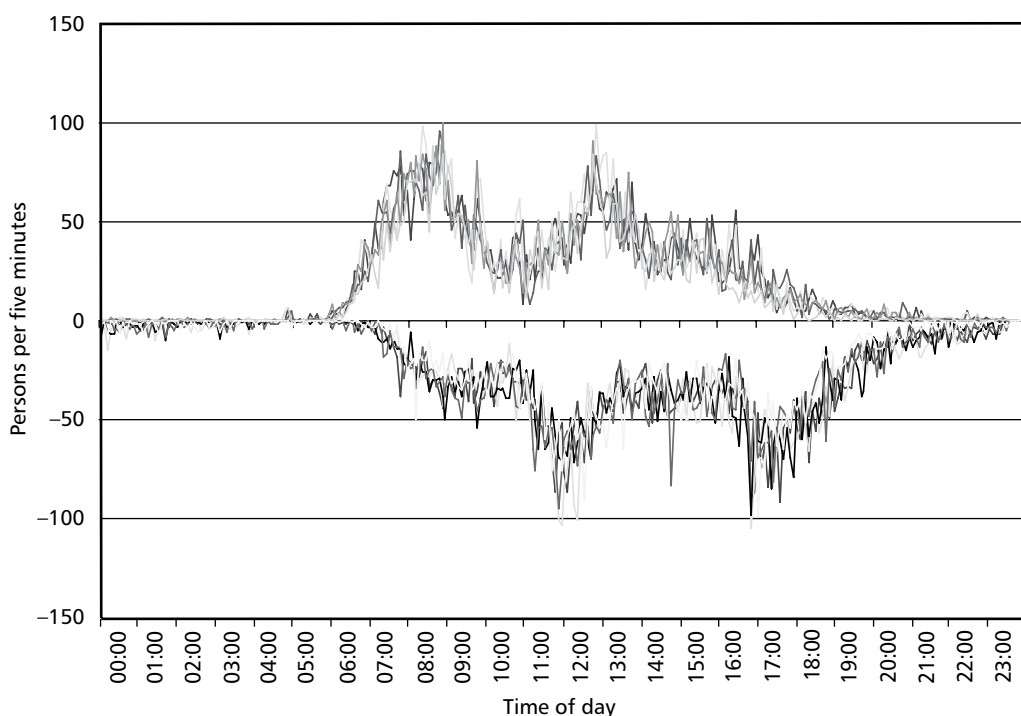


Figure 4.6 Traffic signature for a multi-tenant office building

4.6 Theoretical simulation templates

4.6.1 Background

Since widespread introduction of simulation tools, one of the challenges for the lift industry internationally has been trying to reach a consensus on how to apply simulation. Some designers apply simulation in a way that matches the results of their RTT calculations as closely as possible; some of the issues encountered are discussed in section 4.11. Others prefer templates based on peaks reflecting traffic measurements in buildings, see section 4.7.

4.6.2 prISM simulation method

A range of different theoretical simulation templates are applied by different designers; none are incorrect as they are theoretical system tests, not intended to reflect reality. However, it is not possible to compare the results between the alternative approaches.

In order to simplify the application of simulation, this Guide recommends a single simulation template, based on consultation with the designers and users of simulation tools at open meetings. At the time of writing (March 2015) the approach described in this section is consistent with the provisional ISO Simulation Method (prISM) (ISO, 2015).

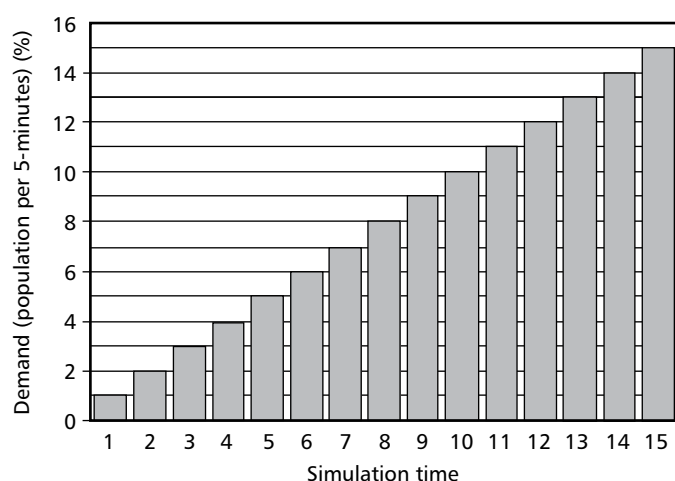


Figure 4.7 Passenger demand for step profile increasing by 1% for each step

The premise of the prISM method is that the system's performance is tested across a range of traffic intensities. The template shown in Figure 4.7 starts with a low demand and increases in stages; the minimum and maximum demand can be selected according to the type of building. The demand can be pure uppeak, or any combination of mixed traffic.

Each stage is two hours long; there is no need to run multiple simulations (see section 4.8.1) as each stage is long enough to provide enough data for the results to be statistically significant in most cases. Between each stage there is a break so that the next step starts again with no traffic remaining from the previous stage. The stages may also be run as separate simulations. Passengers arriving during the first 15 minutes and last 5 minutes of each stage should be disregarded for the analysis. This ensures that no start or end conditions affect the results.

The waiting time, loading (and other parameters) may be presented for each level of demand, both graphically, and in tabular form.

Simulations considering increasing demand are useful for the following reasons:

- They highlight to the customer that the waiting time, loading, and other parameters are dependent on passenger demand. A system that manages 13% of the design population per 5 minutes may be sufficient in most buildings. However, if it can transport a greater demand without saturating, it is more likely to manage, for example, if the building population exceeds the design population.
- They allow for the comparison of control systems, which do not necessarily perform consistently across a range of traffic intensities. For example, at the design handling capacity a conventional system could have a better waiting time than the equivalent system with destination control. However, if demand increases and the conventional system saturates, destination control may have better waiting times.
- They can be used to determine handling capacity of different control systems and traffic patterns in a way that is consistent with the traditional round trip calculation for uppeak and conventional control.

Design criteria may be chosen for consistency with RTT calculations, see chapter 3. However, with simulation, quality of service is normally assessed by considering waiting time (a passenger based indicator) rather than interval (a system based indicator). The relationship between waiting time and interval is complex (Peters, 2013). At low levels of uppeak passenger demand, waiting time can be zero as there is always a lift at the entrance floor(s) ready to load irrespective of the interval. At high levels of passenger demand, waiting time can be much higher than interval as the lifts leave the entrance floor (s) full leaving a queue on than landing.

At the time of writing, the draft International Standard (ISO, 2015) provides passenger lift recommendations given in Table 4.3 (goods or service lifts are not considered). According to the building type, all three office criteria, two hotel or two residential criteria should be satisfied to meet the provisional recommendations. Once the staged simulation is complete, the minimum requirement is met if the average waiting time is less than or equal to the maximum in the range when the passenger demand is set to the lowest in the required handling capacity range.

Table 4.3 Draft ISO recommendations for use with provisional ISO simulation method (ISO, 2015)

Building type and typical traffic mix	Typical range of required handling capacity (HC5) (%)	Typical range of required average waiting time (s)
Office:		
— pure uppeak (100 % incoming)	12–15	20–30
— mixed uppeak (85% incoming, 10% outgoing, 5% interfloor)	11–14	25–35
— lunch 40% incoming, 40% outgoing, 20% interfloor or 45% incoming, 45% outgoing, 10% interfloor	11–14	30–45
Hotel:		
— morning two-way (35 % incoming, 65 % outgoing)	11–13	30–45
— evening two-way (50 % incoming, 50 % outgoing)	11–13	30–45
Residential:		
— morning two-way (15 % incoming, 85 % outgoing)	6–8	30–65
— evening two-way (50 % incoming, 50 % outgoing)	6–8	30–65



Caution: when destination control and other advanced control systems are considered as there are trade-offs between waiting time, transit time and other parameters which are not considered in RTT calculations. A common mistake is to reduce the number of lifts because of the application of destination control without assessing the impact on lobby queue lengths during uppeak, and the waiting time during the lunch period. The response of a lift systems is non-linear, e.g. if an enhanced control system improves uppeak performance it will not necessarily improve lunch time performance. It is easier to assess these trade-offs with simulations based on prospective peak demand patterns, as presented in the following sections.

4.7 Simulation templates derived from traffic surveys

4.7.1 Preamble

Theoretical simulation templates are not intended to represent actual passenger demand in buildings; they are tools used by designers to establish an appropriate design. The approach is valuable when applied by experienced practitioners. However, a more robust position is to design through the application of evidence based research, as discussed in this section. The templates in this section are intended to mimic the worst case measurements of passenger demand.



Warning: it is common for lifts not to perform as well as has been assumed in design calculations and simulations.



Warning: traffic designs based on realistic traffic estimates are the best way to predict actual performance. However, all equipment assumptions should be verified with the lift supplier. It is not unusual for different suppliers to claim a higher rating for equipment with nominally the same specification. For this reason, lift selection should normally be based on generic equipment, and not rely on the enhanced performance claims of one supplier.

It is not uncommon for one or more lifts in a group to be out of service, even in prestige buildings with new lifts. For this reason, designs should also be tested with one lift out of service, and the results reported to the client for their consideration. The contribution to performance made by high quality equipment together with good installation and maintenance cannot be overstated. When it is critical to provide a consistent quality of service, a monitoring system with daily reporting of lift availability and lift performance should be specified.

4.7.2 Office traffic research

Peters Research Ltd. undertook case studies of a range of office buildings for clients between 2007 and 2009. Figure

4.8 shows a plot of average demand normalised against observed population.

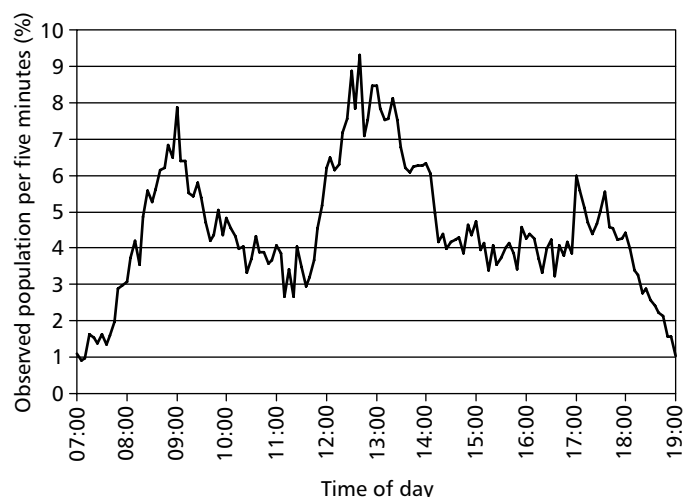


Figure 4.8 Average passenger demand based on survey



Caution: Traffic designs should not be based on average passenger demand. Some buildings have lower demand peaks than indicated in Figure 4.8, other buildings have higher peaks.

Figure 4.9 shows how the demand, on average, is divided between incoming, outgoing and interfloor components. For example, during the early morning, the interfloor traffic comprises a smaller percentage of the total traffic than it does later in the day.

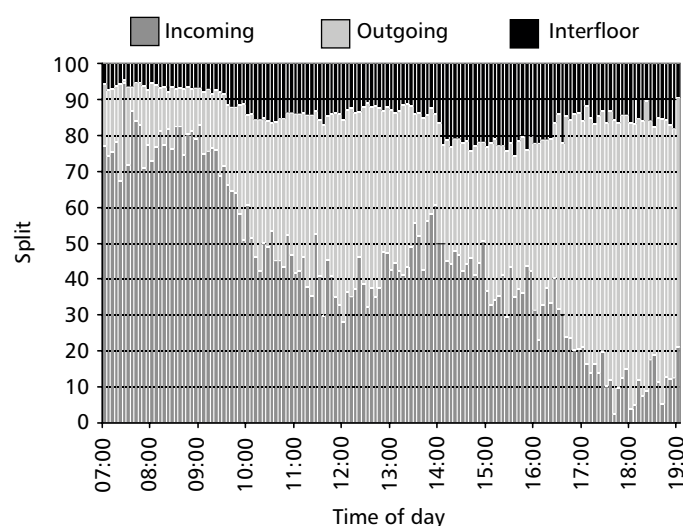


Figure 4.9 Stacked column graph demonstrating the relative contribution of incoming, outgoing and interfloor traffic

Some general observations can be made about modern office buildings:

- Total passenger demand is normally (but not always) greater at lunchtime than it is during the morning uppeak.
- Morning uppeak traffic is now more widely spread than the classical uppeak design suggests.
- Major down peaks are rarely seen.
- Traffic is mixed throughout the whole day, including incoming, outgoing and interfloor components.

In one building the peak demand exceeded 18%. This is characteristic of buildings with low population. In this survey, the population served by the lifts was approximately 200 people. Thus 1% of the population equates to 2 people. With a larger sample size, for example, if the survey was repeated on multiple days, one could expect the average peak to be lower. It is not necessary to design to these high peaks as they do not occur in larger buildings, and in smaller buildings they represent a small number of people. Queues can be cleared in a short time because the high demand is not sustained.

Figure 4.10 shows the range of passenger demand that has been measured in major office (observed population greater than 1000 people) buildings.

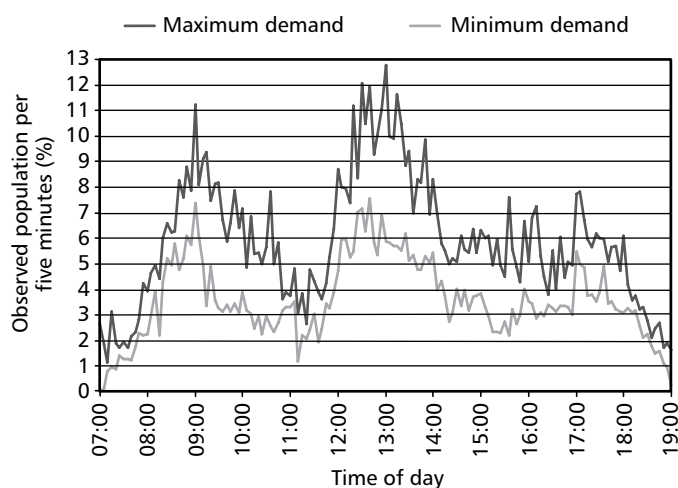


Figure 4.10 Passenger demand range for major office buildings based on surveys of occupied buildings

4.7.3 Office design templates

Design templates to reflect the traffic in modern office buildings are given in Figures 4.11 and 4.12. Each template has twelve, 5-minute periods representing the peak hour. The lunchtime template has been modified from that given in the 2010 edition of this Guide to account for variations in the traffic mix during incoming and outgoing traffic during the lunch period, based on the measurements summarised in Figure 4.9; formerly the division of traffic had been simplified assuming a constant 45% incoming, 45% outgoing, 10% interfloor mix during the whole lunch period.

These templates should be applied when comparing the relative performance of competing proposals during a detailed design. They allow a better assessment to be made of the benefit of enhanced equipment and traffic control systems.

The templates are appropriate for a single tenancy building. Some designers may want to account for multiple tenancy buildings with a reduced demand (see chapter 3).



Caution: some buildings have lift installations that are insufficient because they were designed for multiple tenancies, and are then subsequently occupied by single tenants.

Requirements for quality of service criteria are subjective, and requirements may be different according to county and

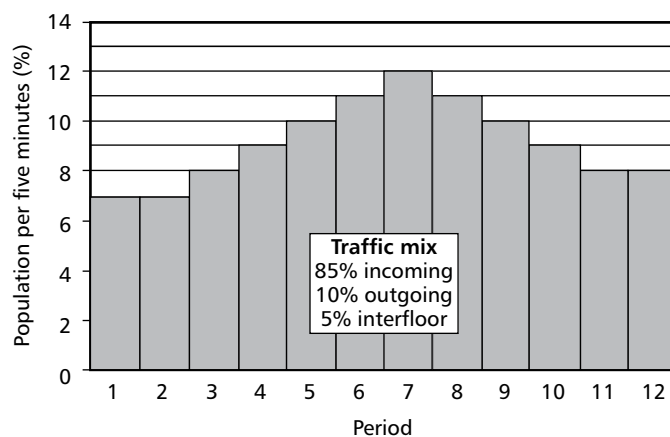


Figure 4.11 Office uppeak traffic templates

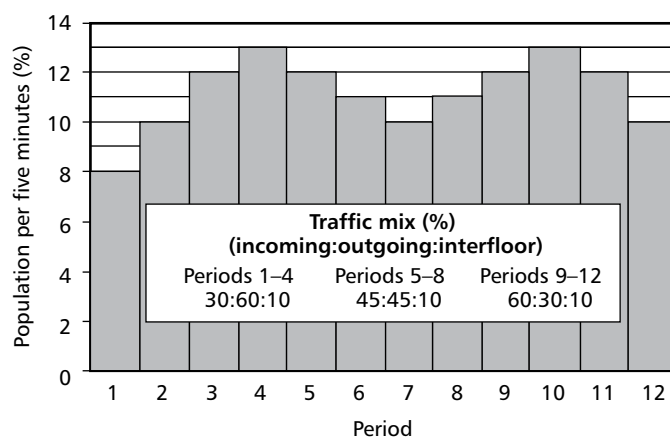


Figure 4.12 Office lunch peak traffic templates

region. British Council for Offices (BCO) recommendations (BCO, 2014) are based on CIBSE modern office demand templates with requirements as summarised below*:

For the uppeak template:

- Target an average waiting time of no more than 25 s. Average waiting times of up to 30 s may be acceptable in cases where the average time to destination is 80 s or less.
- Target an uppeak average time to destination of no more than 90 s. Average time to destination of up to 110 s may be acceptable where the morning uppeak average waiting time is less than 25 s.

For the lunch template:

- Lifts should target an average waiting time of no more than 40 s.

The above requirements allow for the longer waiting times often experienced with destination control, which are traded in return for shorter transit times.

For all traffic conditions the average car loading in any five minutes (including scenic lifts) should not exceed 80 %, allowing 0.21 m² per person.

The waiting time and time to destination are measured for all passengers, irrespective of their origin floor. The average waiting time, time to destination and car loading considered

* BCO 2014 predates this Guide and assumes a constant 45:45:10 traffic mix over the lunch period.

should be the highest result calculated for any 5-minute period in the simulation. Multiple simulations (minimum 10) must be performed to ensure sufficient sample size, see section 4.8.1.

4.7.4 Hotel traffic research

Siikonen (2013) presented measurements for passenger demand based on measurements in five hotel buildings as shown in Figure 4.13. The highest demand was during the morning peak, corresponding to people travelling to/from breakfast, and then leaving the hotel. There are also evening peaks corresponding to dinner and other evening activities; the worst case peak is lower, and the division of incoming and outgoing traffic is similar. So, the evening peak does not need consideration providing service during the morning peak is satisfactory.

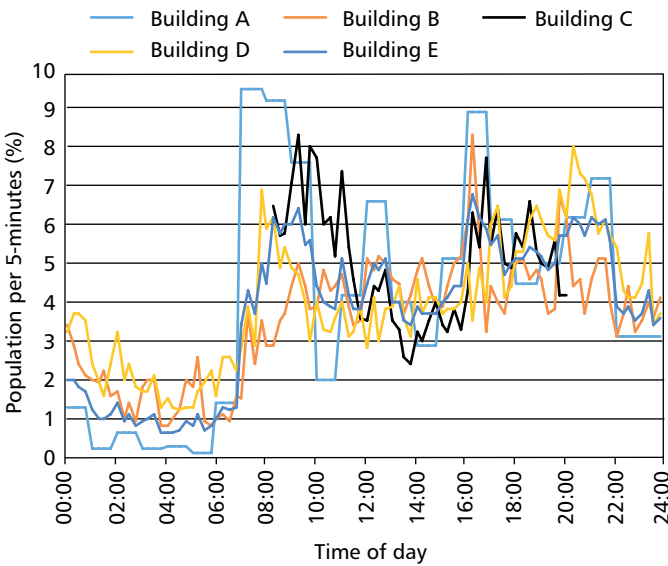


Figure 4.13 Traffic demand in hotel buildings

4.7.5 Hotel traffic template

The CIBSE hotel template for guest lifts is given in Figure 4.14. The template has twelve, 5-minute periods representing the peak hour. As the hotel occupancy was not measured during the Siikonen surveys, the CIBSE hotel profile peaks at 12% pending additional research. Siikonen treats traffic to/from restaurant and other ‘magnet’ floors as interfloor traffic in the traffic description presented in traffic modelling described in section 4.4, so has a higher interfloor traffic component than in CIBSE profile.

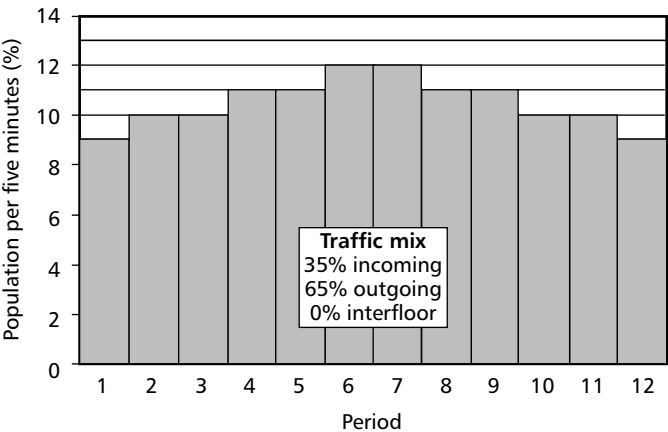


Figure 4.14 Hotel morning peak traffic template

For all traffic conditions the average car loading in any five minutes (including scenic lifts) should not exceed 80%, allowing 0.3 m² per person to account for luggage.

Major international hotel chains often have their own specific waiting time requirement, which can vary according to brand. However, in the absence of specific requirements, target an average waiting time in the range of 30 s to 40 s for a prestigious or business hotel. For an economy higher average waiting times may be acceptable.

The waiting time and time to destination are measured for all passengers, irrespective of their origin floor. The average waiting time, time to destination and car loading considered should be the highest result calculated for any 5-minute period in the simulation. Multiple simulations (minimum 10) must be performed to ensure sufficient sample size.

4.7.6 Residential traffic research

Siikonen (2013) presented measurements for passenger demand based on measurements in five residential buildings as seen in Figure 4.15. There is a morning down peak and a two-way peak in the evening. These have different mixes of traffic, so should be considered separately.

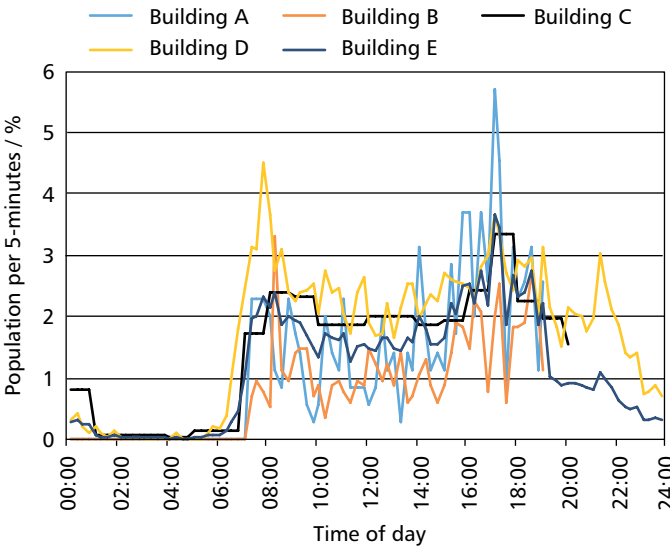


Figure 4.15 Traffic demand in residential buildings

4.7.7 Residential design templates

The CIBSE templates for residential buildings are given in Figures 4.16 and 4.17. Each template has twelve, 5-minute periods representing the peak hour. The traffic peak and traffic mix is based on the worst case of Siikonen’s measurements.

The range of expectations for average waiting time is greatest in residential accommodation as it includes a wider population demographic, including people who would not pay a premium for the service levels found in even the most basic commercial offices and economy hotels. So, for low cost rented housing, higher waiting times may be acceptable.

For all traffic conditions the average car loading in any five minutes (including scenic lifts) should not exceed 80%, allowing 0.3 m² per person to allow for shopping and pushchairs.

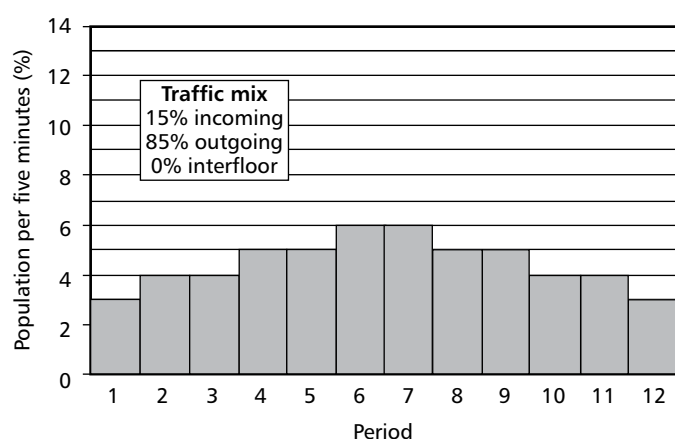


Figure 4.16 Residential morning peak traffic template

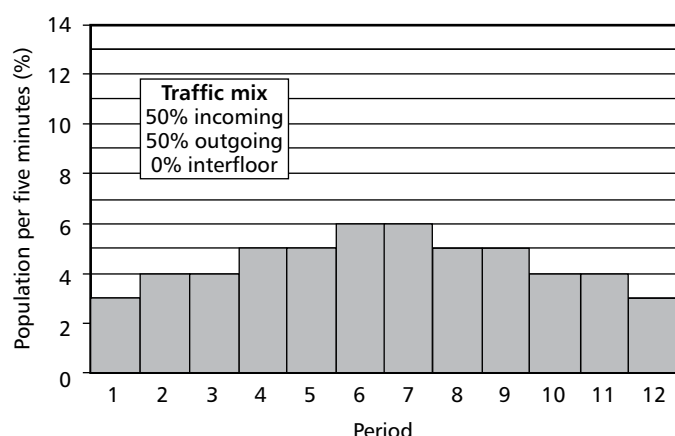


Figure 4.17 Residential evening peak traffic template

For prestige developments, target an average waiting time in the range 30 s to 40 s.

The waiting time and time to destination are measured for all passengers, irrespective of their origin floor. The average waiting time, time to destination and car loading considered should be the highest result calculated for any 5-minute period in the simulation. Multiple simulations (minimum 10) must be performed to ensure sufficient sample size.

4.8 Other considerations

4.8.1 Running multiple simulations

For a simulation to give the same results each time an analysis is run, it must generate the same list of passengers for the same input data. This is achieved by generating passengers according to a random number sequence. This sequence starts at a certain initial value, which can be changed by a process called 'seeding'. When multiple runs are carried out, with different seeds, different results are obtained. It is as if Monday, Tuesday, Wednesday etc., simulations are being run. The results can then be averaged for all the simulations.

Without multiple simulations, the chance element in simulation means that changing a parameter, such as speed or door operating times can sometimes lead to performance results getting worse when it would be expected for them to

improve (or vice versa). Running multiple simulations increases sample size and is the best way to avoid counter-intuitive results.

4.8.2 Not all lifts serving all floors

Where not all lifts service all floors in a lift group, destination control allows the system to send a lift that serves both the origin and destination of the passenger's call. However, the service to and from floors not served by all lifts will normally be worse. To assess the impact on service, examine average waiting time on a floor by floor basis, with and without all lifts serving all floors. Additional simulations will be required to increase sample size. Note that impact of not all lifts serving all floors can be mitigated by allowing reverse journeys (Gerstenmeyer and Peters, 2014). A reverse journey occurs when the control system makes an allocation which allows the passenger to be transported in the opposite direction to their destination before the lift reverses and serves the floor they want to travel to.

4.9 Uppeak design example

4.9.1 Example 4.1

Apply a computer program (Peters, [online]) to select a lift configuration for the following parameters.

Requirements and assumptions:

- Number of office floors above ground: 14
- Population: 1120 (80 persons per floor)
- Interfloor distance: 3.8 m
- RTT losses*: 5%
- Uppeak passenger handling capacity: 12% of population per five minutes
- Maximum interval: 30 s
- Loading time per passenger: 1.2 s
- Unloading time per passenger: 1.2 s
- Maximum capacity factor by mass: 80%
- Passenger mass: 75 kg
- Maximum capacity factor by area: 80%
- Passenger area: 0.21 m²

To determine the maximum practical loading of the car, consider both area and mass. As discussed in chapter 3, the nominal passenger carrying capacity of lifts presented in safety standards should not be used for planning.

Designers used to requiring a higher uppeak handling capacity should note that the limiting factor on handling capacity in this calculation is capacity factor by area. With more optimistic requirements and assumptions, the selected configuration could be demonstrated to achieve 15% handling capacity with 80% capacity factor by mass.

* Some designers increase the RTT by a percentage to allow for controller inefficiencies, door re-openings, and other factors that result in the installed system not being ideal.

The recommendation of this Guide is that designers use lower, more realistic requirements for handling capacity in combination with more realistic assumptions about passenger behaviour and lift performance.

Selected configuration:

- Number of cars: 6
- Rated load: 1600 kg
- Car area: 3.56 m²
- Rated (probable) capacity: 21 (16) persons
- Rated speed (*v*): 2.5 m/s
- Acceleration (*a*): 0.8 m/s²
- Jerk (*j*): 1.0 m/s³
- Start delay time: 0.5 s
- Door open time: 1.8 s
- Door close time: 2.9 s

Calculation results:

- Interval: 27.1 s
- Capacity factor by mass: 57.8%
- Capacity factor by area: 71.6%
- Average number of passengers in car departing home floor: 12.1
- Average number of stops above home floor: 8.3
- Average highest reversal floor above home floor: 13.4

4.9.2 Example 4.2

Repeat analysis of selected configuration in Example 4.1 using the General Analysis RTT calculation (see section 4.2.2).

Calculation results:

- Interval: 26.4 s
- Capacity factor by mass: 56.2%
- Capacity factor by area: 69.6%

Table 4.4 Summary of results Example 4.3 with conventional control

Lift Configuration	Uppeak			Lunch peak		
	Average waiting time (s)	Average time to destination (s)	Capacity factor by area (%)	Average waiting time (s)	Average time to destination (s)	Capacity factor by area (%)
Six 1600 kg cars at 2.5 m/s	24.6	114.8	73.8	38.2	123.9	70.2
Five 1600 kg cars at 2.5 m/s	142.5	242.4	87.2	105.6	206.2	93.4

Table 4.5 Summary of results Example 4.3 with destination control

Lift Configuration	Uppeak			Lunch peak		
	Average waiting time (s)	Average time to destination (s)	Capacity factor by area (%)	Average waiting time (s)	Average time to destination (s)	Capacity factor by area (%)
Six 1600 kg cars at 2.5 m/s	29.6	76.7	46.0	44.1	91.9	41.9
Five 1600 kg cars at 2.5 m/s	40.0	95.6	66.4	60.9	117.7	61.9

- Average number of passengers in car departing home floor: 11.8
- Average number of stops including home floor: 9.0
- Average highest reversal floor (where 1 is lowest floor): 14.2

Designers comparing different calculation programs and manual methods should not be unduly concerned when the results are not precisely the same; the uppeak and General Analysis results are very similar. The General Analysis can also be used to assess buildings with mixed traffic.

4.9.3 Example 4.3

Perform a simulation for the configuration selected in Example 4.1 using the CIBSE uppeak and lunch peak template. Repeat the analysis with a car out of service.

Additional assumptions:

- Passengers may not load beyond the actual car capacity determined by area (16 persons).
- Generic dispatching algorithms: dynamic sectoring operating an uppeak mode, and destination control (adaptive hall call allocation), see chapter 9.
- 10 simulations runs.

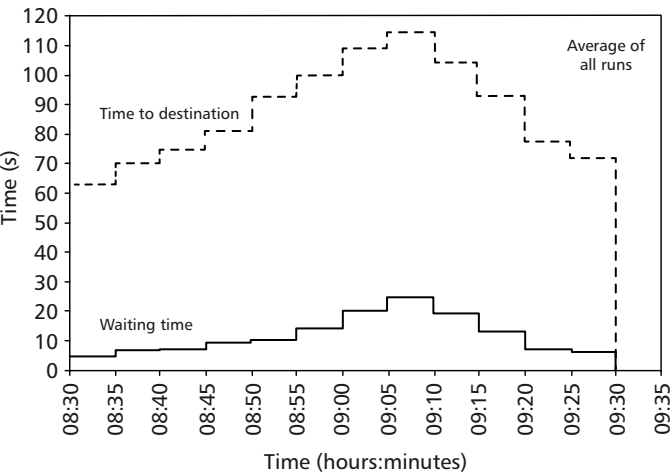


Figure 4.18 Example 4.3: average waiting time and time to destination during uppeak (worst average waiting time during any 5-min. period: 24.6 s; worst average transit time during any 5-min. period: 90.2 s)

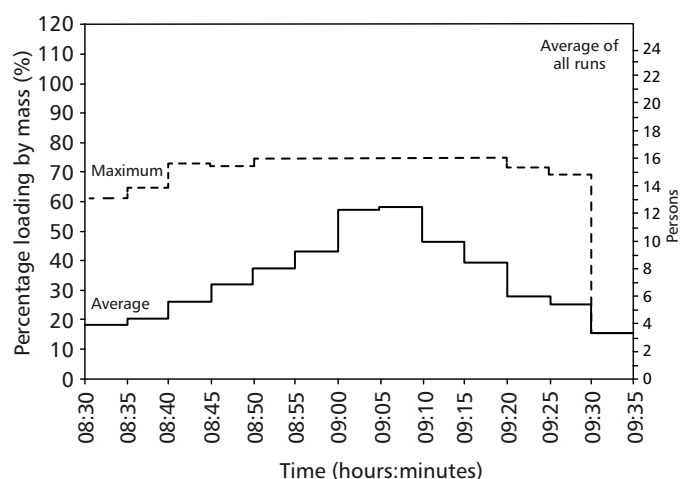


Figure 4.19 Example 4.3: car loading on departure from home floor during uppeak (worst average capacity factor by area during any 5-min. period: 73.8%)

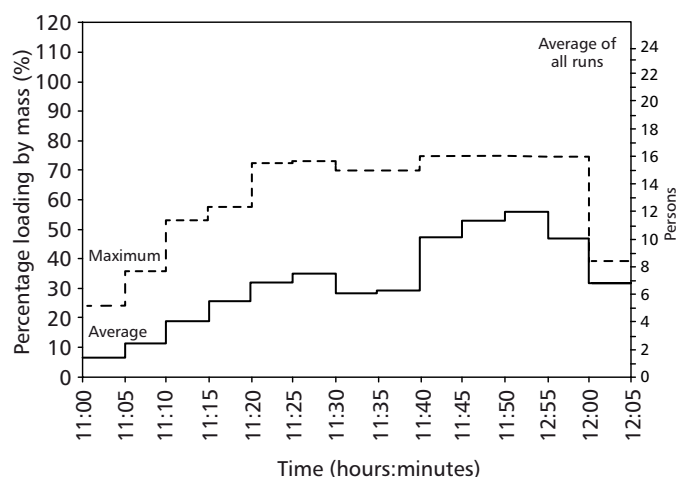


Figure 4.21 Example 4.3: car loading on departure from home floor during lunch peak (worst average capacity factor by area during any 5-min. period: 70.2%)

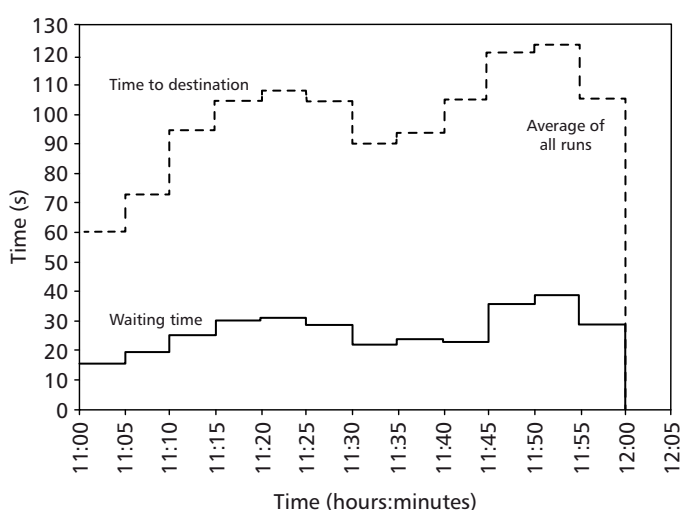


Figure 4.20 Example 4.3: average waiting time and time to destination during lunch peak (worst average waiting time during any 5-min. period: 38.2 s; worst average transit time during any 5-min. period: 87.7 s)

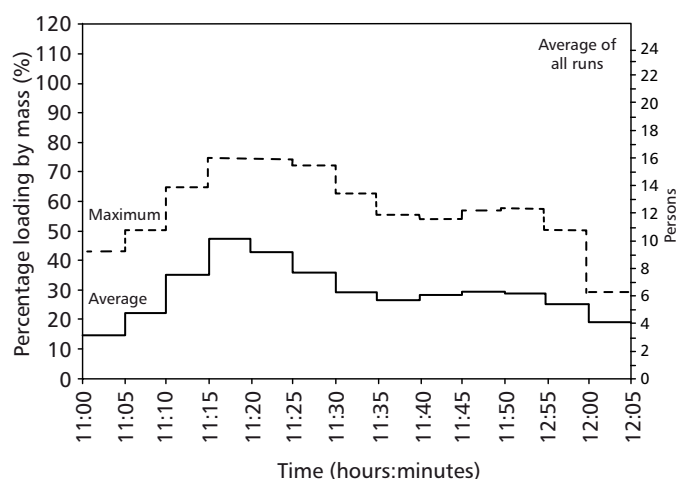


Figure 4.22 Example 4.3: car loading on arrival at home floor during lunch peak (worst average capacity factor by area during any 5-min. period: 59.1%)

- An allowance for door dwell times after passenger transfer is complete (3 s if beam is not broken until cars doors close, 2 s if beams have been broken and have been re-established).
- Doors are allowed to re-open for late arriving passengers if the car has not left the floor.

The results are summarised in Table 4.4.

Figures 4.18 to 4.22 above show typical results plotted by a simulation package for the analysis with all cars in service (six 1600 kg cars at 2.5 m/s). Repeating the simulation with destination control yields the results in Table 4.5.

4.9.4 Discussion of examples

The conventional control solution, six 1600 kg cars at 2.5 m/s, is very close to requirements of the British Council for Offices (BCO, 2014) presented in section 4.7.3. The average time to destination is marginally higher than the recommendation. The number of floors served is close to the maximum designers would consider for a single zone of conventional lifts (see chapter 3), which results in longer transit times. If meeting this requirement were absolutely essential for marketing purposes, most designers would

consider minor improvements in input parameters to meet the target, e.g. allowing for pre-opening doors. With a single car out of service, the quality of service is poor and the cars are crowded at a capacity factor by area of 87.2%. Note that the cars could not load to a capacity factor by area of more than 94% as the platform area (3.54 m²) divided by the passenger area (0.21 m²) yields 16.95 people and simulation will only allow the loading of whole people, 16 in this case. Nevertheless, the system recovers from the peak. It would be worth examining queue lengths to determine how crowded the lobby will become.

The destination control solution, six 1600 kg cars at 2.5 m/s trades longer waiting times for shorter transit times, meeting the uppeak requirements of BCO. For the lunch template, the waiting time is longer than the target. If meeting this requirement was absolutely essential for marketing purposes, a destination control algorithm utilising waiting time optimisation (see chapter 9) may be considered. The destination control solution manages much better with a car out of service; the grouping of passengers (see chapter 9) provides greater handling capacity, so the system is not as close to saturation as the conventional solution. The lifts are not crowded and it would be reasonable to consider a smaller car size. In some regions the lower quality of service provided by five lifts

with destination control may be considered acceptable. However, if the building is fully occupied, when a lift goes out of service the system is likely to saturate.



Caution: the handling capacity of saturated destination control systems can collapse causing lone queue and excessive waiting times (Peters, 2013).

4.10 Simulation applied to modernisation

Simulation is a particularly valuable modernisation tool, as actual lift performance and passenger traffic can be measured and modelled. This allows the benefits of modernisation to be assessed more realistically.

A pre-modernisation design exercise in a major building should always begin with a traffic survey. All other input parameters to a calculation, or simulation, should also be measured on site. Simulation allows designers to answer 'what if' questions such as:

- What might the performance be like during the modernisation when one or more cars are out of service?
- What benefit can increasing rated speed, door times, etc., have on waiting and transit times?
- Can improvement to the traffic control algorithm have any significant benefits?
- If practical, what is the effect of installing additional cars?

Simulation programs that allow for third parties to add their own dispatching algorithms can be applied to demonstrate faults in existing systems, and to justify performance claims by suppliers.

In interpreting results, note:

- any differences between pre- and post-modernisation building populations
- that modernisation may lead to a marginally increased demand on the system, as people are more likely to take the lifts if the service is improved.

4.11 Comparing simulation with round trip time calculations

When comparing RTT calculations with simulations, it is important to note the following:

- Most designers using RTT calculation do not consider door dwell times (although an allowance is possible, see chapter 3).
- RTT calculations are based on averages and may be based on the assumption a car is loaded with, say, 9.9 persons. A simulation with multiple runs also yields an average, but at any one time the car load in persons is always an integer number.

- Unless an RTT inefficiency is used, RTT calculations assume an ideal system with, for example, no bunching, door re-openings or other 'real life' delays.

It is normally possible to show a close correlation between the interval and the car loading calculated using an RTT calculation (Peters, 2013).

As stated in chapter 3, the calculation of waiting time and other passenger based measures using RTT calculations is based on a mathematical model. This is another level of mathematical extrapolation past the calculation of interval. Thus the values calculated with simulation may differ significantly for individual cases. RTT calculations are normally carried out to establish the maximum handling capacity of a system. Thus in simulation the modelling can be near or at the saturation point. When a simulation reaches saturation, long queues may form, with excessive waiting times, as may be seen in a real system. Small variations in demand can change waiting time significantly.

Some simulations are designed to match the results of RTT calculations as closely as possible. This is not an unreasonable approach to demonstrate consistency provided that all assumptions are declared. However this performance reported does not reflect the performance that can be seen in real buildings.

4.12 Traffic analysis and simulation software

4.12.1 Evaluating analysis software

Modern lift traffic analysis software packages provide engineers and designers with a powerful tool for determining the number of lifts required, their speed and the size of the cars. Programs available range from crude and very limited to sophisticated and complex. Thus it is important that a software evaluation exercise is carried out prior to making a purchase. It is recommended that answers to the following questions should be obtained as part of any software evaluation exercise:

- Does the program run locally on your computer or is it web based application which you control via a browser, running the analysis on remote servers?
- If running locally, does the program run on the computer and operating systems intended to be used. If web based, does it require a specific browser, or any additional software?
- Does the program use RTT formulae, simulation, or both?
- Does the program use an iterative process to find the solutions for a level of passenger demand, e.g. 12% uppeak handling capacity, specified by the designer?
- What traffic flows can the program analyse (e.g. uppeak, down peak, etc.)?
- Can the program analyse single lifts, double deck lifts, and multi-car systems with more than one independent lift in a shaft?

- What are the inputs and outputs to the program? Compare these inputs and outputs with those discussed in chapters 3 and 4 of this Guide. If the program omits some inputs it is important that the user is aware of, and satisfied with, the values used and/or assumptions made by the program. If the program omits some outputs, the user must be satisfied that these are not required.
- Does the program provide spreadsheet and graphical output?
- For simulation how are the passengers generated?
- For destination control what happens if a passenger is refused an allocation?



Warning: some simulations results do not start the count of waiting time until the passenger is allocated a destination call, which is inconsistent with the definition of waiting time in chapter 3.

- Who are the developers?
- What quality control procedures are in place to test the results are correct?
- Is the program generally available?
- What are the initial and on-going costs?
- Is a detailed manual provided?
- Is technical support available and, if so, from whom and at what cost?
- Is the program copy-protected? If so, what form of protection is used?
- Is user-training available and, if so, at what cost?
- Is the source code available for review?
- Are there future plans for upgrades, enhancements etc?

4.12.2 Comparing results between different simulation programs

When comparing the results of different simulation programs, note that there must be consistency between:

- input parameters including traffic templates
- definition of inputs and results.



Caution: it should be possible to demonstrate consistency between lift simulation programs when 'like for like' analyses are being compared. Some benefits can be demonstrated by applying enhanced dispatching algorithms. However dramatic discrepancies should be examined closely and treated with caution. Competition between suppliers to demonstrate best performance with proprietary simulation software is of limited value if the assumptions applied by the simulation are not fully documented.

4.13 Epilogue

The CIBSE Lifts Group encourages co-operation between consultants, suppliers and researchers as a means of

improving the industry's understanding of lift traffic demand and lift system performance.

To this end, readers of this guide are invited to submit their traffic survey results to the CIBSE Lifts Group to assist in improving future editions of this Guide. Guidance can be offered for those prepared to share their survey results.

The templates in this section of the guide may be revised, updated, and extended to other building types in future editions of this Guide.

The CIBSE Lifts Group is also pleased to participate in peer review of enhanced performance claims where a supplier claims that their system requires fewer lifts than other suppliers. Genuine enhancements will be acknowledged and reported at the CIBSE Lifts Group website (www.cibseliftsgroup.org).

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Appendix 4.A1: Symbols and formulae

4.A1.1 List of symbols

a	Acceleration (m/s ²)
A_c	Car area (m ²)
A_p	Area per person (m ²)
CC	Car rated (contract) capacity (persons)
%CFM	Capacity factor by mass (%)
%CFA	Capacity factor by area (%)
d	Travel distance (m)
d_H	Distance to reach reversal floor H excluding express zone (m)
d_x	Total height of un-served floors in express zone (m)
H	Average highest reversal floor
h_i	Height of floor i (m)
j	Jerk (m/s ³)
L	Number of lifts
%LOSS	Round-trip time losses (%)
m	Average passenger mass (kg)
N	Number of floors served above the main terminal
P	Average number of passengers in car (persons)
%POP	Percentage population served in uppeak five minutes (%)
RL	Rated load (kg)
RTT	Average round-trip time (s)
S	Average number of stops above main terminal
T	Performance time (s)
t_{ad}	Advanced door opening time (s)
t_c	Door closing time (s)
$t_f(d)$	Flight time for travel distance(s)
t_l	Passenger loading time per person (s)
t_o	Door opening time (s)
t_p	Passenger average transfer time (entry or exit) (s)
t_{sd}	Start delay time (s)
t_u	Passenger unloading time per person (s)
U	Effective building population (persons)
U_i	Population of floor i (persons)
UPPHC	Uppeak handling capacity (persons/5-min)
UPPINT	Average uppeak interval with 80% car load (s)
v	Rated (contract) speed (m/s)

4.A1.2 Formulae

In a manual lift calculation, it is normally assumed that the lift fills with a fixed number of passengers in the car (P), see 3.7.3. This enables the uppeak handling capacity (UPPHC) to be determined. In software, the calculation is often performed iteratively. If the calculated upphc is greater than passenger demand, the capacity factor by mass (CFM) has to be reduced using an iterative procedure until the UPPHC is equal to the required passenger demand.

Rated capacity (CC):

$$CC = \text{floor} \left(\frac{RL}{m} \right) \quad (4.1)$$

where *floor* is a function meaning round down to the nearest whole number.

CC is the rated capacity in persons based on BS/EN standards. It is not the actual capacity, see section 3.7.3. To determine the maximum practical loading of the car, consider both area and mass. As discussed in section 3.7.3, the nominal passenger carrying capacity of lifts presented in safety standards should not be used for planning.

Number of passengers (P) in the lift:

$$P = \left(\frac{\%CFA}{100} \right) CC \quad (4.2)$$

Capacity factor by area (CFA):

$$CFA = 100 \times P (A_p/A_c) \quad (4.3)$$

Effective building population (U):

$$U = \sum_{i=1}^N U_i \quad (4.4)$$

Highest reversal floor (H):

$$H = N - \sum_{j=1}^{N-1} \left(\sum_{i=1}^j \frac{U_i}{U} \right)^P \quad (4.5)$$

See also equation 3.5. Equation 4.5 allows for unequal floor populations.

Probable number of stops (S):

$$S = N - \sum_{i=1}^N \left(1 - \frac{U_i}{U} \right)^P \quad (4.6)$$

See also equation 3.6. Equation 4.6 allows for unequal floor populations.

Passenger average transfer time (t_p):

$$t_p = \frac{t_l + t_u}{2} \quad (4.7)$$

Travel distance to highest reversal floor (d_H):

$$d_H = \left(\sum_{i=0}^{\text{floor}(H-1)} h_i \right) + (H - \text{floor}(H)) h_{\text{floor}(H)} \quad (4.8)$$

Travel time function:

In a manual calculation, most designers use a table to determine the time it takes for a lift to travel between floors. Some typical values are given in section 3.7.6, Table 3.4. This table is based on fixed interfloor heights, and the stated values of speed, acceleration and jerk (rate of change of acceleration).

In software it is possible to write a program that accepts the dynamic parameters (speed, acceleration and jerk) and then calculates the travel time for any lift trip distance.

$$\text{If: } d \geq \frac{a^2 v + v^2 j}{j a} \quad \text{then: } t_f(d) = \frac{d}{v} + \frac{a}{j} + \frac{v}{a} \quad (4.9)$$

$$\text{If: } \frac{2 a^3}{j^2} \leq d < \frac{a^2 v + v^2 j}{j a} \quad \text{then: } t_f(d) = \frac{a}{j} + \sqrt{\frac{4d}{a} + \left(\frac{a}{j} \right)^2} \quad (4.10)$$

$$\text{If: } d < \frac{2 a^3}{j^2} \quad \text{then: } t_f(d) = \left(\frac{32 d}{j} \right)^{\frac{1}{3}} \quad (4.11)$$

For more information about lift kinematics, refer to Appendix A2.

Round trip time (RTT):

$$RTT = \left(\frac{2d_H}{v} + (S+1) \left(T^* - \frac{d_H}{vS} \right) + 2Pt_p + \frac{2d_x}{v} \right) \left(1 + \frac{\%LOSS}{100} \right) \quad (4.12)$$

where:

$$T^* = t_f(d) + t_c + t_o + t_{sd} - t_{ad} \quad (4.13)$$

See also equation 3.1. The conventional RTT equations assume that the lift reaches rated speed in the distance of a single floor jump and that there are no irregularities in floor heights (see section 3.7.5). Equation 4.12 allows for such irregularities. The basis for this approach has been provided by Peters (1997).

For completeness, express zones are included equation 4.12. An assumption of this equation is that the lift reaches full speed in its travel through the express zone (note the $2d_x/v$ term). If this is not the case, the RTT calculation may be optimistic. A better approach would be to determine the actual flight time through the express zone, or to use simulation.

The assumption that traffic control not ideal (see section 3.10(h)) is allowed for by including the term (%LOSS) such as 5–10%.

Uppeak interval (UPPINT):

$$UPPINT = \frac{RTT}{L} \quad (4.14)$$

See also equation 3.2.

Uppeak handling capacity (UPPHC):

$$UPPHC = \frac{300P}{UPPINT} \quad (4.15)$$

See also equation 3.3.

Handling capacity expressed as percentage of building population (%POP):

$$\%POP = \frac{UPPHC}{U} \times 100 \quad (4.16)$$

See also equation 3.4.

5 Types of transportation systems

Principal authors

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5 Types of transportation systems

5.1 Introduction

With unprecedented numbers of tall towers being constructed across the world, the importance of well designed vertical transportation systems in modern buildings cannot be underestimated. The efficient movement of all potential occupants is achieved by providing passenger lifts with adequate capacity and performance, as well as additional lifts to provide goods service, fire fighting and evacuation and other building servicing functions. Chapter 2 indicates the circulation requirements and chapters 3 and 4 detail how to select the number and size of lifts for a building. The present chapter looks at the different types of lifting systems and provides advice on the planning and design of each type.

Lifts are typically provided for passenger service using either an electric traction or hydraulic drive arrangement. Electric traction lifts are available based on either traditional equipment with a separate machine room or machine-room-less (MRL) equipment where the drive and control equipment is mounted within the lift well (see Figures 5.1, 5.2 and 5.3). The rated load and speeds available with MRL traction lifts continues to increase so the large majority of all new lifts being installed are MRL and the use of hydraulic lifts continues to decline as a result. Rack and pinion drives offer an alternative, worthy of consideration for very large goods lifts, or unconventional applications where hydraulic or electric traction lifts are otherwise not practical.

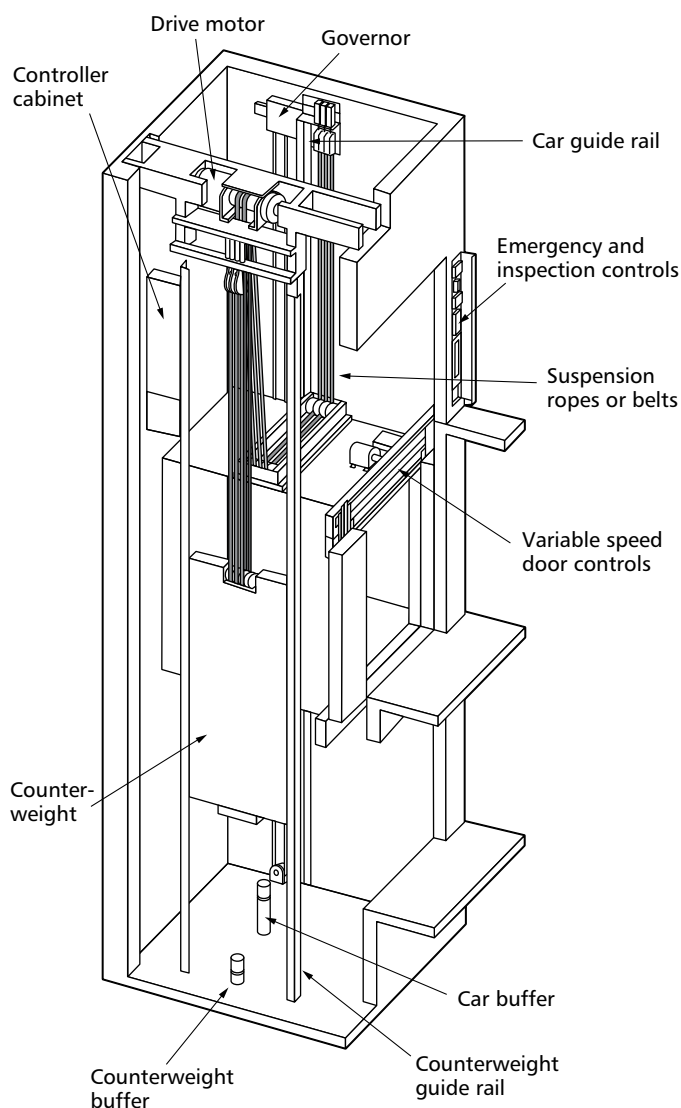


Figure 5.1 General arrangement of a machine-room-less electric traction passenger lift

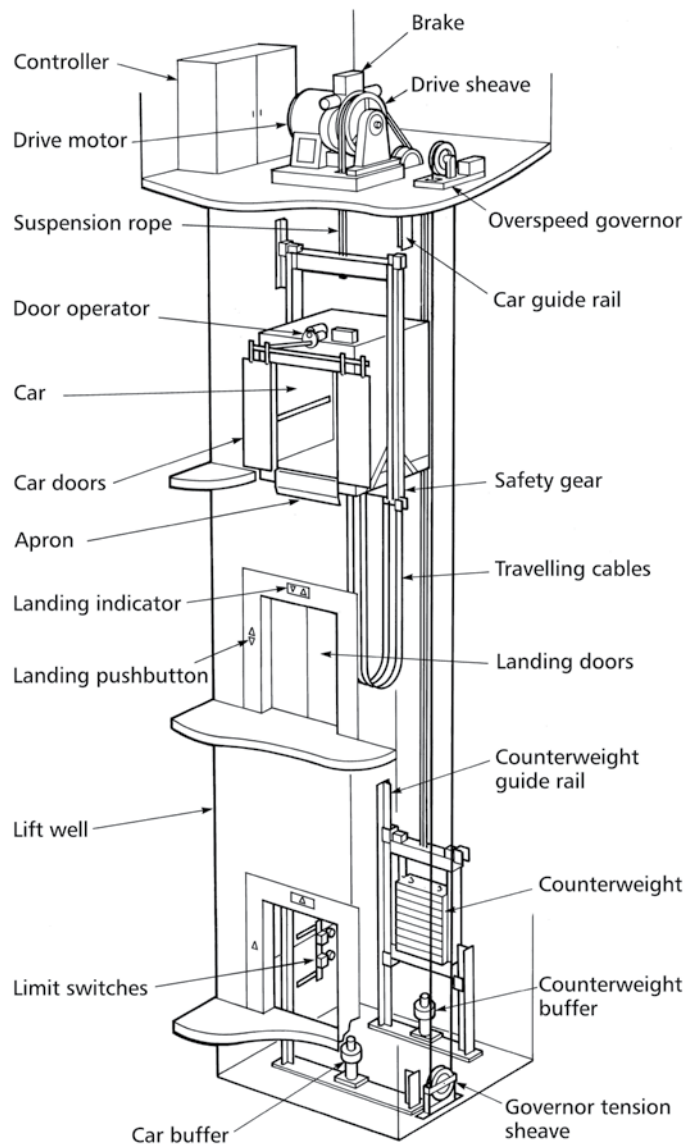


Figure 5.2 General arrangement of an electric traction lift passenger lift

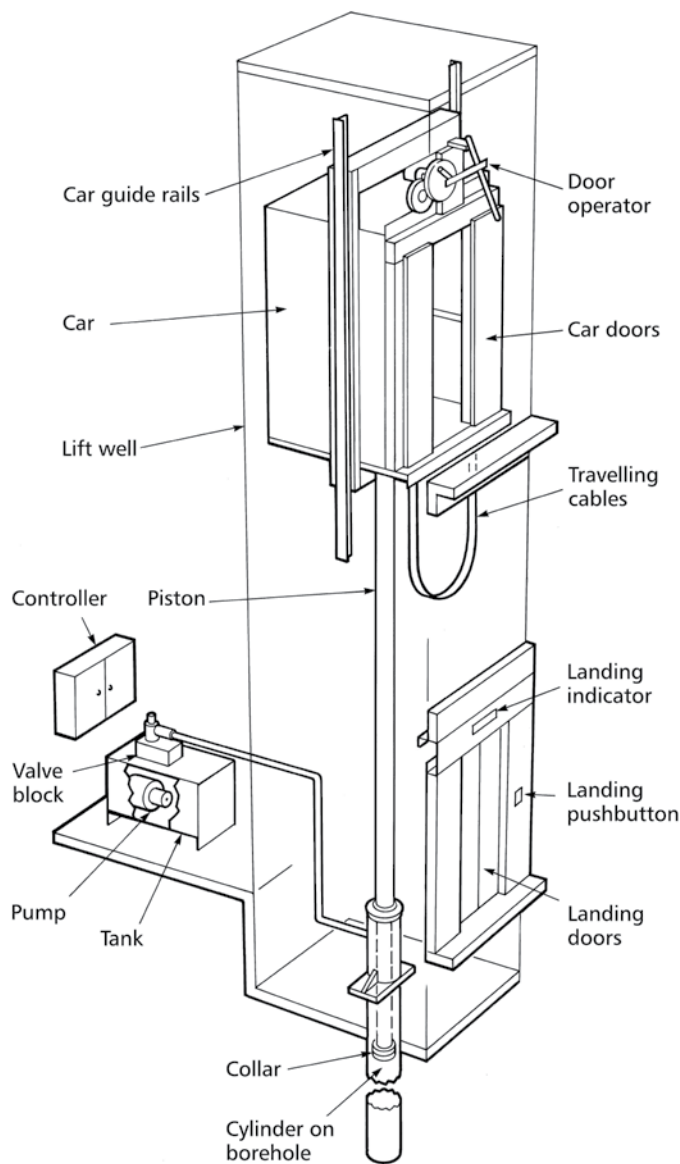


Figure 5.3 General arrangement of a direct acting hydraulic passenger lift

Paternoster systems, consisting of a number of open cars (without doors) moving continuously in a single well, are now obsolete and do not comply with current legislation or safety codes, so cannot be installed in many countries without going through a rigorous series of testing and approvals to demonstrate compliance with the Lifts Regulations 1997 (TSO, 1997). A few systems are still operating in the UK but no new systems have been installed for many years and the relevant British Standard has been withdrawn. For these reasons, paternoster systems are not considered in this Guide.

All new passenger lift systems that are installed must comply with the relevant health and safety codes and satisfy the local building control requirements. Lifts installed under European jurisdiction must satisfy the essential health and safety requirements (EHSRs) laid down in the Lifts Regulations 1997 to ensure the installation provides the necessary levels of safety.

The EHSRs can be met by designing and installing the lift, either in accordance with published harmonised standards or by obtaining approval from a Notified Body for any parts of the design or installation that do not comply with the standard.

Harmonised standards, BS EN 81-20 (BSI, 2014a) and BS EN 81-50 (BSI, 2014b) were published in August 2014. However, in the UK there is a 3-year transition period until 31 August 2017 where BS EN 81-1 and BS EN 81-2, which are also harmonised standards, can continue to be used. Therefore, wherever this chapter references BS EN 81-20, BS EN 81-1/2 remain equally applicable and may be used and adopted for lifts prior to 31 August 2017.

The European EN 81 series of harmonised standards are used extensively all over the world but some countries that have adopted the EN 81 suite of standards, such as the UK, retain national standards (see Appendix A3). In the UK, Code of Practice BS 5655-6 (BSI, 2011a) provides useful guidance on the selection and installation of new lifts and BS 7255 (BSI, 2012a) is the primary standard for safe working on lifts.

The economic life cycle for the types of system depends upon the original design duty and the standard of maintenance employed. Typically, a 20–25 year life span can be anticipated for traditionally engineered lift systems, whilst life spans of less than 15 years and as low as 10 years dependant on usage, might be more realistic for packaged lifts that are mass produced using lightweight materials to keep costs down. During the normal life cycle of all types of lift systems, oil seals, suspension ropes, bearings and other components subject to wear will require maintenance and possibly replacement as part of a planned maintenance regime.

In addition, components such as push buttons, indicators, drives and control systems might be replaced as part of an ongoing modernisation programme to benefit from technological advances and to protect against unreliability that can become a problem in older lifts (see chapter 16).

The type, speed, load and layout of the lift system all contribute to the user's perception of the service provided. The lift car finishes need to suit the particular application to project the required impression, be it the strength and durability of a goods lift or various levels of refinement for passenger lifts. The design, however, should be practical from the users' point of view and push buttons and fixtures, for example, should be selected not only on the basis of appearance but also their practicality. Compliance with any relevant disabled access codes such as BS EN 81-70 (BSI, 2003a), BS 8300 (BSI, 2009) and Building Regulations Approved Document M (NBS, 2013) to achieve compliance with the Equality Act 2010 (TSO, 2010a) should be considered from both the functional and aesthetic point of view, see chapter 11.

BS ISO 4190-1 (BSI, 2010a) for passenger lifts and BS ISO 4190-2 (BSI, 2001) for goods lifts set out recommended dimensions of lift cars and wells for lifts of various standard capacities and dimensional configurations. These sizes may be fine-tuned in negotiation with the lift supplier to suit the particular circumstances. Lift cars with variable dimensions are now readily available although some manufacturers offer lifts based on a range of fixed dimensions offering significant cost savings. Care needs to be taken when accepting a standard lift solution as these may have limited design flexibility and fixed options for car and landing fixtures, fittings and finishes.

Machine-room-less lifts (MRL) are now capable of meeting the requirements of most common speeds and load

applications. Larger MRL lifts do have limitations on the rated speed so that 3 m/s passenger lifts are currently only available up to a capacity of 1800 kg. MRL goods lifts and vehicle lifts are available up to 5000 kg capacity but may have speed limitations of less than 1 m/s. In general, caution is required in the selection of equipment at higher speeds and/or loads as it may restrict the number of suppliers able to meet the specification.

Care should be taken when designing for MRL lifts as the accommodation of drives and control equipment within the lift well sometimes means the well dimensions need to be larger than those recommended by BS ISO 4190 whilst other dimensions may be smaller.

The modern passenger lift appears, or should appear, to be a simple means of transport within a building. This apparent simplicity belies a complex and sophisticated mechanical, electrical and microelectronic system. Passengers and owners expect safe, comfortable, transportation, which is always in service with the following considerations:

- *Safety*: the motion of the doors should be smooth and safety devices should be provided to ensure that passengers entering or leaving the lift car will not be injured if the doors start to close. The levelling of the car to the landing floor should not present a tripping hazard and should allow easy transfer of any wheeled objects such as trolleys, wheelchairs or pushchairs into and out of the lift car.
- *Comfort*: the ride between floors should have acceptable levels of acceleration and jerk (i.e. rate of change in acceleration) and vibration should be kept to a minimum. Quiet operation of the doors and noise levels during travel are important factors in overall passenger comfort. Noise levels emitted on to landings should also be kept to a minimum since some buildings do not have lift lobbies, see section 12.13.1.
- *Service*: passengers regard waiting time as the appropriate measure of quality of service for a lift system. Despite this, many lift designs are based on round trip time calculations to quantify performance levels in terms of a theoretical interval time, related to handling capacity. The emergence and increased use of hall call allocation (HCA) systems (also known as destination control) in modern buildings is seeing simulation techniques being used more widely. With simulation, performance is defined in terms of average passenger waiting times. Other performance measures such as queue lengths, transit times and overall journey times can also be assessed and considered in the lift system design. See chapters 3 and 4.

Safety must be ensured at all times and this applies equally to passengers and to persons working on a lift, e.g. service personnel, surveyors, consultants, inspectors, etc. It is also important that any goods transported, are safe from damage and that the lift does not degrade the environment in which it operates. Any alterations to suit particular or special circumstances should not jeopardise the provision of good, safe access to equipment after installation, since it will be necessary to carry out in-service maintenance and repairs to the equipment during the life of the installation. The final equipment layout should also take into account the

space requirements for possible replacement of major components in the future. This is particularly important with MRL equipment where maintenance operations that would previously have occurred in a protected and normally spacious machine room are carried out within the confines of the lift well, from the car roof. In addition more activities may be required from landing levels, where control or emergency operating equipment is located.

The type of building and the potential traffic demand will determine the choice of control for the lift system. After consideration of any special client requirements or traffic patterns, the vertical transportation designer should select a suitable control system. Historically, single button and down collective controls were often used where appropriate, for cost efficiencies. However, modern manufacturing techniques mean that full collective and group control systems are used almost exclusively on all but the simplest of modern lift installations. Hall call allocation (HCA) systems are becoming more widespread and these too can be considered for non-public installations, see section 9.4.2.3.

The following sections offer guidance to the selection of the type of lift most suitable for the application being considered. Reference may also be made to chapter 7, which describes individual components in detail.

5.2 Passenger lifts

5.2.1 General

Lift suppliers offer ranges of products from 'pre-engineered' or 'packaged' lifts based on standardised configurations and dimensions, to one-off systems designed and manufactured to individual requirements. Packaged lifts may offer a limited choice of options and functions but the production line methods used in manufacture, help to reduce costs, delivery time and installation time and often provide increased reliability on projects where low cost, short lead time and good reliability are a prime consideration.

Custom-tailored systems are appropriate for more complex applications such as observation lifts where a unique and sophisticated aesthetic design may be required, or where a client requires personalised finishes or operational functions. In between these two extremes, MRL lifts are available with enhanced finishes that may accommodate stone floors, glass and mirror finishes but the maximum mass of finishes allowable on standard MRL lifts will vary between manufacturers and should be checked prior to their appointment to ensure the project requirements can be met with the proposed products. With custom or one-off designs, these limitations can be mostly eliminated by the selection of components suited to the required design, however the price reflects the higher design and production costs and longer manufacturing and delivery times will be required.

The lift drive, door control and group control should be correctly specified to ensure the required quality of lift service and safety is achieved for the customer and passengers. In addition, it is important to ensure the equipment installed is suitable for the environment in which it will operate.

The main applicable standard for passenger lifts is BS EN 81-20 (BSI, 2014a). Passenger lifts are designed to carry passengers and although they may occasionally carry goods this is not their primary purpose. Goods passenger lifts transport both passengers and goods and if used mainly for passenger service they may have fixings for drapes to protect the car interior when used for goods, or they may be more robustly fitted out with protective bump rails to protect against impact damage when moving goods on trolleys or in carts. Goods passenger lifts are covered in more detail in section 5.3 and lifts intended to be used for goods only, which are not designed to carry passengers, are covered in section 5.4.

5.2.2 Applications of passenger lifts

This publication considers the different types of lifts in twelve main types of building. The requirements for passenger lifts may differ between the different building types and are detailed in the relevant sections and sub-sections below. (See also sections 2.6 and 3.15.) The different building types are considered below arranged alphabetically for ease of reference, so the order is not intended to represent the relative number of lifts installed in a particular building type.

Where reference is made to disability requirements, readers should refer to BS EN 81-70 (BSI, 2003a), BS 8300 (BSI, 2001a), the Equality Act 2010 (TSO, 2010a) and Building Regulations Approved Document M (NBS, 2013). Where reference is made to vandal resistant lift features, readers should refer to BS EN 81-71 (BSI, 2005).

5.2.2.1 Airports

See also sections 2.6.1 and 3.15.1.

Airports are generally low rise structures with the arrivals and departure facilities on separate levels. Escalators are typically used as the primary means of passenger transfer between levels and moving walks are commonly provided to assist passengers needing to cover long walking distances to and from the boarding gates.

The design of airports should minimise the need to move trolleys vertically wherever possible, but inevitably the provision of lifts will be required to accommodate passengers with trolleys as well those with baggage and persons with disabilities. Passenger lifts should be as large as possible to accommodate large family groups with baggage and also trolleys where these can or need to be moved vertically. In these cases, lifts that can accommodate one or two baggage trolleys are not suitable and the recommended minimum size for a passenger lift is 2000 kg, which will easily provide compliance with the recommendations of BS EN 81-70 (BSI, 2003a) for wheelchair access.

Public lifts in airports should have a 'door open' period (dwell time) sufficiently long to ensure that the doors do not close before passengers can manoeuvre a trolley into the lift. As is common with all modern passenger lifts, full height, electronic, non-contact safety edges should be provided to ensure the doors do not close on passengers or their baggage during loading or unloading. Safety edges are available with audible and visual indication to alert passengers when the doors are closing or about to close and

these should be considered in busy public environments. The requirement for longer door dwell times will detract from the efficiency of the lift system and needs to be considered in determining the number, size and speed of the lifts.

As many of the people who visit an airport will be unfamiliar with the layout of the building, suitable way-finding signage should be provided within the building, giving clear directions to the lifts and the stairs at all levels.

5.2.2.2 Car parks

See also sections 2.6.2 and 3.15.2.

Of all passenger lift types, car park lifts are probably subjected to the greatest misuse. Unlimited public access, combined with limited supervision, means that vandal resistant fixtures are essential. BS EN 81-71 (BSI, 2005) provides design guidance and advice on vandal resistant lifts identifying the need for durable finishes, controls and indicators etc.

Visible fixings on landing and car operating panels should be avoided and key switch control of car lighting and fans or surface mounted fixtures should not be provided as these can attract unwanted attention from vandals and be easily tampered with.

Consideration can be given to incorporating additional safety devices such as 'anti-surfing' devices that sound an alarm and prevent the movement of the lift, in the event of intruders accessing the lift car roof or the pit area. However lifts designed to BS EN 81-71 incorporate security systems to prevent access to the lift well even to persons that have a lift door release key and these additional protective measures should be adopted where practicable.

The biggest deterrent to vandalism is increased visibility and an increased level of observation of lift users. The incorporation of closed circuit television (CCTV) monitoring within lift cars and glazed panels on car and landing doors, to provide a visual link between the car and the landings aid passenger security and are commonly specified by car park operators.

New lifts in public car parks should provide barrier free facilities for disabled persons with dimensions, fixtures, controls and indication designed in accordance with BS EN 81-70 (BSI, 2003a).

Increased protection against vandalism or potential vandalism should be a prime consideration in the improvement of existing car park lifts. Refer also to section 16.5.2.

5.2.2.3 Department stores

See also sections 2.6.3 and 3.15.3.

Department stores may be situated in high streets, where they must make independent provision for vertical transportation of customers, or in retail developments where they may rely on the lift provision of the shopping centre. The lifts will be used by people carrying shopping bags or pushing trolleys and also by people with pushchairs or wheelchairs. They should therefore be sized to carry a

minimum of 17 persons (1275 kg) to provide space for wheelchair passengers to turn around in the car if necessary. Some department stores have their own design standards and may specify larger passenger lifts with a capacity of up to 26 persons (2000 kg). The design recommendations made in BS EN 81-70 (BSI, 2003a) to facilitate use of the lifts by persons with disabilities should be considered.

The finishes in the lift car and on landings should provide a pleasant environment in keeping with the general surroundings whilst providing the necessary contrasting details to offer maximum usability to passengers with any visual impairment. The doors will be electronically controlled to ensure that the lifts are accessible to people with trolleys, pushchairs and wheelchairs and incorporate full height, electronic, non-contact safety edges. Safety edges are available with audible and visual indication to alert passengers when the doors are closing or about to close and these should be considered in busy public environments.

Larger department stores on multiple levels will incorporate a combination of goods and passenger lifts as well as escalators to provide an efficient transportation system.

5.2.2.4 Entertainment centres, cinemas, theatres, sports centres, stadia and concert halls

See also sections 2.6.4 and 3.15.4.

With the exception of stadia, this application generally makes little demand for passenger lift provision, with lifts provided primarily to cater for disabled access.

Modern stadia, however, often incorporate extensive conference, banqueting and corporate entertaining facilities as well as large media centres. These facilities are often spread over a number of floors and lifts will be required to provide access from the entrance level for guests and visitors.

The nature of the events hosted within stadia, involves heavy traffic flows as people arrive before and leave after events. Lifts should be supplemented with easily accessible stairs and ramped walkways. Consideration may also be given to escalators to deal with the high volumes of people particularly servicing concourse areas where a high footfall may be generated by food and beverage concessions.

5.2.2.5 Hospitals

See also sections 2.6.5 and 3.15.5.

The passenger lifts in hospitals serve two distinct functions: the transportation of patients (including those being moved on beds and trolleys) and the transportation of the staff and visitors. In modern hospitals, it is common for dedicated lifts to be provided for each function to ensure patient and staff movements can occur efficiently without being affected by public visitors to the hospital.

In older hospitals where the provision may not be so clearly defined, or where the hospital functions evolve and change requiring shared use of lifts, modern control systems can be introduced to allow staff to call lifts under a priority recall feature for patient or goods use. Such features can be

extended to include priority recall for medical emergencies ensuring the earliest availability of a lift when needed.

The transportation of patients requires lifts that provide a smooth ride so the acceleration and jerk (rate of change of acceleration) of the lift should be kept low with recommended values of $\leq 0.4 \text{ m/s}^2$ for acceleration and $\leq 0.8 \text{ m/s}^3$ for jerk. The operation of the doors should allow for the potentially slow movement of passengers into and out of the lift car. The lift door safety edges should be of the full height, electronic, non-contact type, since any contact with an infirm or elderly patient should be avoided. These considerations will affect the performance of these lifts and should be considered when determining the quantity, size and speed of lifts required for any particular project. The lift groups should be able to perform efficiently during visiting times where, depending on hospital visiting policy, the building population may double within a very short period of time.

For the general public, clear and concise indication of floor and ward locations should be provided in the car. Lift cars should also be designed to be easy to clean, vandal resistant, and incorporate the relevant recommendations of BS EN 81-70 (BSI, 2003a) to provide suitable provisions and accessibility for users. Lifts in hospitals should have suitable lobbies that are recessed from any walkways, corridors or hospital streets, to ensure that waiting passengers do not impede other traffic flows through the hospital.

Other lifts, in addition to the passenger lifts, will be required to service catering and housekeeping activities and goods servicing, including movement of medical waste which may be necessary via a dedicated 'dirty lift'. Goods lifts are covered in more detail in section 5.3.

In addition to BS ISO 4190-1/2 (BSI, 2010a, 2001), further information on lift car dimensions to suit the movement of beds and trolleys is available in Health Building Note HBN 00-04 (DoH, 2013) and design information specific to lifts in hospitals is available in Health Technical Memorandum HTM 08-02 (DoH, 2010). These documents relate to hospital design within the UK or under UK jurisdiction and may not be applicable in other countries.

5.2.2.6 Hotels

See also sections 2.6.6 and 3.15.6.

The requirements of passenger lifts and goods lifts for a hotel are different to those for offices and the company or hotel brand will generally be reflected in the quality and design of the public guest lifts.

The major operational difference is likely to be in the control of the lift doors. These may have a longer door open period (dwell time) than other public lifts to allow guests with luggage, time to enter the lifts before the doors begin to close, thereby giving the use of the lift a more relaxed image. The slower door systems will detract from the efficiency of the lift system and need to be considered in determining the number, size and speed of the lifts. Lift doors should have full height, electronic, non-contact safety edges to hold the doors open while passengers enter and leave the lifts. Safety edges are available with audible and visual indication to alert passengers when the doors are closing or about to close and these may be considered where

the indication will not be create a nuisance by guests in rooms close to the lifts.

In hotels, the level of service with regard to interval and waiting time is not expected to be as high as that in commercial buildings but the sizing of guest lifts should be generous to cater for passengers with luggage and to afford the necessary comfort levels for guests. The minimum recommended car size for a hotel passenger lift is 1275 kg, which will also provide compliance with the recommendations of BS EN 81-70 (BSI, 2003a) for wheelchair access, although many hotel operators may have their own design standards and specify larger lift cars.

Since many of the people who visit a hotel will be unfamiliar with the layout of the building, suitable way-finding signage should be provided within the hotel, giving clear directions to the lifts and the stairs at all levels.

Most hotel operators expect dedicated goods lifts to be available for staff usage in servicing guest rooms. Where a single goods lift is provided, provision should be included in at least one guest lift to provide back-up goods use in the event the single goods lift is unavailable. Goods use of a guest lift should not occur at the expense of guest comfort and for this reason, a separate goods lobby should be considered serviced by a rear entrance to allow the shared lift to be used by staff under priority control and prevent guests having to share the lift with goods and staff.

5.2.2.7 Offices

See also sections 2.6.7 and 3.15.7.

The prime objective when providing lifts in a commercial office is to transport passengers quickly and efficiently to their places of work. The quality of service should be high in terms of an acceptably low lift interval or passenger waiting time. The psychological effects of long waiting times on the user can be significant. Long waiting times will result when large queues build up during peak periods which reflect badly on the building and can affect the marketability of the premises.

The number of lifts, car size, type, speed, type of drive, drive control and door control will all affect the efficiency of the lift system.

The aesthetic aspects of the lift system, e.g. call buttons, car and landing indicators and car interiors together with the ride comfort, reflect the image of the company or the building owner and in larger buildings will often be detailed by the architect to complement the building architecture, meaning standard lift finishes are often not appropriate. The design should also consider passengers with special needs in accordance with the recommendations of BS EN 81-70 (BSI, 2003a) to provide suitable provisions and accessibility for all users.

In smaller office buildings, shared use of one or more passenger lifts may be appropriate for goods handling, however in larger buildings, dedicated goods lifts should be provided. See section 5.3 for more details on office goods lifts.

Larger office buildings may also require fire fighting lifts in accordance with Building Regulations Approved Document B (NBS, 2006), BS 9999 (BSI, 2008a) and BS EN 81-72

(BSI, 2015). Firefighting lifts may be installed in separate cores or as part of the passenger lift provision but should not be used for goods purposes. Chapter 6 provides more detailed information on firefighting lifts.

5.2.2.8 Railway stations

See also sections 2.6.8 and 3.15.8.

Surface railway stations are generally low rise buildings and usually stairs or escalators are provided as the primary means of transfer between levels with lifts providing access primarily for persons with disabilities. Public transport applications often present particular challenges in achieving long term value from capital investment which typically requires high quality, durable products to be used in these public environments. For this reason, public transport operators such as Network Rail in the UK have detailed specifications that require heavy-duty components and enhanced safety standards and vandal resistance to be incorporated into the design of lifts and escalators in stations. These standards typically require equipment to have a minimum life span of 25 years and in some cases up to 40 years. For this reason standard model lifts and commercial grade escalators are generally not suitable for use in railway environments.

Older underground stations, such as those in many parts of London, can be very deep and passenger lift provision may be poor to nonexistent with only recently constructed stations offering passenger lifts as a matter of course. New stations should incorporate lifts to provide compliance with BS EN 81-70 (BSI, 2003a), the Equality Act 2010 (TSO, 2010a) and Building Regulations Part M (TSO, 2010b).

The underground environment of stations is very dusty and the confined conditions introduce additional risks in terms of safety and reliability. Underground train operators such as Transport for London and the New York City Transit Authority address the special requirements with prescriptive codes and standards developed to minimise fire hazards with special protection to the controllers and wiring. Again standard model lifts will not normally be suitable or accepted for such applications.

The poor lift provision within many existing underground stations means that consideration is necessary to introducing new lifts in order to assist the elderly and persons with disabilities, as required by the requirements of the Equality Act 2010, however structural limitations will make this very difficult and will limit the level of compliance that can be achieved.

5.2.2.9 Residential buildings

See also sections 2.6.9 and 3.15.9.

A well-designed residential building ensures that its inhabitants can easily and safely move within the building so that in multistorey blocks, residents and especially those with special needs should be provided with a convenient and reliable lift service meeting the requirements of the Equality Act 2010 (TSO, 2010a).

Residential buildings typically have low populations and a single lift may provide the necessary performance for

residents in a particular building, however consideration should be given to the height of the building and demographics of potential residents to ensure that in the event of the only lift failing, residents can be reasonably expected to walk up to their respective accommodation levels. For this reason a single lift should only be considered in buildings with four or five levels above the entry level. Beyond this it may be unreasonable to expect all residents and visitors to be able to walk up stairs in the event of a lift failure and two lifts should be considered in residential buildings with more than five storeys.

Where the design of a building allows for separate lifts, perhaps at each end of a long block, consideration should be given to linking these with a public corridor to provide redundancy in the event of lift failures.

The location of the lifts in residential buildings needs to provide adequate separation from occupied rooms and in particular bedrooms. Where lifts are located adjacent to occupied rooms, additional acoustic treatment of the well walls should be considered and the location of equipment in the well should be configured to locate noisy and moving parts as far away from the occupied areas as possible.

The required performance and aesthetic appeal of lifts will vary according to the nature of the accommodation, e.g. luxury apartments or local authority housing. For local authority housing, either BS EN 81-71 (BSI, 2005) or the local authorities' own specification should be followed for car interior design. If access to the lifts is not restricted, as is the case in many local authority buildings, car fixtures and fittings should be robust in design and vandal resistant with no visible fixings or surface mounted fixtures and the provision of monitored CCTV cameras should be considered to increase security for lift passengers.

To provide the necessary security and privacy for residents many modern residential buildings have electronic access control systems requiring swipe cards or proximity devices to gain access. Where these systems are provided, it is becoming common to incorporate interfaces between the lifts, the access control system and the apartments. In this way, access to the building or parts of the building can be restricted to people with authorised access cards and residents can grant access to visitors remotely from their apartment via the intercom system with a remote lock release.

In residential buildings with uncontrolled access, consideration can be given to incorporating additional safety devices such as 'anti-surfing' devices that sound an alarm and prevent the movement of the lift, in the event of intruders accessing the lift car roof or the pit area. However lifts designed to BS EN 81-71 incorporate security systems to prevent access to the lift well even to persons that have a lift door release key and these additional protective measures should be adopted where practical.

5.2.2.10 Residential care homes and nursing homes

See also sections 2.6.10 and 3.15.10.

The passenger lift requirements for care and nursing homes will vary greatly depending on the type of premises. Many homes are large old properties converted from domestic housing stock that are unsuitable for accommodating

conventional lifts. In such cases, vertical transportation may be provided by lifting platforms and stairlifts. Where lifting platforms are provided, it must be noted that such devices are not designed or intended for the movement of goods so alternative access for goods must be considered.

Modern purpose built care homes should be designed with conventional lifts where necessary and consideration should be given to providing lifts capable of accommodating stretchers or beds.

The location of the lifts needs to provide adequate separation from occupied rooms and in particular bed rooms. Where lifts are located adjacent to occupied rooms, additional acoustic treatment of the well walls should be considered and the location of equipment in the well should be configured to locate noisy and moving parts as far away from the occupied areas as possible.

Due to the likelihood of elderly and infirm passengers using the lifts, designers should consider fitting folding seats and low level alarm pushes for passengers who may be prone to falling. In many cases, the alarm system within the lift car will be arranged to link into the emergency nurse call system normally provided in care and nursing homes.

5.2.2.11 Shopping centres

See also sections 2.6.11 and 3.15.11.

With the continuing trend for large urban and suburban retail developments, there is a growing demand for lift installations in shopping centres. Often, modern shopping centres incorporate a combination of lifts and escalators to provide an efficient transportation system and the lifts will often be a mixture of conventional passenger lifts with observation lifts in large atria, to enhance the overall aesthetics of the centre. See also section 2.6.

Lifts in public shopping areas may be used by people carrying shopping or pushing trolleys and also by people with pushchairs or wheelchairs. They should therefore be sized to carry a minimum of 17 persons (1275 kg) in order to provide adequate capacity for unattended wheelchair access in accordance with BS EN 81-70 (BSI, 2003a). The full design recommendations made in BS EN 81-70 to facilitate use of lifts by disabled persons should be considered.

Careful consideration should be given at the design stage to the finishes, fixtures and fittings which should be robust and vandal resistant to suit their use in a public environment. The finishes should also provide a pleasant environment in keeping with the general surroundings whilst providing the necessary contrasting details to offer maximum usability to passengers with any visual impairment.

The doors should be electronically controlled to ensure that the lifts are accessible to people with trolleys, push chairs and wheel chairs and incorporate full height, electronic, non-contact safety edges.

5.2.2.12 Universities and other education buildings

See also sections 2.6.12 and 3.15.12.

Universities typically have a variety of building types ranging from low rise to tower blocks. The use of these building types varies from residential accommodation (halls of residence), conference facilities with hotel style accommodation, bars, restaurants, lecture blocks, laboratory and research buildings and office accommodation. The need for passenger and goods lifts should be assessed based on the relevant building types considered in the previous sections.

Consideration should be given to the student demographic with additional attention to increased risk of misuse and abuse which may require the installation of monitored CCTV and vandal resistant fixings for car and landing control panels as well as durable finishes.

5.2.3 Car size and payloads

BS EN 81-20 (BSI, 2014a) requires that all lift cars display a notice detailing the carrying capacity of the lift in terms of the number of passengers and the rated load in kilograms. European standards assume each passenger has a mass of 75 kg for this purpose and tables are provided in the standards to ensure lift cars are rated according to the available floor area. However the relationship between the internal car area and the rated load is not linear and means that lift cars tend to have passenger ratings in excess of the physical capacity that can be accommodated within the available area.

BS ISO 4190-1 (BSI, 2010a) provides internationally recognised standard dimensions and standard configurations for passenger lifts and entrances for rated loads between 630 kg (8-person) and 2500 kg (33-person) capacities.

BS EN 81-70 (BSI, 2003a) specifies the minimum size of lift car, suitable to accommodate a manual wheelchair as a 450 kg lift with internal dimensions of 1000 mm wide and 1250 mm deep. To accommodate a manual wheelchair with an accompanying person the minimum size required is the 630 kg (8-person) car with internal dimensions of 1100 mm wide by 1400 mm deep. The minimum size of lift to accommodate a stretcher is the 1000 kg (13-person) car with internal dimensions of 1100 mm wide by 2100 mm deep. Where full manoeuvrability of the wheelchair is required, a lift with a rated load of 1275 kg (17-person) car is required. See also section 5.9.3 and chapter 11.

BS ISO 4190-1 recognises a lift rated at 320 kg for residential use. This is unsuitable for use in a commercial or public environment since it would not provide sufficient room to accommodate a wheelchair and is below the minimum dimensions for compliance with BS EN 81-70 to meet the requirements of the Equality Act 2010 (TSO, 2010a). This car size is not recommended for any public or commercial applications.

Even where an 8-person lift provides adequate capacity to achieve the required traffic handling performance (see chapter 3), there may be operational reasons for adopting larger cars such as the need to move furniture or stretchers in residential buildings, or the need to provide capacity and comfort for passengers with baggage in commercial or hotel environments.

5.2.4 Entrances, car fittings and finishes

Landing entrances are perhaps the most important aspect of a lift to the user, since they offer the first impression to a prospective passenger of the quality of the installation. For passenger lifts, entrances doors should be automatically operated and incorporate edge protection by way of full height, non-contact electronic safety edges. Mechanical safety edges are no longer in general use and the use of single beam detectors is rare with technological advances and competition making full height curtain protection the norm for all but the very cheapest of model lift packages.

Safety edges are available with audible and visual indication to alert passengers when the doors are closing or about to close. These may be considered in busy public environments such as transport terminals, retail or leisure amenities. Care should be taken to ensure any audible indication will not create a nuisance for building occupants in close proximity to the lifts.

Automatic doors for passenger lifts are available in either centre opening or side opening configurations. Centre opening doors offer improved opening and closing times and better aesthetics so are often preferred on higher quality installations such as those in commercial offices, hotels, shopping centres or luxury residential environments.

Side opening doors can be accommodated in smaller lift wells than that required for the same sized centre opening doors, however due to the longer opening and closing times and the poorer aesthetics, side opening doors are more often used on residential buildings where the usage is not intensive or for goods lifts or hospitals where larger opening widths are required for beds, stretchers or goods handling.

BS ISO 4190-1 (BSI, 2010a) provides internationally recognised standard dimensions for entrance sizes as shown in Table 5.1.

Table 5.1 BS ISO 4190-1 entrance sizes

Class	Usage	Entrance width (mm)
I	Residential	(A) 800, (B) 900
I	General purpose	(A) 800, (B) 900, (C) 1100
III	Health care	1100, 1300, 1400
VI	Intensive duty	1100, 1200

An 800 mm wide entrance is the minimum required under BS EN 81-70 (BSI, 2003a) for accessibility in the UK. However, in other jurisdictions accessibility codes such as Australian Standard AS 1735.12 (SA, 1999) require a minimum entrance width of 900 mm.

The different series references (A), (B) and (C) cover the different entrance requirements of national regulations and localised markets around the world for residential and general purpose passenger lifts. For intensive duty passenger lifts the entrance widths should be larger at 1100 mm or 1200 mm.

Entrance widths of 1300 mm, 1400 mm and wider, are typical for hospital and health care applications designed to transport beds and stretchers and also on passenger goods lifts.

Generally, all the configurations given above are available from most manufacturers' standard product ranges.

5.2.5 Types of drive and operating speeds

For general purpose passenger or goods lifts, electric traction and hydraulic drives can both be considered suitable (see chapter 8). Each has its own advantages and the final choice is likely to be determined by the specific application.

An alternative drive system exists in the form of rack and pinion (see section 5.8) although this is generally only used where a hydraulic or electric traction lift cannot be used and would not typically be considered for passenger applications due to high noise levels and ride quality which is not comparable to either hydraulic or electric traction lifts. In addition, there is currently no harmonised standard for passenger carrying rack and pinion lifts and therefore a Notified Body design approval is essential for a permanently installed rack and pinion lift.

5.2.5.1 Traditional electric traction drive

Traditional electric traction drives are suitable for passenger lifts of any capacity, there are no significant travel or speed limitations and long travel distances may be avoided with passengers transferring at sky lobbies (see section 3.14.7). Rated speeds can be as low as 0.25 m/s and the current fastest speed in service is 17 m/s. With an increase in the number of tall towers being designed and constructed, lifts are commonly being installed at up to 9 m/s but in buildings of more conventional heights, the commonly used range is from 1.0 m/s to 6.0 m/s.

Accurate levelling is achieved by modern solid state control and feedback position monitoring equipment. Single speed, 2-speed, variable speed AC and DC converter power systems are now technologically obsolete and should not generally be considered for use on new passenger lifts. Variable voltage variable frequency (VVVF) drives are now almost exclusively specified and provide good energy efficiency and speed control (refer to chapters 8 and 13).

The limitations of conventional electric traction lifts are mainly concerned with the location of the machine room, available headroom and the possibility of high loads being applied at the very top of the building structure.

5.2.5.2 Hydraulic drive

Historically, hydraulic lifts often incorporated a hydraulic jack mounted in a deep bore hole acting directly on the underside of the lift car. Apart from the high costs associated with providing a bore hole for the jack, the location of the jack in the borehole means it is prone to becoming exposed to water and it cannot be easily inspected.

Most modern hydraulic lifts have the jack mounted within the well to the side of the lift car where they can be easily inspected and maintained and where different roping configurations can be adopted to provide increased travel distances without the need for deep boreholes.

Hydraulic drives are readily available for lifts up to a rated speed of 0.63 m/s and some manufacturers offer speeds of 1.0 m/s. The realistic maximum travel distance for a modern hydraulic lift is around 18 m.

Up to 1275 kg rated load, hydraulic drives can use a single side-acting jack supporting a cantilevered car. This imposes a horizontal load to the supporting wall that must be considered during building design. Above 1275 kg capacity, the most common configuration is twin rams, with one located each side of the car (see section 7.3.2.3), which reduces the horizontal loading on the lift well walls to a minimum.

The energy efficiency of hydraulic lifts is relatively poor since they typically have no balance weight. This is reflected in higher heat outputs from the drive unit and relatively low maximum duty cycles of around 45 starts per hour before additional cooling becomes necessary. The use of hydraulic lifts therefore tends to be limited to installations with low traffic and light usage or where the structural advantages of a hydraulic lift are necessary and the limited duty cycles and heat issues can be accommodated (see section 7.3).

Hydraulic systems are available with variable voltage variable frequency drives and hydraulic accumulator systems that act as a hydraulic counterweight. These are able to offer much improved energy efficiency, lower heat outputs and increased duty cycles without the need for additional cooling and can be considered for more intensive use. Despite these improvements, hydraulic lifts are still unlikely to be selected in preference to electric traction lifts, unless there are alternative benefits achieved with a hydraulic lift such as beneficial structural loadings or improved aesthetics through the use of a single direct acting ram.

Starting currents for hydraulic lifts will generally be higher than those for electric traction lifts and it is recommended that star-delta starting or an alternative means be used in order to limit the starting currents drawn by a hydraulic lift. This may be critical if the capacity of the mains supply to the building is limited or where the lift may require powering from a standby generator and therefore should be considered early in the design process.

Hydraulic lifts traditionally used mineral oil as the hydraulic fluid. Today, many manufacturers are supplying hydraulic lifts with environmentally friendly, biodegradable hydraulic fluids.

5.2.5.3 Machine-room-less (MRL) electric traction drive

Standard machine-room-less (MRL) passenger lifts are available with rated loads between 630 kg and 2000 kg at rated speeds of between 0.5 m/s and 3 m/s although the maximum speed for large lifts may be limited to 2.5 m/s or less dependent on the supplier. Larger machine-room-less lifts are available up to a rated capacity of 5000 kg and suitable for carrying passengers, however these have low rated speeds and are typically only suitable for passenger goods applications. Refer to section 5.3.

Modern machine-room-less lifts are capable of travel distances up to 80 m. Some manufacturers can now readily achieve travel distances of 100 m or more. However, at these

travel heights the speed limitations of 2.5 m/s and 3.0 m/s may make it preferable to consider traditional traction lifts with a machine room since these are capable of higher speeds.

The mounting of the drive machine in the lift well is achieved in different ways by the various manufacturers. Some mount the drive machine directly on the guide rails so that vertical loads are transferred via the guide rails to the pit floor, in a way similar to that for hydraulic lifts. Others adopt a bedplate arrangement built into the structure for which adequate provision must be made in the construction design.

5.2.5.4 Counterweight-less electric traction drive

Machine-room-less lifts are also available without a counterweight. The system employs suspension ropes anchored at the top of the well passing over a series of diverter sheaves in the well and on the car before being anchored in the lift pit. This results in a multiple roping ratio of either 6:1 or 10:1, which reduces the required motor size. The rate of acceleration and deceleration is varied depending on the load in the car to ensure that traction between the suspension ropes and the traction sheave is not broken.

Counterweight-less lifts are currently available for rated loads between 240 kg and 800 kg at rated speeds up to 1.0 m/s and a travel up to 30 m.

The major benefit of these lifts is the ability to maximise lift car dimensions in an existing lift well or to allow car doors to be introduced on older lifts that have been installed without them. This makes these lifts ideal for use in buildings where existing lifts can be replaced by a lift with increased car dimensions or where they can be installed in restricted areas with a smaller well than conventional MRL lifts.

5.2.6 Well

The construction of the lift well must comply with national construction standards which in England and Wales are governed by Building Regulations. In addition BS EN 81-20 (BSI, 2014a) provides guidance on the construction of lift wells that require minimum safety clearances within the pit, the headroom and the lift well, in order to provide a safe lift installation and safe working conditions for maintenance and service personnel. These clearances are required by the Lifts Regulations 1997 to allow the CE marking to be applied to an installation.

BS ISO 4190-1 (2010a) provides guidance on the minimum pit depth and headroom, but since the requirements may vary between different manufacturers, headroom and lift pit dimensions should be checked with lift manufacturers at an early stage of the design process.

Minimum well dimensions for MRL lifts vary between manufacturers due to differences in the type and configuration of drive equipment within the lift well and therefore BS ISO 4190-1 doesn't cover MRL lift dimensions. Where a lift system design will be competitively tendered, lift well dimensions need to accommodate a range of suppliers' equipment and the worst case space requirements

must be established with lift manufacturers early, particularly for non-standard lift sizes.

Appendix 5.A1 to this chapter provides a summary table (Barney et al., 2009) of the BS ISO 4190-1 requirements. Further extensive guidance regarding wells can be found in BS 5655-6 (BSI, 2011a).

5.2.7 Machine room

The machine room or machine space should comply with BS EN 81-20 (BSI, 2014a). All machine room doors and any personnel access doors must be lockable and able to be unlocked from the inside without a key and they should always open outwards, away from the machine room.

All machine rooms should be heated and ventilated to control the temperature and ensure suitable operating conditions for equipment and people accessing and working in the machine rooms (see section 12.10). Lighting is required to a minimum of 200 lux at floor level in working areas.

Appendix 5.A1 to this chapter provides guidance on suitable machine room sizes (Barney et al., 2009).

5.2.7.1 Traditional electric traction lifts

Guidance on the size of the machine room is given in BS ISO 4190-1 (BSI, 2010a). The sizes quoted are generous compared to those achievable by modern equipment but can be used for preliminary spatial planning.



Design tip: typical dimensions for traditional machine rooms above a lift well can be determined by projecting the lift well and landing lobby walls upward from the top floor to create a room outline above the lift well.

Depending on machine size, machine room heights providing a clear height of at least 2000 mm to any structural elements of the ceiling or lifting beams will be required. For large lift systems, taller machine rooms will be required to accommodate the drive machines.

For electric traction drives, the machine room is ideally located directly above the lift well (see section 7.2.7). Bottom and side drives are sometimes used but these increase the structural loading on a building by a factor of two and can be costly. Special engineering for machine mountings may be necessary and maintenance costs may be increased, due to reduced rope life caused by multiple and reverse bends introduced in potentially complicated roping arrangements (see section 7.15).

In all cases, access must be considered for the possible replacement of machine room equipment in the future. With top drive lifts, suitable lifting facilities by way of lifting beams or eyes should be installed overhead to allow lifting of the equipment from the trap door to the approximate operating position. Access to machine rooms must be sufficient for the passage of lift equipment and should be checked carefully as part of the design, particularly when equipment is located in basements or part way up a building where a crane cannot be used. The use of access hatches, whilst acceptable for equipment, is

unsuitable for personnel access and all machine rooms must be accessible via stairs or steps and access landings.

With bottom or side drive, an overhead pulley room is required, which will normally be the same plan dimensions as the lift well and needs a minimum internal height of 1500 mm for safe maintenance access. A separate pulley room may not be required if an underslung car arrangement is employed (see section 7.15.1). Basement machine rooms must be adjacent to the lift well with a plan size to suit the equipment and to provide an adequate safe working area for maintenance. In such installations, the designer should refer to the lift supplier for guidance.

5.2.7.2 Hydraulic lifts

For hydraulic drives, the machine room is ideally located adjacent to the lift at the lowest served level. If necessary the machine room can be located remote from the well but the distance between the machine and the hydraulic jack should not be greater than 6 m. In these circumstances, the lift supplier should be consulted.

Guidance on the size of a hydraulic machine room is given in BS ISO 4190-2 (BSI, 2001), which recommends a minimum machine room size of the lift well width (or depth) by 2000 mm and at least 2000 mm high. This is usually adequate, except for very large capacity lifts requiring more than one tank unit. In such a case, if the machine room is on the short side of the well, it may be necessary to increase the 2000 mm dimension and advice should be sought from a manufacturer. The machine room height will need to be increased if a lifting beam is required. Access to machine rooms for hydraulic lifts must be provided for the passage of lift equipment.

Temperature control in hydraulic machine rooms can be a major issue due to the higher heat outputs of this type of lift. Oil coolers may be fitted to increase the lift duty cycle (typically quoted as the rated number of motor starts a lift can make in one hour) and maintain adequate performance during peak operating periods. Where an oil cooler is used, it must be installed to allow heat to be exhausted or ducted away from the machine-room. Where this is not considered, the output from the cooler simply heats up the machine room and reduces the effectiveness of the oil cooler. In many cases, it is necessary to install cooling equipment in hydraulic lift machine rooms, by way of air conditioning units to maintain suitable ambient temperatures.

Where direct acoustic communication between the lift well and the machine room is not possible, a maintenance intercom is required between the machine room and the lift car.

5.2.7.3 Machine-room-less (MRL) lifts

The concept of MRL lifts is that all equipment is located within the lift well. The pit depth and over-runs on MRL lifts tend to be less than those for conventional lift installations and therefore additional space is not usually required external to the lift well for MRL lifts.

Solutions for accommodating drive machinery, drive units and controller equipment within a lift well have been achieved in a variety of ways. For electric traction lifts, arrangements are available with the drive machine located

within the lift pit, the headroom of the well and in some cases even on the lift car itself. (Refer to section 7.2.8.) For hydraulic MRL lifts the drive unit may be placed in the pit area or in a purpose built cabinet built into the lift well wall.

A control system for MRL lifts is often split between a maintenance or service panel located at the top lift landing within the front wall and accessed from the landing for normal maintenance and emergency release procedures. The larger components such as the drive unit and resistor banks etc. are typically located within the lift well.



Design tip: the size and design of the maintenance service panel will vary between manufacturers and some are able to locate the panel on levels other than the top floor, or remote from the lift well, which can be useful to avoid the impact on the aesthetics of the top floor landing.

The high efficiencies of modern traction gearless machines used for MRL lifts means that additional ventilation is not usually required. However, larger MRL lifts operating at higher speeds or MRL lift wells that are exposed (or partially exposed) to external elements may develop high temperatures at the top of the well near the drive and control equipment. In such cases, advice should be taken from the lift manufacturer on any additional ventilation or cooling required to maintain suitable ambient temperatures in the lift well.

5.3 Goods passenger lifts

5.3.1 General

This section deals with lifts designed primarily to carry goods and passengers that must comply with the Lifts Regulations 1997, either by the use of the harmonised standard BS EN 81-20 (BSI, 2014a), or by certification by a Notified Body. Some lifts designed for the movement of goods are not intended to be used to transport passengers, these are covered in section 5.4.

The width, depth and height of a goods passenger lift is often a function of the nature of the goods carried and the way in which they are moved (e.g. on pallets of a known size or in containers). BS ISO 4190-2 (BSI, 2001) provides dimensions for standardised lift sizes which can be used and will be widely available from many manufacturers.



Design tip: with modern manufacturing techniques, most manufacturers can provide flexibility in the sizes of lift cars with minimal cost impact but there may be cost savings available by adopting a completely standardised solution. This will include the use of the manufacturers standard fixtures, fittings and finishes where they can satisfy the needs of a project but since goods lifts are typically located in back-of-house locations, this should not prove an issue.

Consideration should also be given to the transportation of items other than those for which the lift is normally used. For example, the goods passenger lift may be the only means of transporting items such as office furniture and

partitions between floors. Standard lift doors are not always wide or high enough for such items.

For safe loading and easy access, goods passenger lifts should be located in a position that provides adequate free space in front of the entrance. If wheeled trolleys or fork-lift trucks are to be used, adequate space to manoeuvre these should be provided, with clear access to the loading area. Consideration should also be given to the effect of loading on the lift car sills and flooring. The installation of trolley 'bump rails' should be considered in all goods passenger lifts.

5.3.2 Applications for goods passenger lifts

5.3.2.1 Airports

Airports contain many facilities including offices, car parks, restaurants and shops, all of which may require goods service. Dedicated goods passenger lifts should be provided to avoid the use of airport passenger lifts for goods service. Their specification will depend on their main purpose, as described elsewhere in section 5.3.2.

5.3.2.2 Car parks

The requirement for a dedicated goods passenger lifts in a car park is unlikely.

5.3.2.3 Department stores

Single goods passenger lifts may be provided in smaller department stores, but it is recommended where the goods deliveries are crucial to ongoing retail operations that at least two goods passenger lifts be provided to allow for continued availability during peak delivery periods and redundancy in the event of a lift breakdown.

Goods passenger lifts are usually placed adjacent to vehicle loading/unloading bays or lay-bys and care should be taken to ensure sufficient units are provided. The rated load will depend on the nature of the stores business, but should be at least 2000 kg, except where specialised goods are being transported, when smaller rated loads might be appropriate.

5.3.2.4 Entertainment centres, cinemas, theatres, sports centres, stadia and concert halls

A variety of activities can be found in this type of building application including offices, restaurants, bars, changing rooms, washrooms etc., all of which will require goods service. Dedicated goods passenger lifts may not be necessary, provided one or more passenger lifts are made available and can be used for goods handling without compromising the passenger lift performance or the patron's experience of a venue.

Where catering facilities need to be serviced via a lift, dedicated goods passenger lifts are recommended to avoid the use of passenger lifts for food deliveries and waste movements which can create dirty and untidy lift interiors with unpleasant odours. Service lifts (see section 5.6) may also be required to serve bars, restaurants and kitchens.

5.3.2.5 Hospitals

In addition to passenger lifts, hospitals require lifts to support the facilities management (FM) teams who regularly move trolleys of food, linen, goods and clinical equipment around the hospital. These lifts may be located on dedicated FM, routes although current trends for hospitals designed around a hospital street make this less common. Hospital planning should try to minimise the number and intensity of these journeys by arranging deliveries and collections of different load types so they do not coincide.

In some hospital designs, infection control requirements may dictate a need for 'clean' and 'dirty' service paths resulting in additional goods lifts to allow separation.

Some new hospitals are being designed using automatic guided vehicles (AGVs) for FM movements allowing goods to be moved around the hospital unattended, using computer control and guided tractor units. Vertical movement of the AGV tractors are achieved via a software interface between the AGV and lift control systems allowing the tractors to place calls on the lifts and to wait and enter lifts on arrival. To ensure staff safety, these systems are typically not intended to carry passengers at the same time as AGV tractors and dedicated AGV lifts should be considered.

In addition to BS ISO 4190-1/2 (BSI, 2010a, 2001), which provides recommended lift car and well sizes for hospital goods passenger lifts, information specifically related to hospital trolley dimensions is available in Health Building Note HBN 00-04 (DoH, 2013) and additional design information is available in Health Technical Memorandum HTM 08-02 (DoH, 2010). These documents relate to hospital design within the UK, or under UK jurisdiction and may not be applicable in other countries.

5.3.2.6 Hotels

Generally, service (goods) activities such as baggage transfers, room service, housekeeping, etc. should be separated from the guest access routes and the use of guest lifts for such functions should be avoided. Designers of lift systems for hotels should carefully consider the operational requirements of the hotel and incorporate dedicated goods passenger lifts (and service lifts, see section 5.6) for the use of staff servicing the guest rooms.

Goods passenger lifts should be located in an area not normally accessible to guests (i.e. 'back of house') and will need to be sized to cater for any cleaning or laundry trolleys that may be used. Since such lifts will be used for transporting large amounts of goods and refuse, they should have durable finishes and a minimum load of 1600 kg.

Special requirements may also be necessary for large lifts to service exhibition and conference facilities. These lifts may be required to accommodate large goods such as exhibition displays and possibly even vehicles.

5.3.2.7 Offices

In smaller office buildings, shared use of one or more passenger lifts may be appropriate for goods handling, however in larger buildings, dedicated goods lifts should be provided. Goods lifts should serve from a loading or delivery area into the accommodation levels via a back-of-

house lobby to avoid impacting on the day to day activities of office tenants and staff.

As well as handling day-to-day deliveries and general office goods, a commercial goods lift will often be used for plant replacement and construction type works within an office that may occur fairly regularly.

In large buildings, tenants may carry out upgrades and fit-out works to their tenancies and the landlord or owner will occasionally upgrade common areas so large lift cars with high ceilings should be considered to accommodate building materials and plant equipment.

For building plant replacement purposes, goods lifts should service roof plant levels wherever possible to provide access for maintenance personnel and to allow the movement of services plant and equipment during building maintenance and upgrade works.

See also section 3.15.7.

5.3.2.8 Railway stations

The requirement for goods passenger lifts at railway stations is generally small, as most surface stations are single level and underground stations make other arrangements. Many stations where the platforms are above or below the access road employ ramps for passenger use and these can be used for the movement of goods. Where they are provided, passenger lifts can be used to transport goods provided passengers take priority and the cars are suitably protected.

One exception to this is in modern terminal stations where trains are prepared for long journeys. Such preparation will usually involve the charging of water tanks, restocking of catering facilities and cleaning of the trains and therefore goods passenger lifts may be necessary for these operations to occur efficiently. Some goods passenger lifts may be of a special size to accept baggage trolleys or water tugs and will require early consultation with the station operators to establish the specific requirements.

5.3.2.9 Residential buildings

Most residential buildings are designed with passenger lifts designated for shared goods usage, provided with protective curtains and suitable finishes and designed and intended to contribute to the required passenger handling capacity of the lift system during periods of peak traffic. However, in some high quality prestigious developments, it may be necessary to incorporate dedicated goods passenger lifts that are intended to be available at all times for handling goods and furniture and are not considered to contribute to the required passenger handling capacity. Dedicated goods passenger lifts should also be considered in large residential towers where the churn of residents will generate a regular demand for furniture and goods movements into or out of the building. In this case, the regular use of one of the main passenger lifts for goods movements will reduce the availability of lifts for other residents and result in poor performance. In addition, the regular presence of goods and furniture in the main lobby can prove inconvenient and frustrating to other residents.

Dedicated goods passenger lifts should be sized to accommodate large furniture items and any refuse containers that might be transported in the lift. Ideally they should be located in a separate core to reduce disruption to other residents and to allow the passenger lobbies to be provided with high quality decoration and finishes.

Where shared goods passenger lifts are used, the goods passenger lift should permit the hanging of protective drapes and should be sized to accept stretchers as well as furniture and general goods, etc. The minimum recommended size for dual purpose lifts is a 17-person lift with internal dimensions of 1400 mm wide by 2000 mm deep.

Where a dedicated goods passenger lift is used, larger cars of 1600 kg rated load should be considered to maximise the benefits of providing a dedicated goods lift.

5.3.2.10 Residential care homes and nursing homes

Goods service is unlikely to be required, unless the home is very large in which case dedicated goods passenger lifts may be necessary for the movement of catering and linen supplies similar to a hotel or hospital environment.

5.3.2.11 Shopping centres

Goods passenger lifts provided in shopping centres are usually placed singly, or in pairs, adjacent to vehicle loading/unloading bays or lay-bys and along service corridors at the rear of retail units to ensure goods do not need to be moved through the public malls and walkways.

Each loading dock with a lift or group of lifts will typically service a group of general retail units, although larger stores and department stores may have their own dedicated goods passenger lifts and delivery areas. Care should be taken to ensure sufficient goods passenger lifts are provided to allow for peak deliveries and lift breakdowns.



Design tip: generally one goods passenger lift for every 10 general retail units (not major or department stores) should prove adequate and the rated load should be at least 2000 kg, except where specialised goods are being transported, when smaller rated loads might be appropriate.

5.3.2.12 Universities and other education buildings

Universities typically have a variety of building types ranging from low rise to tower blocks. The use of these building types varies from residential accommodation (halls of residence), conference facilities with hotel style accommodation, bars, restaurants, lecture blocks, laboratory and research buildings and office accommodation. The need for dedicated goods passenger lifts should be considered by reference to the relevant sections for the specific use of each building.

5.3.3 Car sizes and payloads

The first step when selecting a goods passenger lift is to determine the specific type of goods to be moved along with the overall dimensions and the weight of the largest items.

This enables the designer to calculate the volume and total weight expected to be moved at any one time. Additional space should be allowed for any personnel, who will normally be expected to accompany the goods.

The recommended minimum internal width for lift cars is the overall width of the goods plus 600 mm. This allows goods to be stacked to one side whilst leaving an area for accompanying personnel. In the case of 'through cars', with entrances on opposite sides, it is possible that the attendant will have to unload the lift through the opposite entrance and therefore access to both entrances from inside the loaded car is essential.

Having determined the minimum size required, the nearest standard size given in BS ISO 4190-1 (BSI, 2010a) or BS ISO 4190-2 (BSI, 2001) should be selected wherever possible. BS ISO 4190-1 provides internationally recognised standard dimensions and configurations for passenger lifts and BS ISO 4190-2 provides the same information for goods passenger lifts for rated loads between 630 kg (8-person) and 5000 kg (66-person) capacities.

When loading of a lift is carried out by forklift trucks or other wheeled vehicles, the carrying capacity and design of the lift must reflect the additional load imposed by the weight of any vehicle that may enter the lift car. Consideration should be given to the size of the lift car in relation to the loading truck and the also to the number of wheels the vehicle has, as this will affect the point loading on the entrance sills and the lift platform and must be considered in the lift design. Where it is intended for a loading or fork lift truck to travel with the load, the truck weight must be included within the rated load of the lift. This may not require an increase in the size of the car, but the platform construction and the car and landing sills may need to be strengthened to accommodate high point loads imposed by truck wheels. Additional stiffening of the structural sling may also be necessary and needs to be considered as part of the lift design.

The rated load of a hydraulic goods passenger lift may be to a lower ratio of rated load to available car area. This permits the drive system to be smaller for applications where it is known that the lift car will not be required to carry the load given by the normal ratio of rated load to available car area. Examples include airports where baggage trolleys take up significant space, and shopping centres, where shopping trolleys and pushchairs are carried.

5.3.4 Entrances, car fittings and finishes

Door configurations are dealt with in detail in section 7.9. Goods passenger lift doors are most commonly automatic horizontal sliding doors, as used in passenger lifts. For some very heavy duty applications vertical sliding doors might be used however these are typically slow and inefficient in operation, are not recommended for normal goods passenger lift applications and are unsuitable for passenger lift applications.

For horizontal sliding doors, standard entrance widths of 1100 mm, 1300 mm, 1400 mm, 1500 mm, 1800 mm, 2100 mm and 2500 mm are available, although the maximum door widths available from some manufacturers on their standard product ranges may be limited to around

1400 mm. For vertical sliding doors entrance widths of 1400 mm, 1500 mm, 1800 mm, 2100 mm and 2500 mm are available. The slide direction and entrance width will be dependent on the goods to be transported. Special width doors can be supplied by most manufacturers, but are likely to be more expensive.



Design tip: goods passenger lifts need to be robust in service and protection by way of protective bollards in front of the entrances, to avoid impact damage to the doors and surrounding door frames, is recommended where trolleys or powered trucks will be used for loading.

Historically, goods lifts were often provided with manual and sometimes powered folding shutter gates, which present a very robust and durable solution and avoid reliability issues that can easily be generated by damage to automatic doors that rely on close operating clearances, easily affected by accidental impacts during goods use.

Manual shutter gates are used less often these days and there is a widespread preference for multi-panel conventional automatic lift doors in most cases



Warning: where folding shutter-type gates are used with through cars, it is important to check that the distance between the bunched leaves of the gate is adequate. Otherwise goods loaded against the closed gate may encroach on the area required by the leaves of that gate when open and thus prevent the gate from being opened.

Manual doors may be preferred or specified for some goods passenger lifts where heavy duty usage is required such as in busy retail or industrial applications. These should be arranged to give an opening equal to the full width of the car if possible, for maximum flexibility. As well as improved durability over automatic sliding doors, folding shutter gates can be accommodated in lift wells with a narrower width and are easily adapted to suit varying entrance widths. The standardised heights of 2000 mm, or 2300 mm, should be selected wherever possible.



Warning: manual shutter gates require a considerable effort to open and close them. They are not suitable for use by persons with limited strength which may deem them unsuitable in modern retail environments where employers seek opportunities to employ people with wide ranging physical capabilities. The use of manual shutter gates should therefore only be considered following consultation and agreement with the end user.



Design tip: power-operated shutter gates are available and offer a durable, robust solution to applications where tugs, or loading vehicles are used, avoiding the need for lift users to demount and manually open the lift gates. For general goods usage however, conventional horizontal sliding, automatic doors should be considered where manual doors are not suitable.

Good passenger lifts should be rugged and the finishes should be easy to clean and repair, see Figure 5.4. Walls and roofs should be constructed in sections to allow easy replacement of damaged panels. Many materials and finishes are available but the most common are either steel

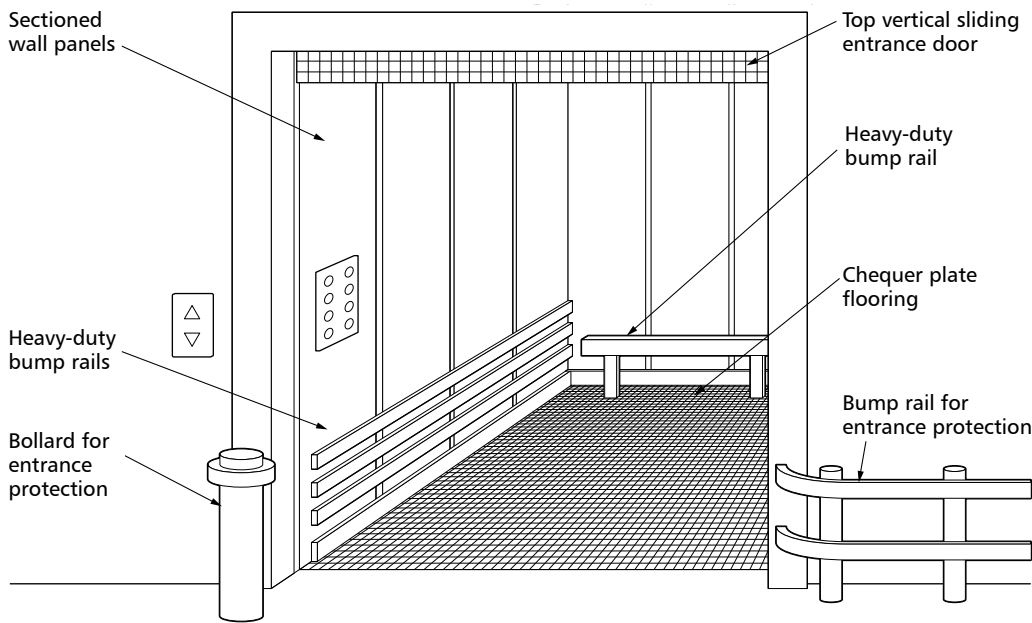


Figure 5.3 Entrances, car fittings and finishes for a rugged goods passenger lift

with a cellulose paint or powder coated finish, or patterned stainless steel. While the latter is initially more expensive, its appearance is superior and it does not require maintenance after installation. For very light duty applications, laminate-faced panels may be used. The appearance is good but the surface is more prone to damage than steel panels.

In all cases it is desirable to fit some form of bumper rail in the car to provide a level of protection for the walls. The rail should be mounted at a suitable height to absorb the impact of trolleys, loading pallets etc. Alternatively, a series of rails may be provided, spaced at various heights to protect against impact from a range of trolleys or cages that may be used for moving goods. The thickness of any protective bump rails should be considered when calculating the required car sizes to ensure adequate clearance is maintained for loading.

The flooring of goods passenger lifts should be replaceable. Patterned 'chequer plate' steel flooring offers a very heavy duty solution but, for lighter duty applications, surfaces such as aluminium chequer plate or vinyl may be preferred.



Warning: steel or aluminium flooring is slippery when wet and should not be used in environments that may be subject to water contamination or in need of regular cleaning with liquids.

In applications where corrosive fluids are carried, epoxy resin or terrazzo flooring may be required and joints between flooring and wall panels should be sealed. Consideration should also be given to the consequences of cleaning lift cars if it is intended for a hospital or food preparation facility. Lifts designed to BS EN 81 are not designed for hosing down or cleaning with excessive amounts of water or cleaning fluids. Where such procedures may be required a special lift needs to be purchased with suitably protected electrical and mechanical components in the lift well and provision for the drainage of liquids from the lift pit.



Design tip: where cleanliness is important, epoxy resin or terrazzo based floor coverings should be considered with sealed joints and if necessary, coved corners to allow easy cleaning without the

risk of water penetrating the lift well or contaminating the floor substrate.

5.3.5 Types of drive and operating speeds

For conventional goods passenger lifts, electric traction, hydraulic and rack and pinion drives can all be considered suitable (see sections 7.2, 7.3 and 5.8). Each has its own advantages and the final choice is likely to be determined by the specific application.

5.3.5.1 Traditional electric traction drive

Electric traction drives are suitable for goods passenger lifts of any capacity and there are virtually no travel or speed limitations. Goods passenger lifts do not depend on travel speed for quality of service since loading and unloading consume the greatest time on the round trips. Typically speeds of 1.0 m/s or 1.6 m/s are satisfactory for a dedicated goods passenger lift and the speed will typically always be lower than that of any passenger lifts in the same building. For this reason, it is unusual to require speeds in excess of 2.5 m/s for dedicated goods passenger lifts in all but the tallest of buildings where speeds up to 5 m/s may become necessary to achieve acceptable travel times.

As with passenger lifts, variable speed variable frequency (VVVF) AC drives are almost exclusively used on modern lifts and provide accurate levelling and good speed control under all loading conditions. Re-levelling is essential on goods passenger lifts since the loading or unloading of heavy loads will cause the lift to lower or raise at the landing floor, due to the elastic stretch of the suspension ropes.

The limitations of electric traction drives are mainly concerned with the location of the machine room, available headroom and the possibility of high loads being applied to the building structure.

5.3.5.2 Hydraulic drive

Goods passenger lifts do not depend on high travel speeds for quality of service since loading and unloading consume

the greatest time on round trips. Therefore, the speed limitations of hydraulic drives, at 0.5 m/s or 0.63 m/s, are not such a limiting factor for goods applications however the practical travel distance for hydraulic lifts is limited to 18 m.

Up to 1275 kg rated load, most modern hydraulic drives use a single side-acting jack unit supporting a cantilever car. This imposes a horizontal load to the supporting wall which must be considered during the building design. Above 1275 kg capacity, the most common configuration is twin jacks, with one located on each side of the car (see section 7.3.2.3). This reduces the horizontal loading to a minimum. Single side-acting jacks should not be considered for goods passenger lifts where there may be heavy loading requirements, e.g. using forklift trucks or large trolleys etc.

Unless VVVF drive and accumulator balancing is used, (see section 8.11.4) heat outputs from large hydraulic lifts will be high and will require the use of oil coolers and machine room cooling to control the ambient machine room temperature. Starting currents can also be higher than those for electric traction lifts and various systems such as star delta starting or VVVF motor control are typically employed in order to limit the starting currents on hydraulic lifts. This may be critical, if the capacity of the mains supply to the building is limited and should be considered early in the design process.

5.3.5.3 Machine-room-less electric traction drive

Standard machine-room-less goods passenger lifts are available with loads up to 5000 kg at speeds of 0.5 m/s although increased speeds up to 1.0 m/s can be used on smaller lifts. The larger applications can utilise up to 4:1 roping ratios (see section 7.15) to reduce the load on the drive machine. With some manufacturers, the drive machine and suspension points are supported on the guide rails to transfer most of the loading vertically to the pit floor, in a way similar to that for hydraulic lifts. Other manufacturers have the machines and suspension points supported directly by the structure where significant loads will need to be considered within the structural design of the well.

5.3.5.4 Rack and pinion drive

Rack and pinion drive is generally only used where a hydraulic or electric traction lift cannot be used and would not typically be considered for permanent passenger carrying applications due to high noise levels and poor ride quality, which are not comparable to those of either hydraulic or electric traction lifts. In addition, there is currently no harmonised standard for passenger carrying rack and pinion lifts and therefore a Notified Body design approval is essential for a permanently installed rack and pinion passenger lift. Goods only rack and pinion lifts should comply with BS EN 81-31 (BSI, 2010b) (refer to section 5.4). Refer to section 5.8 for details of rack and pinion drives.

5.3.6 Well dimensions and construction

The construction of the lift well should comply with BS EN 81-20 (BSI, 2014a), which requires minimum safety clearances within the pit, the headroom and the lift well, in order to provide a safe lift installation and safe working conditions for maintenance and service personal. These clearances are required by the Lifts Regulations 1997 (TSO, 1997) to allow the CE marking to be applied to an installation.

The construction of the lift well must ensure that it will be strong enough to accept all the loads applied by the lift. Where loading and unloading is to be carried out by forklift trucks or trolleys, the additional loads imposed by the loading equipment must be considered. In this case, large loads associated with the mass of the truck are temporarily applied to the stationary lift. This generates a turning moment with high reaction forces on the car guides (or mast assembly in the case of rack and pinion lifts). These loads are transferred to the building structure by the guide rail or mast fixings and the structure must be strong enough to accept these without degradation. While blockwork has a high compressive strength, it is not suitable for expanding bolts or other heavy-duty fixings so steel or reinforced concrete sections should be used. At the very least, local areas of cast concrete blocks, suitably tied and bonded to the wall panel, should be used. It should be noted that lift installers cannot accept responsibility for the design of the building, or its structural strength and integrity.

Guidance on well sizes is provided in BS ISO 4190-2 (BSI, 2001), although this standard deals only with lifts using automatic doors. Minimum well dimensions for MRL lifts vary between manufacturers due to differences in the type and configuration of drive equipment within the lift well and therefore BS ISO 4190-2 does not cover MRL lift dimensions. Where a lift system design will be competitively tendered, lift well dimensions need to accommodate a range of suppliers' equipment and the worst case space requirements must therefore be established with lift manufacturers early, particularly for non-standard lift sizes and lifts with manual doors or manual shutter gates, as may be considered for goods lift applications.

Appendix 5.A1 to this chapter is a summary table of the BS ISO 4190-2 requirements. Further extensive guidance regarding wells can be found in BS 5655-6 (BSI, 2011a).

5.3.7 Machine room

All machine rooms and any personnel access doors must be lockable and able to be unlocked from the inside without a key. They should always open outwards.

All machine rooms should be heated and ventilated to control the temperature and maintain correct operating conditions for both the lift equipment and lift operatives working in the machine room (see section 12.10). Lighting is required in lift machine rooms to a minimum of 200 lux at floor level in working areas.

Appendix 5.A1 to this chapter indicates possible machine room sizes.

5.3.7.1 Traditional electric traction lifts

Guidance on the size of the machine room is given in BS ISO 4190-1 (BSI, 2010a). The sizes appear to be generous compared to those achievable with modern equipment but can be used for preliminary spatial planning.



Design tip: typical dimensions for many machine rooms can be determined by projecting the lift well and landing lobby walls upward from the top floor to create a room outline above the lift well.

Depending on machine size, machine room heights providing a clear height of at least 2000 mm to any structural elements of the ceiling or lifting beams will be required. For large lift systems or faster lifts, higher rooms will be required to accommodate the drive machines.

For electric traction drives, the machine room is ideally located directly above the lift well (see section 7.2.7). Bottom and side drives are sometimes used, but can be costly, requiring special engineering for machine mountings and increased maintenance costs due to reduced rope life caused by multiple and reverse bends introduced in potentially complicated roping arrangements (see section 7.15).

In all cases, access must be considered for the possible replacement of machine room equipment in the future. With top drive lifts, suitable lifting facilities by way of lifting beams or eyes should be installed overhead, to allow lifting of large and heavy equipment from the trap door to the required location. Access routes to machine rooms must be sufficient for the passage of lift equipment and should be checked carefully as part of the design, particularly when equipment is located in basements or part way up a building where a crane cannot be used. The use of access hatches, whilst acceptable for equipment is unsuitable for personnel access and all machine rooms must be accessible via stairs or steps and access landings.

With bottom or side drive, an overhead pulley room is required which will normally be the same plan dimensions as the lift well and needs a minimum internal height of 1500 mm for safe maintenance access. A separate pulley room may not be required if an underslung car arrangement is employed (see section 7.15.1). Basement machine rooms must be adjacent to the lift well with a plan size to suit the equipment and to provide an adequate safe working area for maintenance. In such installations, the designer should refer to the lift supplier for guidance.

5.3.7.2 Hydraulic lifts

For hydraulic drives, the machine room is ideally located adjacent to the lift at the bottom level. If necessary the machine room can be located remote from the well but the distance between the machine and the hydraulic jack should not be greater than 6 m. In these circumstances, the lift supplier should be consulted.

Guidance on the size of the machine room is given in BS ISO 4190-2 (BSI, 2001), which recommends a minimum machine room size of the lift well width (or depth) by 2000 mm and at least 2000 mm high. This is usually adequate, except for very large capacity lifts requiring more than one tank unit. In such a case, if the machine room is on the short side of the well, it may be necessary to increase

the 2000 mm dimension and advice should be sought from a manufacturer. The machine room height will need to be increased if a lifting beam is required. Access to machine rooms for hydraulic lifts must be provided for the passage of lift equipment.

Temperature control in hydraulic machine rooms can be a major issue due to the higher heat outputs of this type of lift. Oil coolers may be fitted to increase the lift duty cycle (typically quoted as the rated number of motor starts a lift can make in one hour) and maintain adequate performance during peak operating periods. Where an oil cooler is used, it must be installed to allow heat to be exhausted or ducted away from the machine room. Where this isn't considered, the output from the cooler simply heats up the machine room and reduces the effectiveness of the oil cooler. In many cases, it is necessary to install cooling equipment by way of air conditioning units to maintain suitable ambient temperatures in hydraulic machine rooms.

Where direct acoustic communication between the lift well and the machine room is not possible, a maintenance intercom is required between the machine room and the lift car.

5.3.7.3 Machine-room-less lifts

The concept of machine-room-less (MRL) lifts is that all equipment is located within the lift well. The pit depth and over-runs on MRL lifts tend to be less than, or at least comparable to conventional lift installations and therefore additional space is not usually required external to the lift well for MRL lifts.

Solutions for accommodating drive machine or drive unit and controller equipment within the lift well have been achieved in a variety of ways. For electric traction lifts, most suppliers have the drive machine at the top of the well, but there are also arrangements with the drive machine located within the lift pit and in some cases on the lift car itself (refer to section 7.2.8). For hydraulic MRL lifts the drive unit is usually placed in the pit area, or in a purpose-built cabinet built into the lift well wall.

A control system for MRL lifts is often split between a maintenance or service panel commonly located at the top lift landing within the front wall and accessed from the landing for normal maintenance and emergency release procedures. Larger components such as the drive unit and resistor banks etc. are located within the lift well and are typically accessed from the lift car roof via the landing doors.



Design tip: the size and design of the maintenance panel will vary between manufacturers and some are able to locate the panel on levels other than the top floor or remote from the lift well which can be useful to avoid the impact on the aesthetics of the top floor landing although this would not normally be an issue for goods passenger lifts.

The high efficiencies of modern traction gearless machines used for MRL lifts means that additional ventilation is rarely required for lift wells that are fully internal to a building (i.e. not exposed to external elements), or where the climate is temperate such as in the UK.

In hotter climates or where a significant section of the top of a lift well may be exposed to direct sunlight consideration should be given to introducing exhaust fans or even mechanical cooling to maintain suitable ambient temperatures around the control and drive equipment. The requirement for any additional ventilation or cooling of the lift well should be checked with the lift manufacturer.

5.3.7.4 Rack and pinion drive

Refer to section 5.8 for details of rack and pinion machine room requirements.

5.4 Goods only lifts

Lifts are available that are designed to carry only goods and as such are legislated under the Machinery Directive (EC, 2006) and BS EN 81-31 (BSI, 2010b) in the UK and not the Lifts Regulations 1997 (TSO, 1997).

These products do not require the same protective devices required by the Lifts Regulations for passenger carrying lifts. Goods only lifts operate at restricted speeds, enabling them to be installed with minimal pit depths and over-runs. This makes them especially useful in warehousing or industrial applications where they can easily be installed on a structural slab with a short ramp up to the entrance without the need for a deep structural pit.

The operational restrictions imposed by not being able to transport passengers with the goods means they are generally not suitable for commercial or retail environments or any applications where high usage may be necessary.



Warning: goods only lifts must be designed so that persons can't easily travel in the lift. Warning signs are not legally acceptable and the lift must have call and send buttons on the landing without the normal car controls found in a conventional lift.

5.5 Observation lifts

5.5.1 General

Refer to sections 3.13.4 and 5.2.1.

Observation lifts consist of a glazed, or partially glazed lift car, running within a glazed or partially enclosed lift well, see Figure 5.5. They are referred to by various names including wall climber, scenic, panoramic, and glass lifts. They are often installed as an architectural feature in a building within an atrium, or occasionally, external to the building. All the guidance offered for passenger lifts in section 5.2 is generally applicable. However, the following additional advice should be taken into account when considering, or designing, observation lifts.

All observation lifts must comply with the Essential Health and Safety Requirements (EHSRs) of the Lifts Regulations 1997 (TSO, 1997). This can be achieved by lifts complying fully with BS EN 81-20 (BSI, 2014a). This standard contains specific clauses to cover the use of glass in and

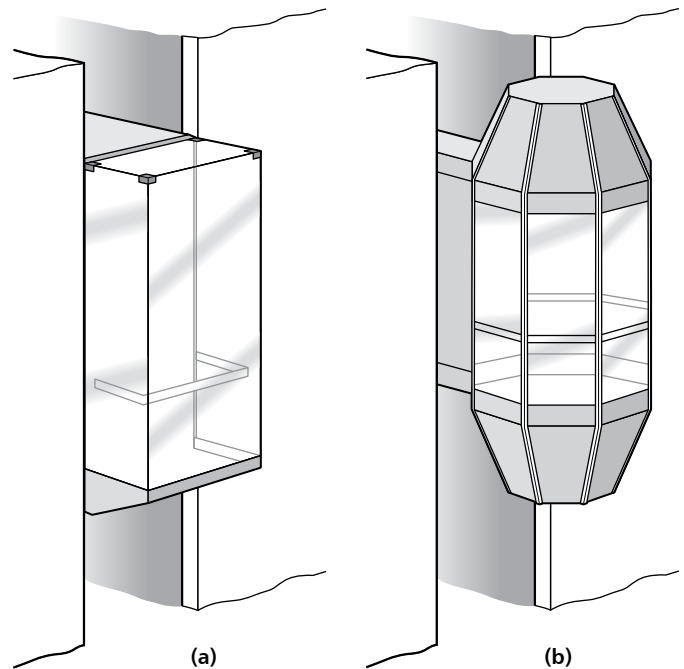


Figure 5.5 Typical observation lift cars; (a) rectangular without mullions, (b) octagonal with mullions

around the lifts and the screening requirements around partially enclosed wells.

Most large lift manufacturers offer pre-engineered observation lift designs. These reduce costs and delivery times because the majority of the design work has already been carried out. Pre-engineered designs range from a normal lift car with a glass window in the back wall and a glass-sided lift well to very sophisticated designs, such as an octagon, round or bespoke shaped cars.

Observation lifts are often tailor-made to suit the particular building in which they are to be installed. For many applications, observation lifts will need to be specially engineered because of structural issues, or space limitations.

An advantage of custom-designed lifts is that they can be designed to match building décor and other architectural requirements. However, it should be noted that the time required for design and manufacture will be greater than that for pre-engineered lifts. Special features, finishes and the need to obtain any approval in accordance with the Lifts Regulations 1997 will further increase delivery times. Therefore the detailed specification should be confirmed, and the lifts ordered, as soon as possible during the planning of the building to ensure that the lift is operational by the time the building is ready for occupation.

As discussed in section 3.13.4 observation lifts do not provide the same handling capacity as conventional lifts of the same specification and there are a number of reasons for this. In public buildings observation lifts attract sightseers and joy riders and many passengers will wish to enjoy an unobstructed view through the glass. This problem however, does not occur to the same extent in offices, or apartments, where users become accustomed to the lifts and are more likely to use them in a conventional manner.

It is common in public places such as shopping malls to position observation lifts individually around a development, to create a repeating architectural feature. Where this is a consideration, the reduced handling capacity of the

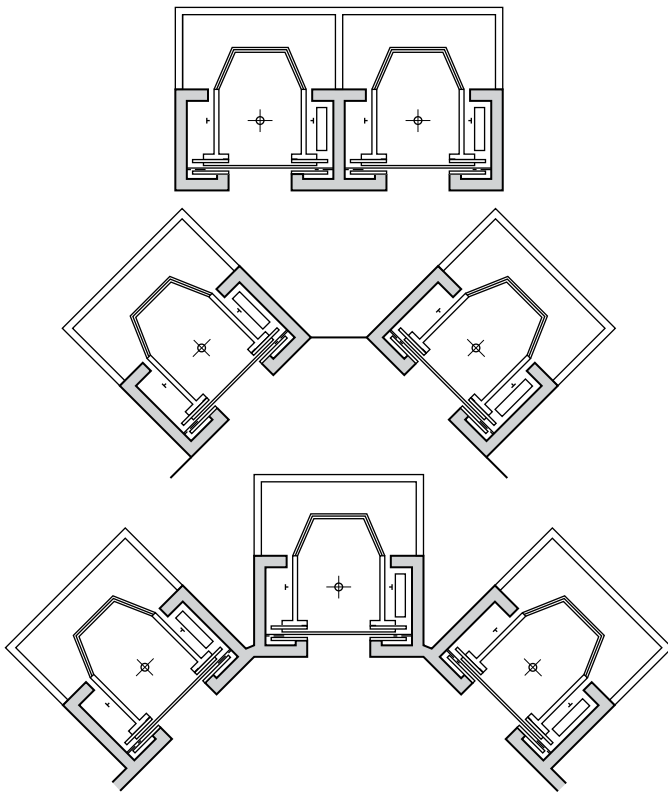


Figure 5.6 Observation lifts; some possible group layouts

individual lifts should be considered within the system design to ensure that the likely traffic demands can be met by individual lifts. Alternatively, they could be grouped together at a single point to maximize efficiency. Figure 5.6 shows some possible configurations.

Observation lifts can also be part of a mixed group comprising conventional and observation lifts. The two types should be clearly distinguishable to passengers before they enter the lift, as some people may dislike glazed lifts and be reluctant to use them. There are also potential negative psychological effects on waiting passengers that need to be considered where glazed doors or fronts are used. With visibility of the lift well from a landing, passengers are able to easily observe lifts passing their floor when they are expecting a lift to stop. This can be necessary for traffic control reasons, or because a car is fully loaded, however, passengers may think the system is malfunctioning which can initiate complaints about the lift performance.

5.5.2 Applications for observation lifts

5.5.2.1 Airports

Historically, observation lifts were relatively rare in airports where functionality is paramount and the low rise nature of airport terminals and the need to use space efficiently limited opportunities to create large atria.

However, steel and glass structures are used extensively within modern airports creating an ideal environment for observation lifts which are now becoming a regular feature in modern airports serving airport lounge areas and retail or food and beverage facilities.

5.5.2.2 Car parks

Observation lifts are not generally suitable for this environment however some car park operating companies have a preference to include glass doors on lifts. This can provide enhanced security allowing passengers to see into and out of a lift car before entering or leaving. In addition, where glass doors are provided, the use of CCTV allows visibility of the car interior and the landing lobby from a single camera position. In such cases, the lifts do not tend to be considered as observation lifts and minimal attention is given to the location and aesthetics of well equipment that is visible through the glass doors.

When using glass doors on car park lifts consideration should be given to the location of the car park and the level of security and management provided to avoid any increased likelihood of vandalism that might occur, such as breakage of glass or attempted entry into the visible lift well.

5.5.2.3 Department stores

Observation lifts are occasionally used in larger department stores to provide a pleasing and leisurely environment. Their rated speed might be reduced to maximise the time passengers are exposed to product displays from within the lift car when viewed through the glass. This needs to be considered in terms of the reduced handling capacity achievable with slower lifts.

5.5.2.4 Entertainment centres, cinemas, theatres, sports centres, stadia and concert halls

Observation lifts are generally not suitable for this environment but they may be found in some exhibition centres over a low rise.

5.5.2.5 Hospitals

Observation lifts are not suitable for this environment.

5.5.2.6 Hotels

Observation lifts may be adopted in large top class hotels to create a spectacular feature in lofty atria. Their performance specification should be similar to that of an enclosed lift especially where the observation lifts form all or part of the primary vertical transportation.

5.5.2.7 Offices

Observation lifts can play an important part in prestige offices where they can provide a spectacular feature in lofty atria. They are also often installed on the perimeter of tall office buildings to provide users with panoramic views over a city or surrounding landscape. The performance specification for observation lifts should be similar to that of an enclosed lift especially where the observation lifts form all or part of the primary vertical transportation.

5.5.2.8 Railway stations

Observation lifts are not generally suitable for most railway stations. However, they have been incorporated in some modern terminus stations where they tend to be architecturally-driven bespoke units. In such cases the lifts are provided as a feature to satisfy the accessibility requirements of mobility impaired passengers, supplementing stairs and escalators which typically provide the main means of vertical circulation in station environments.

5.5.2.9 Residential buildings

Observation lifts are not generally suitable for residential environments since the increased costs associated with observation lifts will ultimately be borne by the residents by way of increased rental or purchase costs and service charges. This makes them difficult to justify from a commercial perspective.

5.5.2.10 Residential care homes and nursing homes

Observation lifts are not suitable for this environment.

5.5.2.11 Shopping centres

Observation lifts are frequently used in shopping centres to provide a pleasing focal point. Their rated speed might be low in order to provide a leisurely environment but their main purpose is to provide accessibility for mobility impaired passengers, supplementing stairs and escalators which would normally provide the primary means of transfer between floors.

5.5.2.12 Universities and other education buildings

Observation lifts offer potential benefits in an educational environment due to the increased visibility of the lift users reducing the likelihood of vandalism or general misuse of lifts that can occur in a student based environment. However, it is rare for such developments to have sufficient funding to support the increased costs of scenic lifts and they are generally not considered.

5.5.3 Car size and payload

Refer to section 5.2.3.

Although the BS ISO 4190-1 (BSI, 2010a) dimensions are still relevant they may not be apply strictly to observation lifts as the shape of the car platform may not be rectangular for aesthetic reasons. However, the rated load/available area requirements of BS EN 81-20 (BSI, 2014a) does apply. Generally the rated load of observation lifts ranges from 800 kg to 1600 kg.

The design of the controls, signals and aesthetics should comply with BS EN 81-70 (BSI, 2003a), which normally requires the car operating panel to be located in the side wall of the car to achieve a minimum distance of 400 mm from a corner to a push. This needs to be considered where glass side walls are proposed since the panel will need to be incorporated into the glass wall.

5.5.4 Entrances, car fittings and finishes

Refer to section 5.2.4.

It is most likely that centre opening doors will be fitted as part of the aesthetic scheme. The entrance width should be as wide as possible for the particular application and a width of 1100 mm is typical.

Door systems with the drive equipment located underneath the car are available and sometimes used on observation lifts to enhance the aesthetic appearance and avoid the need for the door motor and drive equipment on the lift car roof.

Special consideration is required when using glass on doors due to the higher friction level of glass that increases the risk of children's hands being dragged along and pinched between the door and adjacent trims or architraves. Protection can be provided by using coatings with a low coefficient of friction, reducing the running clearances between the doors and trims or by introducing mechanical or electrical sensors to detect the presence of hands or fingers. An alternative solution using a 'hi-tech' approach is 'active glass'. Active glass incorporates a crystal interlayer that becomes opaque when charged with an electrical current. In this way, the doors can be switched to opaque when a lift arrives or passes a floor removing the temptation of young children to lean against the glass to watch and also providing modesty screening. The method of protection selected will depend on the equipment supplied and should be discussed with the manufacturer.

Building Regulations in England and Wales require the use of visual manifestation on glass walls, doors and enclosures to aid passengers with visual impairments. Care needs to be taken when using glass to ensure that adequate contrast and visibility exists for such passengers. Low level manifestation should also be considered for glazed doors and walls to provide modesty screening for passengers.

All glass should incorporate markings indicating the name of the supplier, the type of glass and the trade mark. These should remain visible when the glass is installed.

The car interior fit-out is likely to be more elaborate than for a conventional passenger lift. However, it is important that handrails, of a sturdy appearance, are fitted all round the glazed area to provide assistance and reassurance to the passengers.

5.5.5 Types of drive and operating speeds

Refer to section 5.2.5.

The power system and drive chosen for any lift installation depends on the required speed, likely usage and desired comfort of ride. Observation lifts can utilise all the different types of drives and configurations appropriate to passenger lifts (see also chapter 7). However, observation lifts are often associated with prestigious installations and the quality of ride and levelling accuracy should be appropriate to the situation.

Modern traction lifts are almost exclusively specified with variable voltage variable frequency (VVVF) AC drives which

offer sophisticated control and high standards of levelling accuracy. Acceleration and deceleration are smooth and the fast approach to floors achievable with modern controls ensures the best possible ride quality with minimum flight times.

Modern hydraulic drive systems also offer smooth and comfortable ride conditions with accurate floor levelling along with the ability to incorporate a remote machine pump room. They are, however, incapable of the short flight times and duty achieved by electric traction drives and their travel is usually limited to a maximum of 18 m, (see section 7.3). Hydraulic drives with the jack installed in a borehole can make an attractive architectural feature where problems with hiding ropes and pulleys that are required on suspended lift cars are eliminated and the control equipment and pump unit can be located remote from the lift. However, the 'wall climbing' illusion is lost due to the visibility of the hydraulic jack under the car.

The available headroom, lift speed and required rise are important considerations when selecting the drive system. If there is sufficient headroom to accommodate a machine or pulley room above the lift and the rise is more than 20 m, electric traction drive would be appropriate since the required lift speed is dependent on the rise.

In situations where headroom is limited, hydraulic lifts are often more suitable although their speed and maximum rise are limited (see section 7.3). Electric traction drives using an underslung configuration (see section 7.15) or machine-room-less lifts offer alternative solutions without the limitations on speed and rise that apply with hydraulic lifts. With machine-room-less lifts, the drive and control equipment may be visible through glazed doors or front wall panels. In addition, suspension ropes that run up the side of the car in the underslung arrangements adopted on many machine-room-less lifts may be visible through glazed lift car panels unless solid sections are included to conceal these elements.

The use of machine-room-less lifts for observation lift applications may result in limited options for lift car design in terms of finishes and car dimensions. However machine-room-less product ranges are developing all the time and most manufacturers are now able to offer variable lift car dimensions and improved drive technology now offers the ability to accommodate the heavier car finishes presented with glass cars on observation lifts.

The speed of travel of an observation lift is very important to the comfort of the passengers. Low speeds suitable for short travel lifts will give a leisurely journey, which enables passengers to observe the view and instils a sense of safety, whilst still providing the required service levels. With higher rises, speeds need to be higher to maintain good service levels, but this can only be achieved at the expense of a leisurely journey. There is also the possibility that people may feel less secure at higher speeds as the lift passes walls or structural elements of the building at high speeds, which may create a stroboscopic effect.

Historically, it was considered that the speed of observation lifts should be limited to a maximum of 1.6 m/s in situations where there is a close focal point for the passengers. Modern observation lifts however, particularly in offices or other private buildings, commonly travel at speeds up to 2.5 m/s

and within Europe, there are partial observation lifts that travel at 6 m/s.

Where higher speeds are required, alternative enclosed lifts should be available for people who do not like to travel in high speed observation lifts.

5.5.6 Well

Refer to section 5.2.6.

Owing to the often irregular shape of observation lift cars the dimensional recommendations of BS ISO 4190-1 (BSI, 2010a) are largely irrelevant. As observation lifts are often installed with virtually no well structure it is important to prevent access to unauthorised persons. BS EN 81-20 (BSI, 2014a) requires screening to a height of 3.50 m on the entrance sides of a lift well. On the other sides, screens should be provided to a height of 2.50 m, where people would otherwise have access to the lift area. This dimension can be reduced progressively to a minimum of 1.10 m, where the distance to any moving part is greater than 2.0 m.

Any glass used for lift well enclosures within reach of persons must be laminated. All glass must also incorporate markings indicating the name of the supplier, the type of glass and the trade mark. These should remain visible when the glass is installed. Care also needs to be taken when using glass to ensure that adequate contrast and visibility exists so that all passengers can detect its presence. Manifestation at low levels or active glass (see section 5.5.4), should be considered for glazed doors or walls to provide modesty screening for passengers.

Since the essence of observation lifts is to provide a visually pleasing installation, it is essential that early discussions be held between the architect or designer and the lift manufacturers. These discussions should develop the original design concept, taking into account both the technical and visual limitations of the lift equipment required to provide the complete installation.

Consideration may be required to concealing switches in the lift well and to specially designed guide rail and switch support brackets. The use of roller guide shoes running on dry guide rails is recommended for all observation lifts. This will eliminate oil splatter onto glazed parts of the lift car or well and in the pit, which may occur if lubricated guide rails are used in conjunction with sliding shoes.

Due to the often unusual layout of the lift wells associated with observation lifts, the space requirements may quite differ to those of conventional lifts. The counterweight and travelling cables may be required to run in a screened-off area and the shape of the car may be irregular, requiring a large pit area that will need to be screened.

Despite this, safe and easy access for maintenance must be provided over the total height of the lift well and access to the exterior panels of the lift car is required for cleaning. Consideration of the cleaning regime is required at an early stage in the design process to ensure that safe access is available and can be accommodated within the architectural and structural design.

External observation lifts will be exposed to the elements and considerable care is required to ensure that extreme

temperatures will not affect the safety and reliability of the lift or the safety and comfort of passengers during its use. In the UK, where frosts and sub-zero temperatures occur regularly, the use of trace heating should be considered on exposed equipment and, in particular, the guide rails, safety gear, buffers and door equipment. For glazed cars exposed to direct sunlight, the potential for solar gain should be considered and air conditioning installed to provide cooling in the lift car. This is particularly important where a glazed lift car is located in a glazed well. There are few buildings around the world that rely on external observation lifts as the sole means of vertical transportation and where they do, development and engineering costs are very high. Such lifts require weatherproof landing entrances to prevent water ingress into the building and suitable protection of mechanical and electrical components that will be subject to extremes of temperatures and inevitably moisture through rain water or condensation.

5.5.7 Machine room

Refer to section 5.2.7.

The machine room should comply with BS EN 81-20 (BSI, 2014a). Its position, for an observation lift, may be constrained by aesthetic requirements. If space permits, for an electric traction lift the best position is above the well. An alternative is to use a bottom drive and place the machine room at the lowest level. This option however, presents problems in hiding or disguising the extra roping runs that will run up the lift well. Hydraulic lifts provide an easier option as their machine room can be remote from the lift well or even below it.

5.6 Service lifts

5.6.1 General

Service lifts, or 'dumb waiters' are designed for carrying goods only and are classified as non-accessible goods only lifts with their internal dimensions and designs arranged to prevent their use for carrying persons. Service lifts can be provided conforming to BS EN 81-3 (BSI, 2000), which contains many of the provisions of BS EN 81-20 (BSI, 2014a), and should ensure reliability and safety in operation.

5.6.2 Applications for service lifts

The main use of service lifts is to transport: books, documents, food and beverages, money, laundry, papers, post, retail stock, refuse, etc., so they are suited to applications in department stores, entertainment centres, cinemas, theatres, sports centres and concert halls, hospitals, hotels, offices, residential buildings, residential care homes and nursing homes, shopping centres, universities and other education buildings. Their principal area of use, however, is in kitchens and restaurants.

5.6.3 Car size and payloads

Most manufacturers offer a range of standard car sizes, normally in 100 mm increments, with limitations on the

maximum dimensions imposed by BS EN 81-3 (BSI, 2000) as follows:

- maximum floor area: 1.0 m²
- maximum car depth: 1.0 m
- maximum height: 1.2 m

The maximum height may be more, subject to the use of a permanently fixed shelf that restricts the height of each compartment to less than 1.2 m.

Unlike the rating of passenger lifts under BS EN 81-20 (BSI, 2014a), the rated load is not based on the available floor area and instead is limited to a maximum of 300 kg by BS EN 81-3.

Within these limitations, the lift car dimensions should be appropriate for the size of the goods to be carried. Any containers to be used should be taken into account since these could affect the rated load.

5.6.4 Entrances, car fittings and finishes

When deciding on the size of the car and its entrance, it is important to take into account the need for clear access for loading and unloading. The size of packaging and transportation containers should be considered as well as handling clearances.

On cars with adjacent (i.e. front and side) entrances, the maximum width of one or both entrances may be limited by the proximity of the doors to each other and careful coordination is necessary during the design. When selecting such cars it is imperative to ensure that items loaded through the front entrance can be unloaded from the side entrance.

Car doors are recommended where there is a risk of goods being transported coming into contact with the well walls. Where car doors are not provided, it may be necessary to include means of immobilising any loads that may be prone to movement during the lift journey.

With a through car arrangement, car doors should be provided or if not, mechanical protection is required to prevent entanglement of goods with the lift well or landing door equipment during travel.

Where car entrance protection is provided, the clear entrance width may be less than the full width of the lift car and this should be taken into account to ensure easy loading and unloading of the car.

Floor level or counter-height entrances can be provided for loading and unloading service lifts, depending on the nature of the items being transported. Entrance doors or gates may be either manual or power-operated.

Manual vertical operating shutters (bi-parting or 'rise and fall') are normally fitted at serving height on landings and may also be fitted to the car. Hinged doors for landings are sometimes provided at floor level as an alternative.

Open collapsible gates or roller shutters may be provided for car entrance protection. A drop-bar (barrier) or similar protection for cars is also available to ensure that goods are

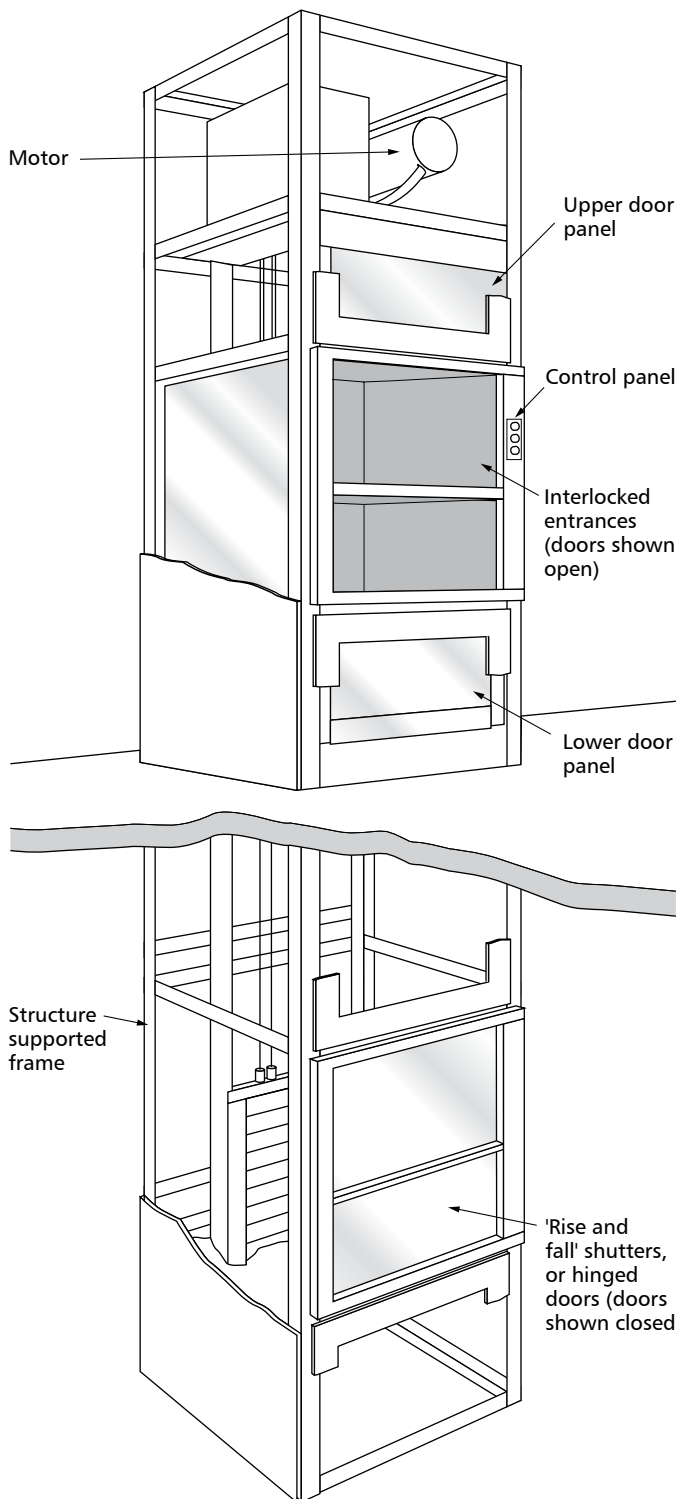


Figure 5.7 Cutaway section of a typical service lift serving two levels

restrained during travel, but these methods are suitable only for service lifts that carry bulky items or containers.

Power-operated vertical shutters or automatic closing hinged doors may be provided. Full power operation for hinged doors can be provided but this is expensive and normally a self-closing mechanism is adequate.

Automatic loading and unloading systems are available that employ a power-operated roller conveyor in the car with a non-powered roller conveyor on the landings. For carrying items such as documents, the car may be fitted with tilting trays and collection boxes at each landing. In

both cases power-operated entrances are required on the car and landing.

Side runners can be provided within the car to support serving trays etc. These remain permanently in place, and would need to be specified to suit a given size of tray. Alternatively, removable frame systems, custom made to requirements, can be provided.

For transporting food, heating panels can be fitted within the car. In this application, solid protection for car entrances is required and it is also advisable to specify stainless steel finishes with smooth edges and corners within the car to enable easy cleaning.

5.6.5 Types of drive and operating speeds

Service lifts normally employ electric motor drive, using either a drum, sprocket or counterweight arrangement. The ideal position for the drive is directly above the well and since the machines are relatively small they can often be accommodated at the top of the well within the room height of the top floor served to avoid the need for more costly locations to the bottom or side of the well.

Rated speeds are usually between 0.2 and 0.5 m/s but may be as high as 1.0 m/s, if required to suit longer travel distances, or for special operational requirements.

5.6.6 Well

Most service lifts are supplied with their own structural frames to minimise builder's work. The lift and the frame are normally to the manufacturer's standard details and therefore well sizes for service lifts are similar and initial spatial planning can be based on the following guidance.

- well width: car width plus 500 mm
- well depth: car depth plus 300 mm.

The actual sizes will need to be confirmed by the lift supplier who will take into account the lift arrangement, entrance details and any necessary space required for the enclosure.

The height of the soffit of the well (i.e. to the underside of the pulley or machine room floor) from the floor level of the highest floor served should be the height of the serving hatch plus the car height plus an allowance up to 1000 mm.

Where access to all serviceable parts is not possible from the landings, the lift must be designed to accommodate service personnel in the well with a clear height of 1800 mm above the top of the car at the top floor served. This is likely to cause the enclosure to penetrate the ceiling above the top floor served and should be avoided if possible.

For floor level service, a pit depth from 150 mm to 1000 mm is required, depending on the car design and landing door configuration. A pit is also required if the height of the serving hatch is such that there is insufficient height below the hatch to accommodate vertically sliding landing shutters.

Where the pit is accessible for servicing, or maintenance, a minimum clear height of 1.8 m must be created in the well for maintenance access by using a prop that is stored in the lift well and can be deployed under the car when access is required.

5.6.7 Machine room

For service lifts with a machine room above, a minimum height of 600 mm is required for the machine room. The plan dimensions should be the same as the lift well. In some instances a separate area will be required to accommodate a control panel if this cannot be accommodated within the machine room itself.

For service lifts with a machine room adjacent or below the well, a pulley room is required above the well which should have the same plan area as the well and a height of between 200 mm and 500 mm.

The machine room can be directly below the serving height of the lowest floor, positioned to either side of the well or within the well.

Items of equipment will need to be moved into and out of the machine room for installation, replacement and repair. A minimum access opening of 600 mm by 600 mm is normally recommended, but the final size depends on the equipment contained in the machine room. The access to the machine area must remain clear of ducting, piping, ceiling panels etc.

5.7 Motor vehicle lifts

5.7.1 General

There is currently no specific standard for vehicle lifts but where passengers are to be transported with the vehicle, they need to be designed to BS EN 81-20 (BSI, 2014a). Vehicle lifts will, of necessity, have to provide a relatively large platform. The rated load for a given area is given in

Table 6 of BS EN 81-20 for electric traction lifts and Table 7 of BS EN 81-20 for hydraulic goods passenger lifts.

Where vehicles only are transported, the lift can be provided under the Machinery Directive (EC, 2006), enacted as the Supply of Machinery (Safety) Regulations 2008 (TSO, 2008) (as amended (TSO, 2011)), which allows a more realistic loading requirement to be provided. If vehicles and any persons are to be transported, a Machinery Directive lift can still be installed provided its rated speed is less than 0.15 m/s and it is operated by 'hold to run' controls. Provision of vehicle lifts under the Machinery Directive may only be made after a risk assessment has been carried out to determine the maximum loading.

Special indication and features for operation are required for motor vehicle lifts, as detailed below. Figure 5.8 illustrates the features of a vehicle lift

5.7.2 Applications for motor vehicle lifts

The most common application for motor vehicle lifts is to gain access to restricted garage parking associated with commercial, office, institutional, residential, and theatrical/entertainment premises. When considering this type of lift, it is important to allow adequate space for turning from the road and for manoeuvring within the garage area. Provision should be made for the removal of fumes from the lift car and lift well, in addition to their removal from the garage area itself.

5.7.3 Car sizes and payloads

Unless small vehicles only are to be carried, the lift car dimensions should be adequate to accommodate the largest standard production models, to allow for driver errors in alignment and to provide room to allow the driver to leave their vehicle in an emergency.

Special consideration may be required if there is a possibility of accommodating 'stretch' limousines and modern off-

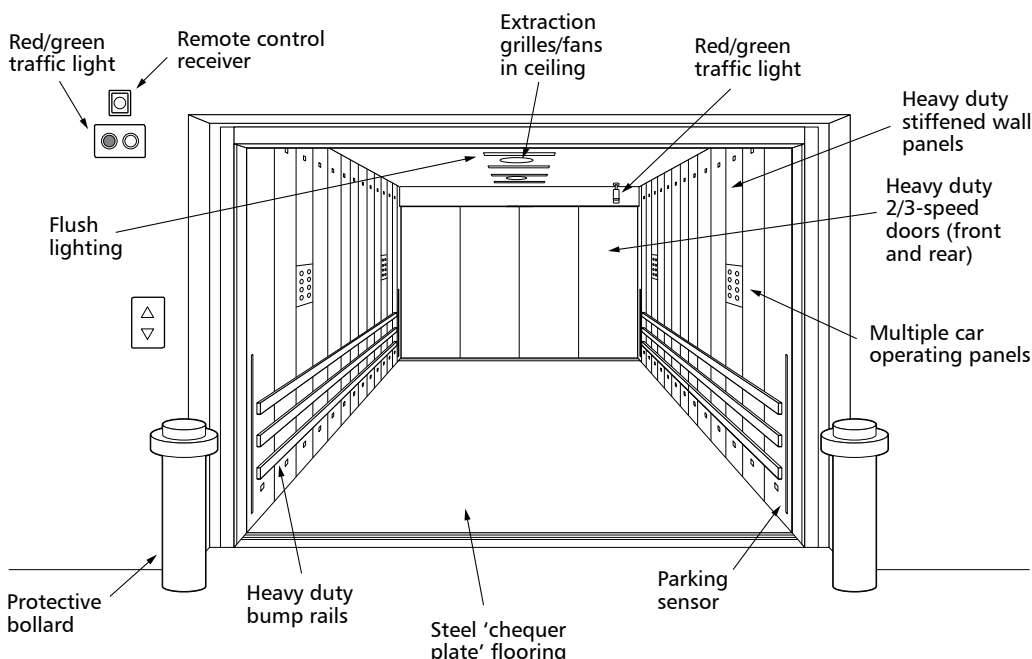


Figure 5.8 Features of a vehicle lift

road vehicles, or vans, which may require additional length or height for the lift car and doors.

The recommended internal dimensions are:

- *width*: motor vehicle width plus 750 mm (375 mm clearance on each side)
- *depth*: motor vehicle length plus 500 mm (250 mm clearance at each end)

A lift car height of 2100 mm is satisfactory for most production vehicles, but an increased height should be allowed if the lift is required to carry vehicles fitted with roof racks, commercial vans, lorries or vehicles arranged to carry roof mounted wheelchairs or similar accessibility equipment. The lift car height should be at least as high as the lowest point on the route to the lift so that if it is possible to drive up to the lift it is also possible to use it. In any case, clear signage advising the minimum height restriction in the lift car should be provided on the landing outside each lift entrance.

The rated load of any lift designed to carry passengers within the car should be in accordance with the relevant BS EN 81 standard.

5.7.4 Entrances, car fittings and finishes

The entrance does not need to be the full width of the lift car, but should be large enough for easy access including sufficient clearance for wing mirrors and roof racks etc. Entrances, particularly in basement areas, will usually require fire rating and it is important to advise the lift supplier accordingly.

Many vehicle lifts will have access from street level with an entrance exposed to external elements. In such cases, consideration should be given to weather-proofing the equipment, including control stations and doors. Lift sills at exposed entrances should be raised a minimum of 25 mm above floor level with a short ramped section to prevent rainwater from entering the lift well.

Consideration should also be given to providing mechanical protection to landing entrances by using bollards to avoid accidental impact damage from vehicles.

Folding leaf shutter gates are not recommended for vehicle lifts as they require the driver to leave the vehicle in order to open and shut the gate.

Older vehicle lifts often adopted vertical bi-parting door systems which take up little plan well space and are very heavy duty, making them particularly suitable for garage environments. However whilst they are still available, they are expensive compared to horizontal bi-parting lift doors and they also have to be operated by continuous pressure control buttons which can prove difficult for passengers using controls from within a vehicle. This type of door is now generally only used in heavy duty applications where conventional lift doors might be considered inappropriate. Where they are used, they require vertical clearance for the rise and fall door panels at the top and bottom entrances that can impact on the required pit and headroom dimensions.

Conventional power operated lift doors with four, or even six panel, horizontal sliding, centre-opening doors provide a reliable and relatively inexpensive system. These doors often require well space beyond the platform width to accommodate the open doors.

Where automatic power-operated entrances are used, it is important to provide additional door closing protection to both the landing and the car entrances to ensure the doors cannot close on a vehicle. This protection should take the form of a light beam or series of beams in the landing architrave and lift car side wall (or the entrance front return where fitted). The beams can be connected to a traffic signal type system to indicate to the driver when the car is positioned correctly, similar to those fitted in many automatic car wash systems.

Control stations should be positioned within easy reach of a passenger sitting in a vehicle and a series of push button stations might be considered on both sides of the lift car to permit operation from within the vehicle.

Consideration should be given to providing mechanical protection to the entrances, car floor and walls. Refer to section 5.3.4 for guidance.

5.7.5 Types of drive and operating speeds

Vehicle lifts tend to be required over low rises of perhaps three or four floors with a travel of around 10 m. Twin-ram hydraulic systems, with speeds in the range 0.2 to 0.3 m/s, remain a good choice for this type of application. The emergence of MRL vehicle lifts offers an alternative solution with potential benefits in terms of energy efficiency and space savings due to the lack of a separate hydraulic pump room. Hydraulic lifts using a direct-acting central piston provide an economic solution where ground works permit the required borehole. However, the cost savings resulting from the simpler system will be offset by the additional costs of providing the borehole. The costs associated with the need for future inspection of a borehole mounted jack should also not be overlooked. Hydraulic lifts also tend to require lower headroom with requirements of between 3.50 m and 4.0 m being typical. The equivalent MRL vehicle lifts currently require in excess of 4.5 m.

For higher travels, in excess of 12 m, either traditional or MRL electric traction drives with speeds up to 0.5 m/s become more attractive in providing faster flight times and better duty cycles. For traditional traction lifts, the ideal drive position is directly above the lift well, however in view of the high payloads it is common to use roping factors up to 4:1 to reduce the load on the drive machine. In the past, floor levelling was an important consideration but, with modern control systems, floor levelling to an accuracy of ± 6 mm would be expected and is easy to achieve.

Twin mast rack and pinion lifts can also be used with the same benefits indicated in section 5.8 and at speeds up to 0.3 m/s.

5.7.6 Well

In the absence of specific guidance in any published standards, the dimensions in Table 5.2 are offered as

guidance for initial space planning purposes, based on lift cars with front and rear entrances, for both hydraulic and electric traction motor vehicle lifts.

Table 5.2 Well sizes for vehicle lifts

Door type	Well width (mm)	Well depth (mm)
Manual folding leaf	Lift car width plus 900 mm	Lift car depth plus 600 mm
Power operated vertical	Lift car width plus 900 mm	Lift car depth plus 500 mm
Power operated horizontal, centre opening (including bunched car doors)	Lift car width plus greater of either 900 mm or 1.5 × clear door opening width	Lift car depth plus 800 mm

Note: electric traction lifts with bottom drive and without a pulley room require the well widths to be increased by 500 mm

All dimensions should be checked with the lift installer before construction commences to avoid costly remedial works.

For initial planning of electric traction and hydraulic lifts, the headroom for a lift car 2100 mm high should be based on 4200 mm from the top floor served to the underside of the lift well roof slab. The headroom will increase by 100 mm for each additional 100 mm of car height. For rack and pinion lifts the requirements will depend upon the location of the drive motors and should be checked with the lift manufacturer.

For electric traction and hydraulic lifts with horizontal sliding doors, the typical minimum pit depth required is 1800 mm. If vertical bi-parting doors are required, the pit depth will depend upon the configuration of the doors and should be checked with the lift manufacturer. For rack and pinion lifts the requirements will depend upon the location of the drive motors and should be checked with the lift manufacturer.

5.7.7 Machine room

The machine room requirements will be the same as those for goods lifts and are given in section 5.3

5.8 Rack and pinion lifts

5.8.1 General

The basic components of a rack and pinion drive are a continuous length of machine-cut toothed bar (rack) and a pinion (or pinions) held in permanent mesh with the rack, mounted on a mast or masts, see Figure 5.9. Due to the ease of erection of the mast from the car roof (a practice developed over many years of experience with construction hoists) there is no need for a scaffold to be erected in the well during installation of the lift.

Rack and pinion lifts normally have the drive equipment mounted on the lift car providing virtually unlimited travel with minimal loading on the building fabric. Travel

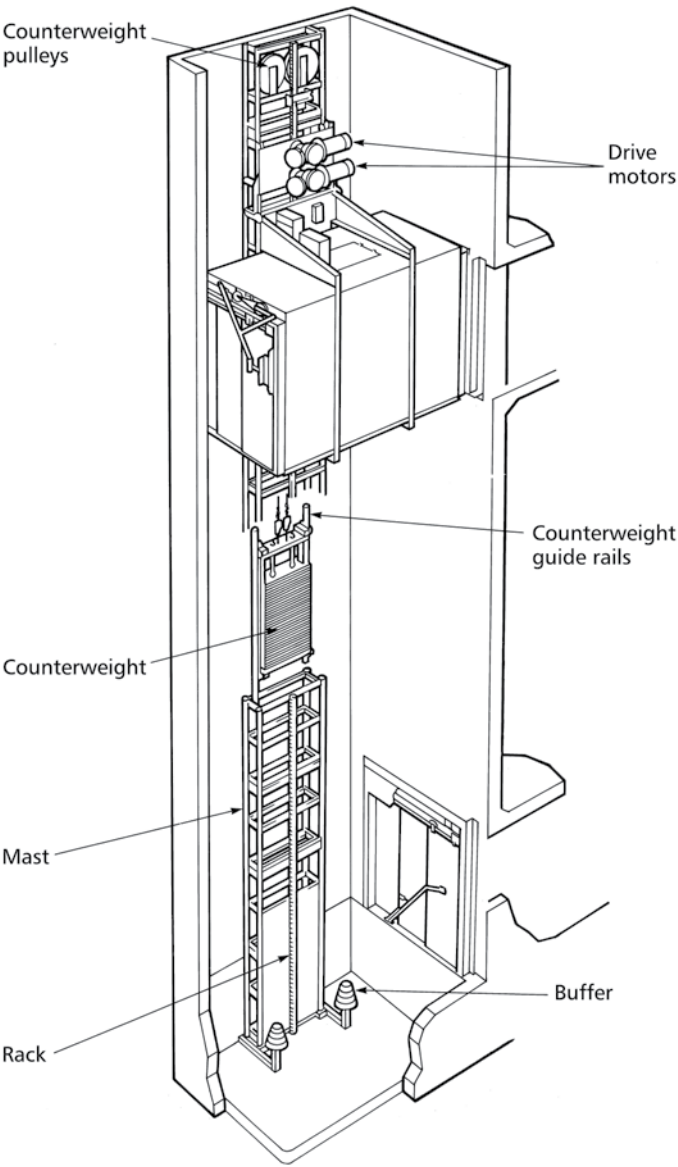


Figure 5.9 General arrangement of rack and pinion lift

distances are largely unlimited: the tallest known installation above ground at the time of publication is 640 m, although rack and pinions lifts have been installed to a depth of 1000 m in underground mining applications.

Provisional European Standard prEN 81-7 (CEN, 2009) prescribes the minimum safety standards for permanently installed rack and pinion lifts. EN 81 passenger carrying rack and pinion lifts are required to meet similar levels of safety to electric traction and hydraulic passenger lifts and floor call systems, alarms, telephones, car-top control and landing levelling accuracy are all required by the safety code.

5.8.2 Applications for rack and pinion lifts

The main applications for permanently installed rack and pinion lifts are in factories, warehouses and retail buildings where goods, heavy duty goods and heavy vehicle lifts are required. Rack and pinion lifts are particularly suited to situations where the lift is installed without a well such as lifts on the exterior of a building. There is no requirement for the erection of accurately plumbed and parallel guide rails and the speed of installation and the possibility for

external application makes rack and pinion lifts particularly suitable for temporary lifting facilities, e.g. in residential buildings where an existing lift is being repaired or modernised.

Rack and pinion drive has been widely applied to the vertical transportation of passengers and goods in the construction and mining industries since about 1960. The ease of initial erection and subsequent extension as building work progresses allowed the rack and pinion lift to replace the rope hoist for passenger transportation on building sites around the world. The height of travel can be increased easily by adding prefabricated sections of rack to allow the lift to access additional floors of a building during construction.

Rack and pinion lifts can also be relocated relatively easily and quickly making them ideal for industrial environments such as factories where plant and equipment may be reconfigured and a lift may need to be moved.

The use of rack and pinion drive with a pre-formed rack provides the opportunity for the lift car to follow a non-linear path whilst being retained in a vertical position. This makes them particularly suitable for high chimneys and offshore platforms where the structures do not always lend themselves to lifts that are mounted vertically in a straight run.

Rack and pinion drives are being used increasingly for heavy duty applications. They can be used with a single mast supporting a cantilevered car on lifts with a capacity up to 2000 kg, or with a double mast for larger installations. The single mast arrangement imposes a horizontal load to the supporting wall, which should be considered during the building design. Twin mast arrangements transfer the loading to the pit floor thus minimising any horizontal loading on the structure.



Warning: where a rack and pinion lift solution is being considered, it must be noted that they generate much higher noise and vibration levels than conventional electric traction or hydraulic lifts. This should be brought to the attention of the purchaser or building owner to ensure that it will be acceptable.

Rack and pinion drives may be used for funicular railways and inclined lifts (see section 5.9.8), where the directional flexibility is again important.

In addition to the general applications already mentioned, special applications suited to the use of rack and pinion lifts include:

- TV and radio masts
- chimneys
- cranes
- grain silos
- offshore exploration/production platforms.

5.8.3 Car size and payload

Unlike conventional electric traction lifts, rack and pinion lifts have not evolved into mass produced, standardised products and can therefore generally be supplied to bespoke dimensions to satisfy the specific requirements of a project.

The load rating of the lift is dependent upon the available car area as defined in BS EN 81-20 (BSI, 2014a). The range of rated loads and car sizes are as given in BS ISO 4190-1 (BSI, 2010a) or BS ISO 4190-2 (BSI, 2001).

Smaller cars, for loads down to 200 kg, are available for special applications such as warehouses or tower cranes where they can be located within the tower section of the crane to provide access for crane drivers to cabins at high level.

The car is fitted into the sling similarly to electric traction or hydraulic lifts and can be cantilevered from a single guide mast, allowing applications where building support can be offered from one side of the lift only, as with some types of observation lift and installations without a well. For applications with a rated load in excess of 2000 kg a twin mast arrangement should be considered, which eliminates the high loading imposed on the building support in cantilevered applications.

5.8.4 Entrances, car fittings and finishes

Car doors, landing doors, well and pit clearance dimensions are all required in accordance with the relevant parts of BS EN 81-20 (BSI, 2014a). Doors may be manual or power-operated however, due to the potential deflection of masts, particularly on single mast installations, special attention is required to ensure that automatic doors will operate reliably and provide correct alignment of the car and landing doors under all operating conditions. It is possible to incorporate automatically driven landing doors with no mechanical linkage to car doors to eliminate this problem.

5.8.5 Types of drive and operating speeds

The operation of a rack and pinion drive requires a pinion or pinions to be held in permanent mesh with the rack, see Figure 5.10. The pinions are driven by individual motors (usually electric but may be hydraulic, petrol or diesel) through reduction gearing. In order to simplify the range of components and to maintain constant motor and pinion sizes, high payload requirements are often met by using one, two or three drive units, each unit having an identical motor, gear box and pinion. The drive units are usually mounted on the lift frame, above the car.

The mechanical nature of rack and pinion drive provides the ability to maintain floor level position during loading and unloading of heavy loads, without the need for locking devices such as safety pawls, making it particularly suited to heavy goods lifts applications.

The speed of rack and pinion lifts whilst available up to 1.5 m/s is generally considered to be more acceptable at less than 0.5 m/s due to the excessive noise generated by high speed units. Speeds above 0.5 m/s tend to be used on

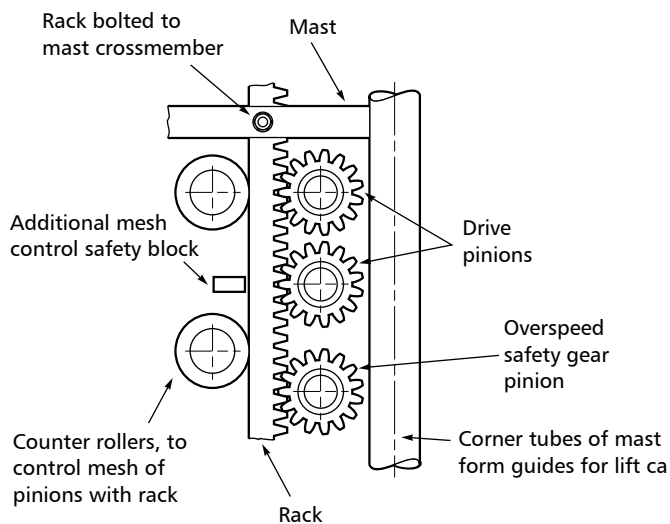


Figure 5.10 Detail of rack and pinion mechanism

building site hoists where fast journey times are important to the efficient operation of the site and passenger comfort is not a priority. If noise is considered a nuisance then rack and pinion lifts should only be considered at speeds up to 0.3 m/s with a reduced module size. Noise levels can also be reduced by employing lower speeds and by reducing the module size which provides a finer mesh pitch between the rack and the pinions but are unlikely ever to match those of electric traction or hydraulic lifts.



Warning: the noise and vibration levels generated by the mechanical meshing of the pinion with the rack and by the motors mounted directly onto the lift car frame can prove intrusive and should be considered during the design stages to ensure that they will not become a nuisance to building owners or occupiers.

5.8.6 Runway

A rack and pinion lift does not run in a conventional well, but up a mast, or masts. The rack is bolted to a rigid mast section, the rack and the mast typically being produced in standard 1.5 m lengths. These are bolted together to give the required lifting height. The mast forms the guide rails and also provides the structural support for the complete lift. The mast sections may be preformed so that the lift can follow a varying radius of curvature, as may be required on offshore platform support legs and cooling towers, etc, whilst the car is restrained to remain vertical. The corner tubes of the mast are enclosed by the guide rollers and the car is thus cantilevered from the mast and restrained to follow the path set by the mast. At various intervals, generally between 3 m and 12 m, the mast is laterally restrained by ties to the building. These ties can be adjusted to accommodate discrepancies in building verticality.

The single mast arrangement imposes a horizontal load to the supporting wall similar to that of hydraulic lifts and again these loads must be considered during building design. Twin mast arrangements may be adopted to eliminate the cantilever loads or for larger lifts. The twin mast arrangement transfers the vertical loading to the pit floor greatly reducing any horizontal loading on the structure.

The safety gear will normally be of the type used on construction hoists since the 1960s, which requires drop tests to prove the safety gear under loaded and mobile conditions. The systems are designed to enable quick and easy proving of the safety gear, without damage to components, and they are typically tested at each of the 6-monthly thorough examinations required by the Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) (TSO, 1998) for passenger carrying lifts.

The overspeed safety gear is normally mounted on the car sling and acts directly between the car and rack giving immediate response to an overspeed condition. There is neither a governor rope nor any well-mounted equipment. The overspeed governor and arrester gear are usually contained within a sealed enclosure and act as a single system. The overspeed governor is directly driven at car speed by a steel pinion in permanent mesh with the mast rack. The arrester gear applies braking torque to the same pinion and brings the lift to a halt with all the arresting forces being absorbed through the rack. Braking is very progressive and typical braking distances are about 1 m from the point of tripping.

The brakes themselves are of a centrifugal design and, once activated, facilities can be provided to enable the brake to be released manually from within the car to provide a means of self rescue. This might be used on industrial applications such as chimneys, masts or cranes etc where it is otherwise not possible to access the lift car from an alternative external location. Means of self rescue should only be provided where they can be deployed by trained operatives and as such they should not be provided on lifts used by the public or other untrained users.



Warning: if rack and pinion drives are used to operate passenger carrying lifts at speeds above 0.15 m/s they are classified as lifts under the Lifts Directive and must comply in all respects to the regulations, including the use of type tested components such as safety gears and door locks.

Rack and pinion lifts are usually installed without a counterweight. However, counterweight units are used for heavy capacity applications, the weights being guided within the mast with all vertical forces being transmitted directly to the foundation. The pulleys associated with the counterweight are mounted in the top mast section.

5.8.7 Machinery location

There is no requirement for a large machine or pump room and a well is not required to support the vertical loads and forces associated with a rack and pinion lift. All vertical loads from the lift are transferred via the rack to the mast and the drive motors and gearboxes are mounted directly onto the lift car frame. This greatly reduces the need for machinery space and often a small room capable of accommodating the main switchgear, distribution board and the controller cabinet is all that is required. In some cases, it is possible to mount the control cabinet behind an access panel on the lift car producing a machine-room-less installation. However, maintenance access and emergency rescue procedures need to be planned carefully in such cases.

5.9 Lifts for other purposes

5.9.1 Firefighting lifts

Firefighting lifts are described in detail in section 6.3.

5.9.2 Evacuation lifts

Evacuation lifts are described in detail in section 6.5.

5.9.3 Passenger lifts for use by persons with disabilities

Transportation systems for people with disabilities are covered in detail in chapter 11, with conventional passenger lifts detailed in section 11.7.2.

5.9.4 Lifting platforms for use by persons with disabilities

Transportation systems for people with disabilities are covered in detail in chapter 11, with lifting platforms covered in sections 11.7.3 and 11.7.4.

5.9.5 Stairlifts for use by persons with disabilities

Transportation systems for people with disabilities is covered in detail in chapter 11, and section 11.7.5 details the recommendations and requirements for stairlifts.

5.9.6 Explosion protected lifts

For many decades, specialist lift manufacturers have produced a small quantity of explosion protected lifts specifically for use in hazardous areas where there is a high risk of explosion that could be triggered by loose sparks or excessive heat. The number of such lifts is controlled by the limited demand compared with the numbers of lifts in non-hazardous areas. The volume of related paperwork, the demanding quality controls and the variety of administrative demands imposed by authorities, result in very few companies being willing to become involved in this market. The manufacturer would need to employ flexible production schedules in order to accommodate an explosion protected unit, therefore suppliers of batch produced or 'packaged' lifts usually cannot contend with such specialist demands.

When a specification is being prepared for an explosion protected lift, the first consideration is whether the lift can be located, where no explosion hazard exists. If an alternative location would involve an increase in cost, this may well be offset by the higher cost of an explosion protected lift. There is usually a cost ratio of more than three to one between conventional and explosion protected lifts of otherwise similar performance, owing to the more expensive equipment required such as motors, switches, enclosures for controls, choice of materials and, above all, the cost of the preparation and collation of supporting documentation.

Explosion protected (Ex) lifts fall under the ATEX Directive (EC, 1994), the explosion protected type of electrical apparatus (EEx) to BS EN 60079-0 (2013) and BS EN 81-20 (BSI, 2014a). These requirements are very stringent and owing to the specialised nature of this type of lift a detailed discussion is not appropriate here.

5.9.7 Goods scissor lifts

5.9.7.1 General

Goods scissor lifts provide a simple, robust and low-cost means of lifting loads through short distances. While geometrically inefficient, the lifting mechanism is all contained within the dimensions of the base frame thereby providing a very compact lifting device.

Lifting capacities range from a few kilograms to tens of thousands of kilograms and most scissor lifts are bespoke designs manufactured to suit the particular requirements of the specifier. A typical scissor lift is shown in Figure 5.11.

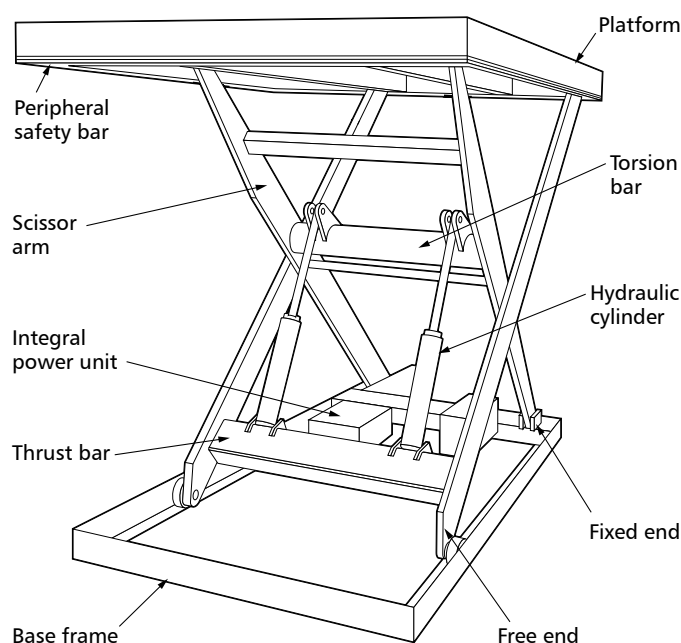


Figure 5.11 Typical scissor lift

5.9.7.2 Application

Scissor lifts for goods applications are manufactured in accordance with BS EN 1570-1 (BSI, 2011d). Static or mobile types are available and typical applications include:

- lorry loading/unloading (dock levellers)
- feeding materials to machines
- transferring of materials/equipment.

When positioning scissor lifts, consideration should be given to the configuration of the lift to ensure stability. Scissor lifts are most stable when they are loaded over the platform and the load being applied is parallel to the plane of the scissor legs.

Safety of the load on the platform can be ensured by handrails, interlocking platform and landing gates, wheel stops, loading flaps, or some combination of these or similar restraining devices.

All scissor lifts have a closed height and this may obstruct access onto the lift platform or cause an obstruction. In such cases a pit will be necessary, the depth being determined by the closed height of the scissor lift. External pits should be provided with suitable drainage.

Most scissor lifts will have a safety trip-bar, mounted around the perimeter of the underside of the platform to arrest downward travel in the case of an obstruction. Consideration should be given to guarding the underside of the scissor lift to prevent the trapping of people and objects. In certain locations, e.g. a loading bay, barrier protection must be provided to prevent unsafe access. BS EN 1570-1 gives recommendations on guarding requirements.

5.9.7.3 Platform size and payloads

The load rating depends upon manufacture, but can be as high as 30 000 kg for lorry lifting applications.

The platform length is dependent upon the vertical travel dimension because the scissor arms are accommodated beneath the platform when in the closed position. For this reason, longer travel units generally require a larger platform or a multiple scissor mechanism resulting in a deeper pit. For longer rises, consideration should be given to providing vertical guides to maintain stability of the platform when extended.

5.9.7.4 Type of drive and operating speeds

The power system usually consists of an electric pump, hydraulic fluid reservoir and control unit but some units may use a screw drive. The drive system is most frequently accommodated beneath the platform, but occasionally, the control panel may need to be remote from the machine. Controls can be fixed or hand-held. The maximum voltage for fixed controls is 240 volts and 110 volts for hand-held controls. The use of electronic valves is not common and therefore the starting and stopping of scissor lifts tends to be abrupt under the control of a simple solenoid valve.

Speeds are generally slower than other types of lift up to around 0.05 m/s (50 mm/s).

5.9.8 Inclined lifts

5.9.8.1 General

Inclined lifts have for many years been installed in coastal locations worldwide to provide access to hill-side apartments, hotels, beaches, churches, etc. Older types of so-called 'inclined lifts', such as the cliff lifts at Bournemouth in England, or the lifts of Valparaise in Chile (built 1883–1915) are considered as funicular railways and generally fall under tram codes and design specifications. These installations have often been modernised using lift equipment, but are still regarded as funiculars.

Inclined lifts are defined as permanently installed electric lifts, with traction (counterweighted) or positive drive, serving defined landings, with a vehicle designed to convey passengers, or passengers and loads, pulled by ropes, or chains, along guide rails on an inclined path at an angle between 15° and 75° to the vertical, without limitation of

the travel. By contrast, conventional lifts move on guide rails inclined up to 15° from the vertical.

Modern inclined lifts adopt many of the same components that are used in conventional vertical lifts and should be designed, installed and operated according to BS EN 81-20 (BSI, 2014a) supported by the requirements of the proposed BS EN 81-22 (BSI, 2014e) to deal with the wide range of inclinations possible.

5.9.8.2 Application

Many modern applications for inclined lifts still occur where access is provided to buildings up a cliff face or other naturally inclined aspects. There are however architectural based solutions like the lifts in The Luxor Hotel in Las Vegas and Urbis in Manchester (UK) that follow an inclined travel path within the building.

Inclined lifts have the ability to solve the accessibility problems of older underground railway stations and have been installed in some applications adjacent to escalators or stairs to provide access for wheelchair users or passengers unable to use escalators. In such schemes, the lift should be arranged to run at a slower speed than the escalators so as to discourage able-bodied people from using it.

5.9.8.3 Car sizes and payload

Car sizes and payload are based on BS EN 81-20 requirements linking the available area to the rated load. The limitations of size and rated load will be essentially the same as that for conventional lifts and inclined lifts should be sized to accommodate the likely peak passenger volumes up to a practical limit of 100 persons.

5.9.8.4 Type of drive and operating speed

Using conventional lift machinery with geared or gearless drives and VVVF control allows the lift car mounted on wheels or rollers to be driven along tracks or tee guide rails using tension ropes on pulleys.

The introduction of the vector control system has made inclined lifts a viable lift system where smooth acceleration, deceleration and stopping can easily be achieved and limit the horizontal forces imposed on passengers. Inclined lifts can operate over a fixed or variable slope or angle and at speeds up to 4.0 m/s, though it is recommended that 2.5 m/s be considered a practical limit due to the slow acceleration and deceleration rates that need to be adopted.

Parameters such as acceleration and deceleration values, especially for emergency braking, need to be taken into account. Excessive horizontal acceleration or deceleration arising from the inclined movement of the lift will introduce a risk of passengers falling.

5.9.8.5 Travel path/runway

Being used to access remote buildings on cliffs, many inclined lifts are external and have no lift well so like rack and pinion lifts they would be considered to be within a runway. Care should be taken in such instances to ensure that the runway is not accessible to people and if necessary,

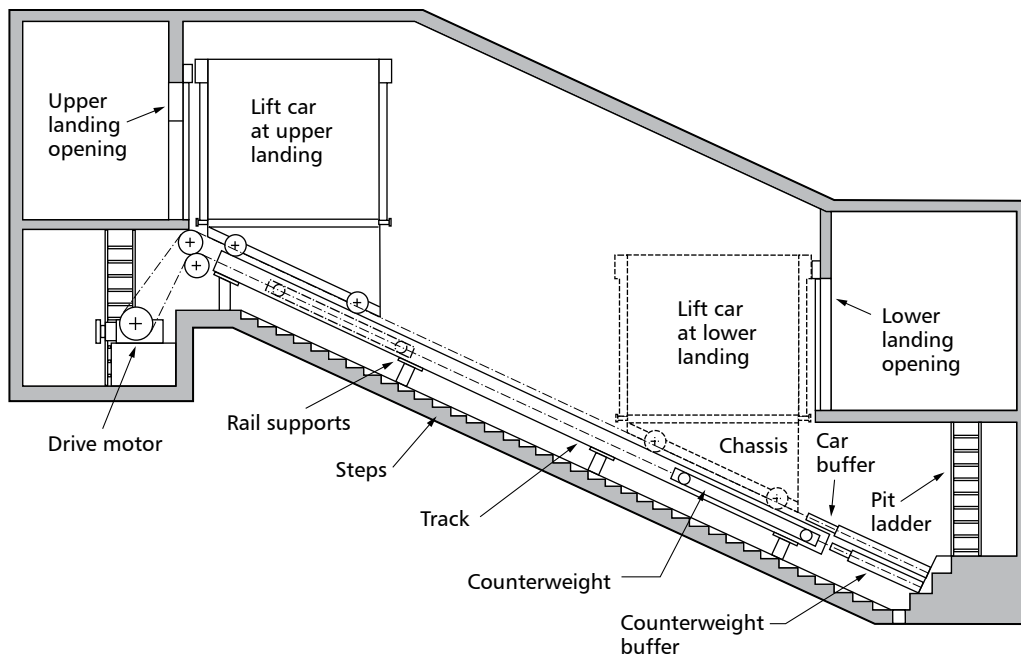


Figure 5.12 Schematic of a typical inclined lift with counterweight

guarding and fencing should be installed to create a safe environment.

For internal applications, a well will typically be formed by a full enclosure. Specialist advice should be sought to establish the structural requirements of such a well.

5.9.8.6 Machine room

The configuration of the machine room will be dependent on a number of factors, notably the incline and the availability of suitable space. Specialist advice should be obtained to suit a particular application.

Figure 5.12 shows a typical inclined lift, with a counterweight.

5.10 Future concepts

The introduction of the safety elevator back in 1857 allowed buildings to become taller and taller and the development of lift control and drive technology in the prevailing 150 years has provided the ability to lift the super-tall buildings of the modern era.

Developments in controls and drive technology have kept pace with technological advances in electronics and motor design, however the basic principle of electric traction lifts that service modern buildings remains largely unchanged from the earliest traction lifts.

Until only recently, the traction system was reliant on the use of steel ropes which limits the vertical travel distance for a lift to around 500 m, meaning modern lifts do not have the ability to travel the full height of some of the tallest buildings in the world.

For this reason, the tallest buildings rely on multiple lifts for passengers to reach the top and the industry continues to develop solutions to better service taller buildings.

The recent development of a carbon fibre cored suspension medium, which is lighter and stronger than steel, allows traction lifts to travel up to 1000 m. However, having the ability to travel such distances in a single lift does not solve all the issues with lifting super-tall buildings.

A lift travelling 1000 m at 17 m/s, which is the same speed as the fastest lifts currently in service, will take a full minute to travel to the top. The atmospheric pressure increase when travelling down such distances means that passengers can suffer ear discomfort, so the downward speed is typically reduced meaning and the down journey times would be significantly longer than 1 minute.

So for conventional traction lifts to take full advantage of the advances in suspension materials for passenger applications, these physiological issues will need to be addressed. It remains possible that the 500 m limit imposed by steel ropes may continue to be necessary for physiological and lift performance reasons with the use of zoned lifts required to provide acceptable journey times. Goods lifts and specialist lifts such as firefighting or evacuation lifts may therefore offer the best opportunity to make use of extended travel distances achievable with carbon fibre suspension systems.

Another development, however, looks set to provide potentially unlimited travel distances. Attempts have been made in the past to use linear induction motors on lifts but the technology has yet to become commercially available. However, a system is in development and a prototype is planned to be operational in 2016 or 2017.

The system in development has no counterweight and no suspension ropes or belts and is proposed to use multiple lift cars operating in each shaft. Using horizontal transfers the system will link shafts and allow lift cars to transfer horizontally between shafts, so lifts can follow each other and cycle around a building travelling up and down in different lift shafts. The ability for lifts to transfer horizontally means that they can travel in shafts that follow the form of a building, rather than being limited within vertical cores.

The system is proposed with a maximum speed of 5 m/s, which will maintain separation between lift cars but will increase the travel times significantly over that of conventional lifts operating in their own shaft.

The ability to have multiple lifts in each shaft will provide increased passenger capacity and allow the system to transport people away from lobbies, possibly with better average waiting times than current designs consider. However the relatively slow lift speeds will result in increased transit times. With unlimited travel distances possible, passenger transit times could be much longer than is considered acceptable for current designs.

The commercial benefits of running multiple lifts in each shaft and reducing the number of shafts in a building will be attractive to building developers, owners and their designers.

The system promises to make super-tall buildings more efficient by allowing many more people to be transported in each shaft, thus reducing the required core area to deal with the high populations in tall towers. However, the longer transit times resulting from the lower lift speeds will require a relaxation in design expectations for performance measures such as transit times, which could in turn affect expectations for traditional lifts in conventionally lifted buildings.

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Appendix 5.A1: Car, well, headroom, pit and machine room sizes

The values for car, well, headroom and pit sizes (Tables 5.A1.1 to 5.A1.3) are for guidance only as factors such as door height, door type, internal car height, position of counterweight, provision of counterweight safety gear, multiple lifts in well, equipment in the well (MRLs) etc., would require confirmation from the lift installer.

The values for machine room sizes (Tables 5.A1.4 to 5.A1.7) are the minimum sizes recommended and are for guidance only for single lifts, as factors such as access arrangements, split levels, machine room height, machine position, position of counterweight, multiple lifts in well, equipment in the well, etc., would require confirmation from the lift installer.

Table 5.A1.1 Car, well, headroom and pit sizes: residential and health care lifts (source: BS ISO 4190-1: 2010 (BSI, 2010))

Speed (m/s)	Dimension	Size for given rated load							
		Residential class			Health care class				
		450 kg	630 kg	1000 kg	1275 kg	1275 kg	1600 kg	2000 kg	2500 kg
N/A	Car:								
	— internal area (m ²)	1.30	1.66	2.40	2.95	2.95	3.56	4.20	5.00
	— internal width (mm)	1000	1100	1100	1200	1300	1400	1500	1800
	— internal depth (mm)	1250	1400	2100	2300	2100	2400	2700	2700
N/A	Well:								
	— width (mm)	1600 (A)	1600 (A)	1600 (A)	2100 (C)	2500 (C)	2400 (E)	2400 (E)	2700 (E)
	— depth (mm)	1700 (A)	1900 (A)	2600 (A)	2900 (C)	2650 (C)	3000 (E)	3300 (E)	3300 (E)
	— width (mm)	—	1700 (B)	1700 (B)	—	—	—	—	2700 (F)
	— depth (mm)	—	1900 (B)	2600 (B)	—	—	—	—	3300 (F)
0.40*	Headroom (mm)	3600	3600	3600	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	1400	1400	1400	N/S	N/S	N/S	N/S	N/S
0.63	Headroom (mm)	3600	3600	3600	4400	4400	4400	4400	4600
	Pit depth (mm)	1400	1400	1400	1600	1600	1600	1600	1800
0.75	Headroom (mm)	3600	3600	3600	—	—	—	—	—
	Pit depth (mm)	1400	1400	1400	—	—	—	—	—
1.00	Headroom (mm)	3700	3700	3700	4400	4400	4400	4400	4600
	Pit depth (mm)	1400	1400	1400	1700	1700	1700	1700	1900
1.60	Headroom (mm)	3800	3800	3800	4400	4400	4400	4400	4600
	Pit depth (mm)	1600	1600	1600	1900	1900	1900	1900	2100
1.75	Headroom (mm)	3800	3800	3800	—	—	—	—	—
	Pit depth (mm)	1600	1600	1600	—	—	—	—	—
2.00	Headroom (mm)	N/S	4300	4300	4600	4600	4600	4600	4800
	Pit depth (mm)	N/S	1750	1750	2100	2100	2100	2100	2300
2.50	Headroom (mm)	N/S	5000	5000	5400	5400	5400	5400	5600
	Pit depth (mm)	N/S	2200	2200	2500	2500	2500	2500	2500

* Hydraulic lifts only

N/S indicates non-standard configuration

Notes:

- (1) Accommodation: 450 kg wheelchair only; 630/800/1000 kg wheelchair and attendant; 1275 kg and larger provides full manoeuvrability.
- (2) Health care lifts accommodate patient trolleys, beds (various sizes), instruments and attendants.
- (3) Door widths: A = 800 mm; B = 900 mm; C = 1100 mm; D = 1200 mm; E = 1300 mm; F = 1400 mm.
- (4) Headroom = top terminal finished floor to well ceiling; pit depth = bottom terminal finished floor to pit floor

Table 5.A1.2 Car, well, headroom and pit sizes: general purpose and intensive traffic lifts (source: BS ISO 4190-1: 2010 (BSI, 2010))

Speed (m/s)	Dimension	Size for given rated load									
		General purpose class					Intensive traffic class				
		630 kg	800 kg	1000 kg	1275 kg	1350 kg	1275 kg	1350 kg	1600 kg	1800 kg	2000 kg
N/A	Car:										
	— internal area (m ²)	1.66	2.00	2.40	2.95	3.10	2.95	3.10	3.56	3.88	4.20
	— internal width (mm)	1100	1350	1600	2000	2000	2000	2000	2100	2350	2350
	— internal depth (mm)	1400	1400	1400	1400	1500	1400	1500	1600	1600	1700
N/A	Well:										
	— width (mm)	1800 (A)	1900 (A)	2200 (B)	2500 (C)	2550 (C)	2600 (C)	2650 (C)	2700 (C)	3000 (D)	3000 (D)
	— depth (mm)	2100 (A)	2200 (A)	2200 (B)	2200 (C)	2350 (C)	2300 (C)	2450 (C)	2500 (C)	2500 (D)	2600 (D)
	— width (mm)	2000 (B)	2000 (B)	2400 (C)	—	—	—	—	—	—	—
	— depth (mm)	2100 (B)	2200 (B)	2200 (C)	—	—	—	—	—	—	—
0.63	Headroom (mm)	3800	3800	4200	4200	N/S	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	1400	1400	1400	1400	N/S	N/S	N/S	N/S	N/S	N/S
0.75	Headroom (mm)	3800	3800	4200	4200	N/S	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	1400	1400	1400	1400	N/S	N/S	N/S	N/S	N/S	N/S
1.00	Headroom (mm)	3800	3800	4200	4200	N/S	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	1400	1400	1400	1400	N/S	N/S	N/S	N/S	N/S	N/S
1.50	Headroom (mm)	4000	4000	4200	4200	N/S	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	1600	1600	1600	1600	N/S	N/S	N/S	N/S	N/S	N/S
1.60	Headroom (mm)	4000	4000	4200	4200	N/S	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	1600	1600	1600	1600	N/S	N/S	N/S	N/S	N/S	N/S
1.75	Headroom (mm)	4000	4000	4200	4200	N/S	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	1600	1600	1600	1600	N/S	N/S	N/S	N/S	N/S	N/S
2.00	Headroom (mm)	N/S	4400	4400	4400	N/S	N/S	N/S	N/S	N/S	N/S
	Pit depth (mm)	N/S	1750	1750	1750	N/S	N/S	N/S	N/S	N/S	N/S
2.50	Headroom (mm)	N/S	5000	5200	5200	—	5500	5500	5500	5500	5500
	Pit depth (mm)	N/S	2200	2200	2200	—	2200	2200	2200	2200	2200
3.00	Headroom (mm)	N/S	N/S	N/S	N/S	—	5500	—	5500	5500	5500
	Pit depth (mm)	N/S	N/S	N/S	N/S	—	3200	—	3200	3200	3200
3.50	Headroom (mm)	N/S	N/S	N/S	N/S	—	5700	—	5700	5700	5700
	Pit depth (mm)	N/S	N/S	N/S	N/S	—	3400	—	3400	3400	3400
4.00†	Headroom (mm)	N/S	N/S	N/S	N/S	—	5700	—	5700	5700	5700
	Pit depth (mm)	N/S	N/S	N/S	N/S	—	3800	—	3800	3800	3800
5.00†	Headroom (mm)	N/S	N/S	N/S	N/S	—	5700	—	5700	5700	5700
	Pit depth (mm)	N/S	N/S	N/S	N/S	—	3800	—	3800	3800	3800
6.00†	Headroom (mm)	N/S	N/S	N/S	N/S	—	6200	—	6200	6200	6200
	Pit depth (mm)	N/S	N/S	N/S	N/S	—	4000	—	4000	4000	4000

† Using reduced stroke buffering

N/S indicates non-standard configuration

Notes:

- (1) Accommodation: 630/800/1000 kg wheelchair and attendant; 1275 kg and larger provides full manoeuvrability.
- (2) Door widths: A = 800 mm; B = 900 mm; C = 1100 mm; D = 1200 mm; E = 1300 mm; F = 1400 mm.
- (3) Headroom = top terminal finished floor to well ceiling; pit depth = bottom terminal finished floor to pit floor

Table 5.A1.3 Car, well, headroom and pit sizes: goods lifts — Series A (Europe; EN 81-20) (source: BS ISO 4190-2: 2001 (BSI, 2001))

Speed (m/s)	Dimension	Size for given rated load						
		630 kg	1000 kg	1600 kg	2000 kg	2500 kg	3500 kg	5000 kg
N/A	Car:							
	— internal area (m ²)	1.66	2.00	3.56	4.20	5.00	6.60	9.00
	— width† (mm)	1100	1350	1400	1500	1800	2100	2500
	— depth (mm)	1400	1750	2400	2700	2700	3000	3500
N/A	Well:							
	— width (mm)	2100 (A)	2400 (A)	2500 (A)	2700 (A)	3000 (A)	3500 (A)	4100 (A)
	— depth (mm)	1900 (A)	2200 (A)	2850 (A)	3150 (A)	3150 (A)	3550 (A)	4050 (A)
	— width (mm)	—	2400 (B)	2500 (B)	2700 (B)	3000 (B)	3500 (B)	4100 (B)
	— depth (mm)	—	2300 (B)	2950 (B)	3250 (B)	3250 (B)	3700 (B)	4200 (B)
	— width (mm)‡	—	—	2200 (C)	2300 (C)	2600 (C)	2900 (C)	3300 (C)
	— depth (mm)	—	—	3050 (C)	3350 (C)	3350 (C)	3650 (C)	4150 (C)
	— width (mm)‡	—	—	2200 (D)	2300 (D)	2600 (D)	2900 (D)	3300 (D)
	— depth (mm)	—	—	3400 (D)	3700 (D)	3700 (D)	4000 (D)	4500 (D)
0.25	Headroom (mm)	3700	3700	4200	4200	4600	4600	4600
	Pit depth (mm)	1400	1400	1600	1600	1600	1600	1600
0.40	Headroom (mm)	3700	3700	4200	4200	4600	4600	4600
	Pit depth (mm)	1400	1400	1600	1600	1600	1600	1600
0.50	Headroom (mm)	3700	3700	4200	4200	4600	4600	4600
	Pit depth (mm)	1400	1400	1600	1600	1600	1600	1600
0.63	Headroom (mm)	3700	3700	4200	4200	4600	4600	4600
	Pit depth (mm)	1400	1400	1600	1600	1600	1600	1600
1.00	Headroom (mm)	3700	3700	4200	4200	4600	4600	4600
	Pit depth (mm)	1400	1400	1600	1600	1600	1600	1600

† Also clear door opening width

‡ Add 150 mm for telescopic vertical sliding doors

Notes:

- (1) Door types: A = single entrance, horizontal sliding; B = two opposing entrances, horizontal sliding; C = single entrance, vertical sliding; D = two opposing entrances, vertical sliding.
- (2) Headroom = top terminal finished floor to well ceiling; pit depth = bottom terminal finished floor to pit floor

Table 5.A1.4 Machine room sizes: passenger lifts (sources: BS ISO 4190-1: 2010 (BSI, 2010), BS ISO 4190-2: 2001 (BSI, 2001))

Speed (m/s)	Dimension	Size for given rated load			
		320–630 kg	800–1000 kg	1275–1600 kg	1800–2000 kg
0.63–1.75	Min. width (mm)	2500	3200	3200	3000
	Min. depth (mm)	3700	4900	4900	5000
2.00–3.00	Min. width (mm)	—	2700	3000	3300
	Min. depth (mm)	—	5100	5300	5700
3.50–6.00	Min. width (mm)	—	3000	3000	3300
	Min. depth (mm)	—	5700	5700	5700

Notes:

- (1) For multiple lifts (side-by-side or facing), see formulae given in BS ISO 4190.
- (2) Machine room clear height to be in accordance with local building regulations.

Table 5.A1.5 Machine room sizes: health care lifts (sources: BS ISO 4190-1: 2010 (BSI, 2010) and BS ISO 4190-2: 2001 (BSI, 2001))

Speed (m/s)	Dimension	Size for given rated load		
		1275–1600 kg	2000 kg	2500 kg
0.63–2.50	Min. width (mm)	3200	3200	3500
	Min. depth (mm)	5500	5800	5800
	Area (m ²)	25	27	29

Notes:

- (1) For multiple lifts (side-by-side or facing), see formulae given in BS ISO 4190.
- (2) Machine room clear height to be in accordance with local building regulations.

Table 5.A1.6 Machine room sizes: electric traction goods lifts; Series A (Europe; EN 81-20) (sources: BS ISO 4190-1: 2010 (BSI, 2010) and BS ISO 4190-2: 2001 (BSI, 2001))

Speed (m/s)	Dimension	Size for given rated load		
		630 kg	1000/1600/2000 kg	2500/3500/5000 kg
0.25–1.00	Min. width (mm)	2500	3200	3000
	Min. depth (mm)	3700	4900	5000

Notes:

- (1) For multiple lifts (side-by-side or facing), see formulae given in BS ISO 4190.
- (2) Machine room clear height to be in accordance with local building regulations.

Table 5.A1.7 Machine room sizes: all hydraulic lifts (passenger and goods) (sources: BS ISO 4190-1: 2010 (BSI, 2010), BS ISO 4190-2: 2001 (BSI, 2001))

Speed (m/s)	Dimension	Size for given rated load
		320–5000 kg
0.25–1.00	Area (m ²)	Well width (m) or well depth (m) × 2000 mm

Notes:

- (1) For multiple lifts (side-by-side or facing), see formulae given in BS ISO 4190.
- (2) Machine room clear height to be in accordance with local building regulations.

6 Firefighting lifts and evacuation lifts for people with disabilities

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6 Firefighting lifts and evacuation lifts for people with disabilities

6.1 Introduction

This chapter explains the basic requirements for lifts that are intended to be used in the event of fire in a building. In the event of fire, evacuation routes for occupants of buildings are usually via stairways enclosed in a fire resisting construction. However, provision may still have to be made for a lift to operate during a fire either to enable firefighters to access upper floors safely or to assist in the evacuation of persons with limited mobility before the fire service arrives.

Standards such as BS 9999: *Code of practice for fire safety in the design, management and use of buildings* (BSI, 2008) and BS 9991: *Fire safety in the design, management and use of residential buildings. Code of practice* (BSI, 2011a) recommend when a building needs firefighters' lifts or evacuation lifts. These are standards for the design of the building for fire; the decision on whether a lift should be a firefighting or evacuation lift is one made as part of the building design. Note that at the time of writing, both these standards are under revision so readers are advised to make reference to the most recent versions.

A firefighting lift is intended to be used by firefighters in fighting a fire in a building and so has additional design features for use by firefighters and with additional protection. BS EN 81-72: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Firefighters lifts* (BSI, 2003, 2015) is the harmonized European standard that describes these extra features. Note that until the end of August 2017, both the 2003 and 2015 editions of this standard will coexist.

An evacuation lift is quite different and is intended to be used by building management to help with evacuation of persons with disabilities and limited mobility from the building. The extra requirements for an evacuation lift are in Annex G of BS 9999.

Note that at the time of writing, work has started on EN 81-76, which may become a harmonised standard; readers are advised to check the publication and status of this document.

Where the lift is not required to be used in the event of fire, then it should be returned to an exit floor and doors opened to allow persons travelling in the lift car to exit the car and then taken out of service. Where a recall device, such as a suitable interface from a fire detection system or from a manual recall switch, is provided as part of the building design then BS EN 81-73: *Behaviour of lifts in the event of fire* (BSI, 2005) gives requirements for the return of the lift to an exit floor. Note that BS EN 81-73 does not apply to either firefighting lifts or lifts used for the evacuation of a building because the intention in BS EN 81-73 is to remove those lifts from service that are not intended to remain in service

during a fire. At the time of writing, this standard is under revision; readers should refer to the new edition for guidance when published.

This chapter provides guidance on the relationship between the standards listed and also discusses other documents relating to firefighting and evacuation lifts.

6.2 Need for firefighting lifts

6.2.1 General

A standard lift fitted with a fire service switch cannot be considered as a firefighting lift. The provision of firefighting lifts requires substantial expenditure and therefore the need for such a lift should be properly established. This section provides guidance on firefighting lifts. Its aim is to provide a basic understanding of the relevant standards and how they affect lifts. It is not, however, intended to be comprehensive and, where appropriate, reference should be made to the Building Regulations and relevant British Standards.

6.2.2 History and development

As early as 1930, it was recognised that firefighters should be provided with a means of swift access to the upper floors of large buildings. This resulted in conventional passenger lifts being fitted with a break-glass key switch at the firefighter's access floor that, when operated, brought the lift to that floor quickly.

It was determined that such lifts should have power-operated doors 2 ft 9 in (800 mm) wide. Their capacity should be at least 1200 lb (550 kg) and they would be sufficiently fast to travel the height of the building in less than one minute. Additional requirements, such as fire resistant landing doors rated at half the value of the structure (normally one hour), were gradually introduced. Some local authorities imposed further specific requirements such as those contained in Section 20 of the London Building Acts 1939 (HMSO, 1939).

The main requirements for the lift were taken into BS 2655: Part 1 (BSI, 1970), which had requirements for 'fireman's lifts'. This was superseded in 1979 by BS 5655 but this standard did not contain any requirements for fireman's lifts. Requirements for firefighting lifts were first included in BS 5588-5: 1986 (BSI, 1986), with revisions published in 1991 and 2004. Its content was incorporated within BS 9999: 2008 (BSI, 2008). Requirements for the design of firefighting lifts are no longer contained in BS 9999 but were included in BS EN 81-72 (BSI, 2003), which was the first European standard for firefighters' lifts. Since

then, BS 9991 (BSI, 2011) was published to cover residential buildings in 2011.

Note: for new lifts, use of terms such as ‘fireman’s lift’ or ‘fireman’s control’ are misnomers since they relate to a type of lift long since superseded by firefighting lifts.

Details of recommendations for the building design and use in relation to firefighting shafts are contained within BS 9999, which also provides guidance on the circumstances in which such a lift should be provided. Guidance is also contained within Building Regulations Approved Document B (NBS, 2006), which currently directs the reader to BS 5588 because it was published before BS 9999 (although this will be corrected at the next revision).

It is now recognised that modern firefighting techniques involve the use of equipment that needs to be moved by means of lifts. Furthermore, firefighters need a safe and reliable means of access to the upper floors of large buildings. The concept of the firefighting lift was devised to meet these requirements and today BS 9991 or BS 9999 provide the guidance on when such lifts should be provided, as well as aspects of the building design, such as fire resistance requirements for the structure of the lift well. BS 9991 and BS 9999 therefore have no role to play in relation to the design of a firefighting lift and reference should be made to BS EN 81-72, which defines the technical rules for the design of the lift itself.

The ongoing development of these standards for lifts and buildings is the result of changes in the way that fires are tackled and firefighting techniques need to be understood in order to appreciate fully why the recommendations should be met.

On arrival at a fire, the fire service first establishes where the fire is located. This information can be gained by various means such as fire detection systems, or from persons who have seen the fire. While this information is being obtained, the firefighting lift is called to the fire access lobby and taken under the control of the fire service. When the location of the fire has been established (until which time there is serious risk if the lift goes to a floor affected by fire), a team of usually four firefighters may use the lift to travel to a floor below the floor on which the fire is located — typically two floors below. These firefighters can be carrying various items of equipment, including breathing apparatus, and so require at least the space offered by an 8-person (630 kg) lift car.

On reaching a floor below the fire, three firefighters would leave the lift and make their way by the stairs to the floor on which the fire is located. Meanwhile the remaining firefighter may use the lift to return to the fire lobby in order to bring up more firefighters and equipment. In large fires, a floor below the fire is normally established as a base where fire crews may rest and recharge breathing equipment, and where casualties may wait for transport to the Fire Service Access Level (FSAL). In such cases, the importance of the lift increases, rather than diminishes, as the fire develops and therefore it is essential that the fire service can maintain good communication with the lift car and retain full control over it.

6.2.3 Scope of BS 9999

BS 9999 (BSI, 2008) gives recommendations and guidance on the design, management and use of buildings to achieve reasonable standards of fire safety for all people in and around buildings. It is not applicable to individual dwelling-houses and might have only limited applicability to certain specialist building and areas of buildings (e.g. areas of lawful detention).

This British Standard is applicable to the design of new building and to alterations, extensions and changes of use of an existing building. It also provides guidance on the ongoing management of fire safety in a building throughout the entire life cycle of the building, including guidance for designers to ensure that the overall design of a building assists and enhances the management of fire safety. It can be used as a tool for assessing existing buildings, although fundamental change in line with the guidelines might well be limited or not practicable.

The recommendations and guidance given in the standard are intended to safeguard the lives of building occupants and firefighters. Whilst some of the recommendations and guidance might also assist in the achievement of other fire safety objectives — such as protection of property, the environment, communities and business/service viability. Additional measures might be necessary which are outside the scope of the standard.

While BS 9999 is referenced in this chapter, following such a code of practice is not the only approach to building design for fire as set out in the foreword to BS 9999. BS 7974: *Application of fire safety engineering principles to the design of buildings. Code of practice* (BSI, 2001) and various parts of PD 7974: *Application of fire safety engineering principles to the design of buildings* (BSI, 2002–2014) provide a fire safety engineering approach. The parts of PD 7974 dealing with firefighting provision generally refer back to BS 9999 for the details of firefighting shafts and firefighting lifts.

BS 9999 does not cover fire safety design strategies for extreme events such as terrorist actions. In buildings where risks such as terrorism are considered to be high the implications must be considered in the design of the building.

6.2.4 General lift recommendations of BS 9999

At the time of writing, a revision of BS 9999 is underway. Readers are advised to check and refer to a later revision when published. The recommendations are complex and to some extent depend on the building use, size, floors etc. To determine exactly what is required in a given building requires reference to the standard itself, but in essence the following is a general guide.

The standard suggests that buildings, or parts of buildings, where either:

- (a) the height of the surface of the floor of the topmost storey (excluding any storey consisting entirely of plant rooms) exceeds 18 m

or:

- (b) the depth of the surface of the floor of the lowermost storey exceeds 10 m

should be provided with a firefighting shaft containing a firefighting stair, a firefighting lobby with a fire main, and a firefighting lift.

The number of shafts is determined by the length of the hose laying distance combined with floor area. The standard recommends that sufficient shafts be provided and positioned to give one firefighting shaft for buildings with a floor area up to 900 m² on any storey and at least two shafts where the floor area on any storey exceeds 900 m². The hose laying distance between the shaft and the accommodation to any point on the storey should not exceed 60 m in buildings with automatic sprinkler systems and should not exceed 45 m in buildings without sprinklers. If the internal layout is not known, a hose laying distance of $\frac{2}{3}$ of the direct route may be used for planning purposes.

Whilst it is desirable for lifts to serve all storeys of a building, it is not essential. In large complexes, several lifts may be provided for firefighting, some of which may serve upper floors while others serve basements. Figure 6.1 outlines the extent of travel required by a firefighting lift.

The location of firefighting shafts should be such that they allow access to every part of every storey that they serve and should, wherever possible, be located against an exterior wall.

If it is not possible to locate the firefighting shaft against an exterior wall, the route from the fire service entrance to the firefighting shaft (protected corridor) should be as short as possible and be protected by fire-resisting construction to ensure that fire does not affect the route or cut off the means of escape for fire service or other personnel within the building.

The layout of the firefighting shaft at fire service access level should be arranged so that firefighters and persons escaping down the firefighting stair do not get in each other's way.

It should not be necessary for persons escaping down the stair to pass through the firefighting lobby at the fire service access level. Where a protected corridor for firefighting access also forms part of the means of escape from the accommodation, it should be at least 500 mm wider than that required for means of escape purposes (to allow room for fire service personnel to move towards the firefighting shaft), and the firefighting lobby should have a minimum area of 5 m² clear of any escape routes so that it can act as a fire service mustering point.

The firefighting lobby at the fire service access level should be big enough to act as a command post where firefighters and firefighting equipment can be safely assembled.

It should be noted that, although passengers may use the lift during normal operation, its primary function should not be for the transportation of goods, i.e. it should not be a goods lift.

Whichever layout or position is selected, firefighting lifts should be within a firefighting shaft which contains stairs, lobbies, fire main and the lift itself. The entire shaft should be enclosed by a structure which is fire resistant (usually for two hours). Figure 6.2 shows a typical arrangement.

Without the provision of a lobby and stairs, the ability of a lift to operate during a fire is questionable. The lobby provides additional protection to the lift well and forms a refuge for those who are unable to escape down the stairs and may need assistance. It is not possible to ensure that the lift can withstand fire and so a lobby must be provided. In the event of a lift failure, an alternative exit from lobbies

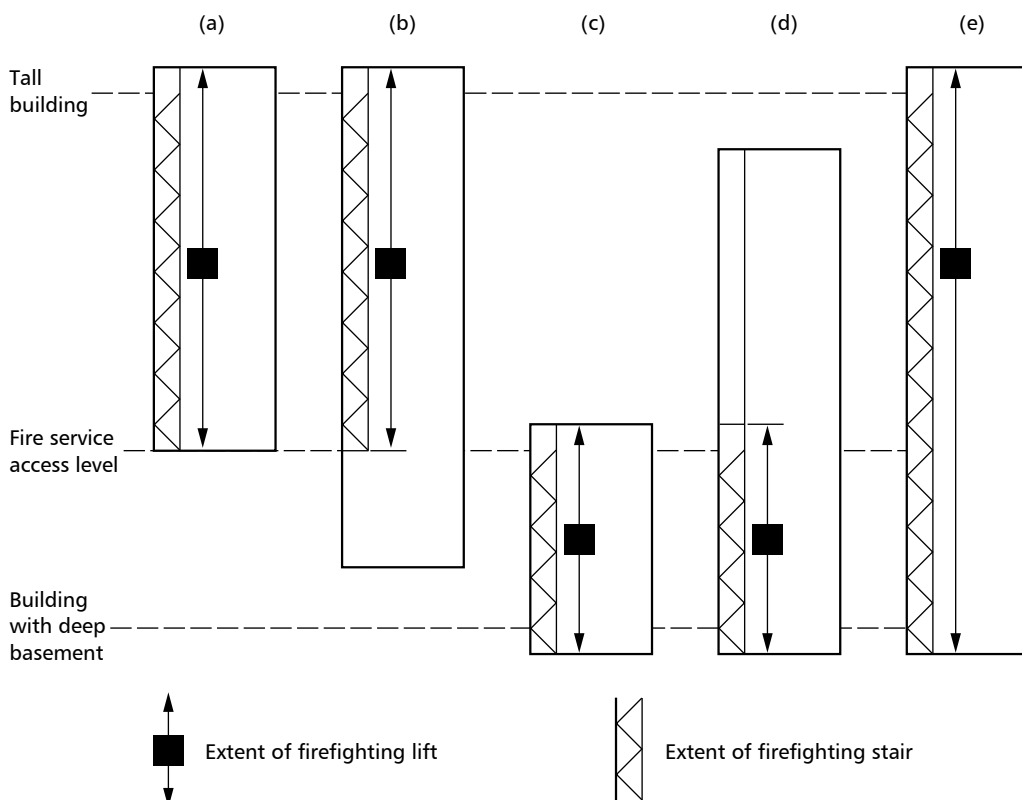


Figure 6.1 Extent of travel of firefighting lift; (a) buildings over 18 m high without basement, (b) buildings over 18 m high with basement less than 10 m deep, (c) buildings with basement only; (d) buildings less than 18 m high with deep basement, (e) buildings over 18 m high with deep basement

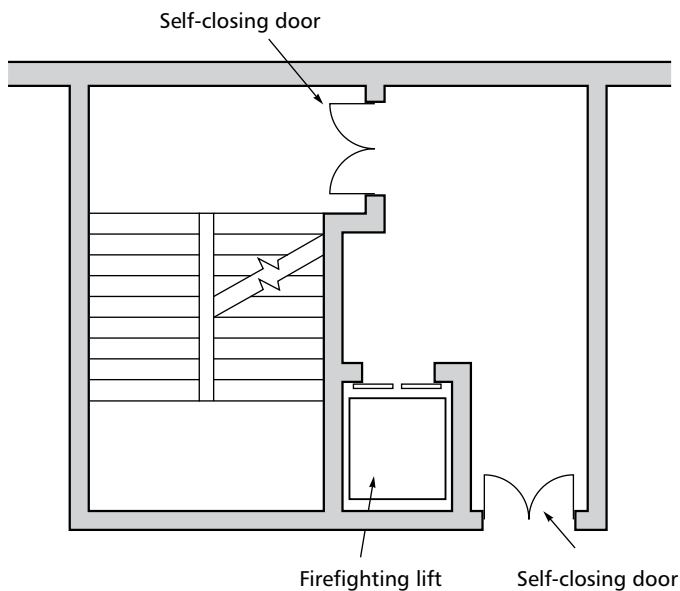


Figure 6.2 Typical layout for firefighting shaft

should be provided for firefighters, hence the need for stairs.

The firefighting lift may share a common well with other lifts, see Figure 6.3. In such cases it should also share a common lobby and all lifts in the shaft should be constructed to a similar standard in terms of the fire resistance of the materials used in the cars and all should have fire resistant landing doors.

BS 9999 also provides detailed guidance on the design of fire escape routes, stairs as well as lifts use. While detailed consideration of escape routes and stairs is outside the scope of this Guide, it is important to note that pressurisation of firefighting shafts may be used in certain circumstances. The lift supplier should be informed of this intention (see also 'items for negotiation' in BS EN 81-72: 2015 (BSI, 2015)). Following the principles now given in BS 9999 the system provided should keep both the firefighting lift well and stair enclosure clear of smoke. In the event of smoke entering the firefighting lobby, the pressure within the stair enclosure should not drive smoke and hot gas into the lift well or vice versa. Information on the control of heat and smoke is contained within BS 9999, clause 28. This includes typical leakage rates through lift doors. It should be noted that it is not practical to seal the lift doors to reduce leakage

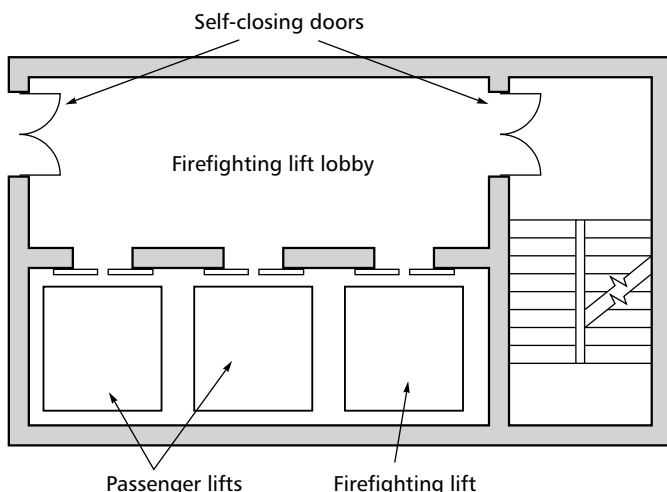


Figure 6.3 Layout of a firefighting cell with shared lift shaft

and the addition of brush or similar seals may invalidate the fire certification applicable to the doors. Typical pressure levels for such systems are in the range 30–60 Pa and, while such pressures may not generally disturb operation of the doors, it is advisable to notify the lift supplier of the intention to pressurise the installation and provide details of the likely pressures.

6.3 Design considerations for firefighting lifts

6.3.1 General

BS 9999 provides detailed guidance on the design of the building, the location of firefighting shafts and what should be contained within a firefighting shaft. When a firefighting lift is provided, BS 9999 does not define how it should be designed, but instead refers to BS EN 81-72 for this detail.

BS EN 81-72: 2003 (BSI, 2003) references BS EN 81-1 (BSI, 1998a) or BS EN 81-2 (BSI, 1998b); these standards will be withdrawn together on 31 August 2017. For new firefighting lifts in conformity with BS EN 81-20 (BSI, 2014a), BS EN 81-72: 2015 (BSI, 2015) provides the further requirements for a firefighters lift. The national foreword of BS EN 81-72: 2015 sets out these relationships. In principle, the use of BS EN 81-72: 2003 with BS EN 81-20 or the use of BS EN 81-72: 2015 with BS EN 81-1/2 (+ A3: 2009) would require the involvement of a notified body. However, on the basis that so doing would not entail a reduction in safety, this should not be seen as a barrier to the use of the latest standards.

Should any of the recommendations of BS 9999 or the requirements of the building design necessitate a deviation from a harmonised European standard such as BS EN 81-1/2 (+ A3: 2009), or BS EN 81-20, or BS EN 81-72, then notified body approval must be obtained.

BS EN 81-72, as its subtitle suggests, refers to firefighters' lifts, and has the following main requirements:

- Firefighters' lifts should be at least 630 kg rated load; the internal dimensions of the car should be at least 1100 mm wide by 1400 mm deep. In the case of a dual entry firefighters' lift or where the lift is to be used also for evacuation, the lift car should be a minimum of 1100 mm wide and 2100 mm deep.
- The rated speed should be sufficient to enable the lift to run the full travel of the building in less than 60 seconds. Note that, for very tall buildings, BS EN 81-72: 2015 allows a further one second for each 3 m of travel for lifts with greater than 200 m travel. (An approximation of the minimum speed required may be obtained by dividing the total travel by 60 seconds minus 8 seconds for the car to accelerate and decelerate.)
- Automatic power-operated doors should be provided, at least 800 mm wide by 2000 mm high. BS EN 81-72 refers to national regulations to determine the fire rating; at least one hour is usually required for the doors by Building Regulations.

- Lift position indicators should be provided both in the car and at the firefighter's access level to show the car position at all times while power is available.
- A two-way intercom should be provided between the car, machine room (or emergency and inspection panel for machine room-less lifts) and fire service access level. It should be switched on automatically when the lift is put to firefighting operation. A handset should not be used for the fire service access level or car, which should use built-in devices. It is important to note that this lift communication system is for the fire service, but is not part of the Fire Service communication system that is required in firefighting shafts according to BS 9999, clause 24.
- A trapdoor should be provided in the lift car roof. For a 630 kg lift this trapdoor should measure at least 0.4 m × 0.5 m. In the case of larger lifts the trap door should be at least 0.5 m × 0.7 m.
- According to BS EN 81-72 provision shall be made for rescue from inside and outside the car. Rescue from inside the car is not called for in BS 9999 but is required if claiming conformity to BS EN 81-72. The rescue provisions should be the subject of negotiation between the lift contractor and the client to establish exactly what is required with regards to rescue provisions.
- Car buttons and controls should be protected from the effects of dripping water and, in addition to the normal storey markings, should indicate the Fire Service Access Level with a pictogram (see Figure 6.4) on or near the controls.
- Electrical equipment on landings, within the lift car and lift well should be protected against the effects of water. Required protection levels are defined in BS EN 81-72.
- An audible (and preferably also a visual) alarm should be provided within the shaft and machine room to alert lift maintenance personnel to the operation of the firefighting switch while on inspection control.



Illustration in white. Background in red.

Size:

- 20 mm x 20 mm for a symbol on the car operating panel
- a minimum of 100 mm x 100 mm on a landing

Figure 6.4 Pictogram to identify fire service access level

- The lift should have a secondary supply. In the event of loss of the mains supply and on establishment of the secondary supply, the lift should re-establish its position with only limited movement in the direction of the fire service access floor. See section 12.6 for more details of the secondary supply and applicable standards.

The main changes in BS EN 81-72: 2015 are set out in the foreword to the standard on which the following is based.

EN 81-72: 2015 is a full revision of the standard which reflects developments since the publication of EN 81-72: 2003 and experience gained from its application. Consequently, most clauses have some change and reference should be made to the standard for details. The main changes can be identified as follows:

- 'Safe area' is used in place of 'lobby' to be consistent with CEN/TS 81-76 (CEN, 2011). The two terms are interchangeable.
- Revision of the elements dealing with building design and the inclusion of a new informative annex on the building interface. Items to be considered in the use of pressurisation of lift wells have been added including the noise level at the fire communication points.
- Deletion of the requirement for a firefighters' lift to serve every floor of the building. The floors to be served are assumed to be determined as part of the design of the building for fire.
- New requirements for protection of electrical equipment against water; in the lift well and the roof and walls of the lift car.
- New measures to prevent water ingress into the lift well which are strongly preferred over to measures to control the level of water in the lift pit alone. The measures considered are described in a new annex on water management. This includes measures to prevent water entering the lift well based on previous requirements in BS 5588-5 and recommendations in Annex L of BS 9999.
- Revision of clauses dealing with the rescue of trapped firefighters with rationalised requirements for movable ladders and reduced maximum distance between consecutive landings (from 11 m to 7 m). The use of fixed ladders and rope ladders have been removed.
- New requirements for the interface between firefighters lift switches and the control system.
- New requirements for dual entry lift cars where not all the safe areas to be used in firefighting operations are on the same side i.e. more than one car door could be used during firefighting operations.
- Revision of requirements for the control system including new requirements for when a firefighters' key switch is used in the lift car (subject to negotiation). It should be noted that the use of a car key switch is not UK practice and so this should not be provided unless specifically agreed between all parties.

- Revised requirements, in phase 2, for car doors to close under constant pressure from door close or car call buttons and for opening under constant pressure until the doors are within 50 mm of being fully open.
- Addition of requirements for keypad operation of the firefighters lift car in phase 2.
- Inclusion of a new informative annex on maintenance requirements.

BS 9999 lists the following, which it notes are building signs and not part of the firefighting lift as defined in BS EN 81-72:

- Firefighting lobbies containing lifts should be clearly marked in accordance with BS 5499-1 (BSI, 2002):

FIREFIGHTING LIFT
DO NOT OBSTRUCT DOORS
DO NOT USE FOR STORAGE

- In buildings where the firefighting lift is the only lift, an additional notice should be provided stating:

DO NOT OBSTRUCT DOORS

Where firefighting lifts are installed, these should be clearly signed at the fire service access level; relevant information should be available detailing the locations of the lift main switch, rescue controls and machinery spaces. To this end, BS EN 81-72: 2015 includes a recommendation for the locations of the lift main switch, emergency and testing panel or machine room to be included in a label at the fire service access level.

6.3.2 Car entrances

Cars for firefighting lifts should preferably be front opening, i.e. entrance to the car is from one side only. If a dual-entry lift with front and rear openings also serves as the firefighting lift, additional precautions for the rear entrance may be required and it is usually necessary to provide a second fire lobby, as shown in Figure 6.5. However, the additional cost of such arrangements should be carefully considered.

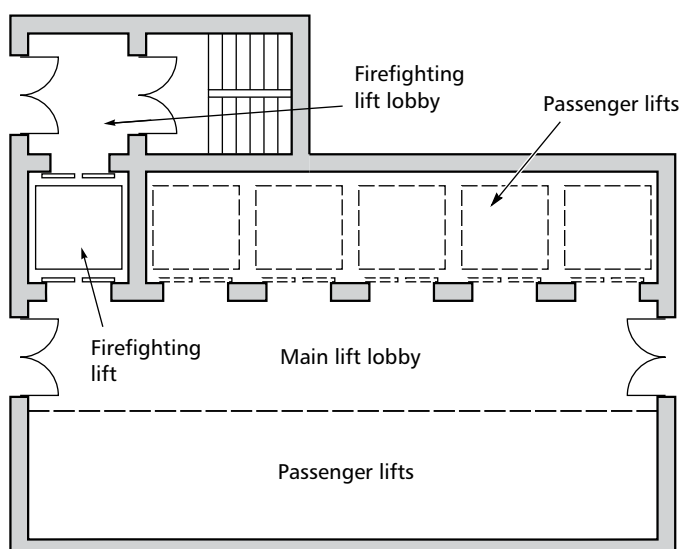


Figure 6.5 Provision of additional fire lobby for a dual-entry car

One of the major changes in BS EN 81-72: 2015 is the inclusion of further requirements for dual entry lifts (the previous BS EN 81-72 considered only open through lift cars where all the firefighting lobbies were on the same side). However the inclusion of these, especially where it is intended for the firefighting lift to open on different sides at different floors while in firefighting mode, should be carefully considered along with the guidance in BS 9999 for the further precautions to be taken.

6.3.3 Machine room location

Where provided, a lift machine room (machinery space) should preferably be sited above the lift well and access should be via the firefighting stairway adjacent to the lift. If it is essential to locate the machine room at the bottom of the building, it should be towards the rear or side of the lift well rather than directly below where it is vulnerable to falling water. Access to such machine rooms should still be via a fire protected route, preferably the firefighting stairway. Any apertures in walls or floors separating machine rooms from lift shafts should always be kept to a minimum. Water should be prevented from entering the machine room and machinery spaces.

Machine room-less lifts are now common; their use is permitted by BS 9999 and BS EN 81-72. With these lifts, the machines, controllers, drives and other equipment traditionally placed in the machine room are now possibly located in the lift well, see section 7.2.8. For lifts without machine rooms, the equipment should preferably be located away from the pit area to avoid complex water protection of the equipment.

Sprinklers should not be installed in machine rooms or lift wells for these types of lifts. While BS EN 81-20 allows sprinklers to be installed in lift spaces subject to further requirements, BS EN 81-72: 2015 prohibits their use in firefighters' lifts.

6.3.4 Protection of lift well from water

BS 9999 advises that during a fire, considerable quantities of water might be present on landings. The most likely source of water would be from fire hoses or accidental discharge from risers located in the lift lobby. The flow rate from such sources may be assumed to be approximately 25 litres per second. Every effort should be made to prevent this water from entering the lift well. Floors in the fire lobby should be sloped away from the lift, with drains or scuppers provided to remove water from the immediate area in front of the lift doors. Water should also be directed away from stairways.

BS EN 81-72: 2015 recognises the use of these measures, which have been in BS 5588-5 and BS 9999 for many years. Indeed, it is preferable to prevent water from entering the lift well in significant quantities than to provide drainage measures from the lift pit as BS EN 81-72: 2015 makes clear. However, despite these measures, some water can find its way into the lift well. For this reason it is necessary to provide some degree of water protection to any electrical components in the lift.

BS EN 81-72 requires that protection be provided to electrical lift equipment in the well that is located within 1 m of the lift well front wall. The protection should cater for splashing water by providing IPX3 protected equipment that meets the requirements of BS EN 60529 (+ A2: 2013) (BSI, 1992).

6.3.5 Power supplies

Two independent power supply systems are required by both BS 9999 and BS EN 81-72. The primary electrical supply should be from a sub-main circuit exclusive to the lift and independent of any other main or sub-main circuit, see Figure 6.6. Other lifts in the firefighting shaft may be fed from the same primary supply, provided that the supply is adequate for the purpose. Such an arrangement should be designed so that a fault occurring in any other lift in the firefighting shaft, or in the power supplies to any of these lifts, should not affect the operation of the firefighting lift.

BS 9999 contains a note stating that for legal reasons power supply companies have reservations about offering a power supply from a secondary substation. See BS 9999 clause 38.2.3.3 and section 12.6 of this Guide where more general guidance on secondary power supplies can be found.

For the reasons given in the discussion in section 12.6, the lift supplier should not be asked to provide this secondary supply since it serves not only the lifts but also the firefighting shaft. The lift supplier cannot be expected to know what other plant is to be connected to it. The secondary supply should have sufficient capacity to:

- maintain the firefighting lift in operation for at least two hours
- support any auxiliary equipment such as lighting, ventilation or pressurisation plant
- and, if required, to be able to recover all other lifts to a specified safe location, one at a time within the firefighting shaft.

According to BS 9999, clause 29, an indication of the status of the following should be provided adjacent to the firefighting lift switch:

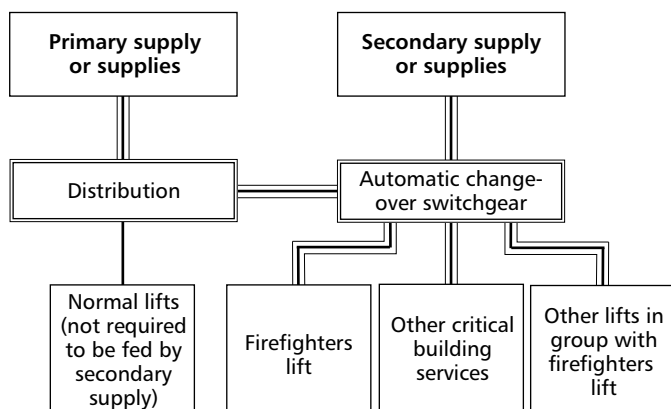


Figure 6.6 Block diagram for independent power supplies to firefighting lifts (reproduced from BS EN 81-72 by permission of the British Standards Institution)

- the primary and secondary power supplies
- any powered ventilation or pressurization systems.

Primary and secondary power status indicators are not provided as part of the lift and it should be clarified within the specification that these indicators are to be provided by those providing the electrical supplies.

6.3.6 Firefighters' lift switch and operation

A firefighters' lift switch located within a face plate and marked with a pictogram (see Figure 6.4) should be positioned adjacent to the lift entrance at the fire service access level. Operation of the switch should be by means of a triangular key with the 'on' position (marked by 'I') and the 'off' position (marked by 'O'). Operation of the switch puts the lift into firefighting service, as follows:

- All special services except maintenance, inspection and emergency electrical operation should be ignored. All lifts within the firefighting shaft should return to the fire access level without stopping if not already returned.
- When any lift arrives at the fire service access level, it should discharge its passengers and then go out of service unless it is a firefighting or evacuation lift. Firefighting lifts park with their doors open.
- All landing calls should be made inoperative but car calls in the firefighting car remain active. On dual-entry cars only the doors on the firefighting lobby side should operate (see section 6.3.2). Passenger detectors or other similar door reversal devices which could be affected by heat or smoke should be made inoperative and the communication system, switched on automatically.

The firefighters' operation of the lift is as follows:

- If a call is entered in the firefighting lift car, it responds to that call and no other.
- It should be possible to enter another car call but this should cancel the previous call.
- When the lift stops at a floor its doors should open only when there is sustained pressure on the door button and if the button is released while the doors are opening, they should immediately re-close.
- Once fully open, the doors should close only in response to constant pressure on another car call button. The buttons should illuminate to indicate any call that is registered. Alternatively, a separate indicator light may be provided.

6.3.7 Owners information manual

The owner should be provided with a manual that explains how the lift is to be used and how its features work. This should include a description of the firefighting lift operation and the importance of keeping the lift properly maintained.

6.4 Testing and maintenance of firefighting lifts

6.4.1 Operational tests prior to handover

A suitable test document for firefighting lifts is provided in BS 8486-1 (+ A1: 2011), Annex D (BSI, 2007). A conformity verification table is provided in clause 6 of BS EN 81-72. The lift supplier should carry out tests to satisfy themselves that the lift fully meets the requirements. There is no requirement for the supplier to issue a test certificate to the owner, but they are required to state on the lift's Declaration of Conformity those standards to which the lift is in conformity.

6.4.2 Routine inspection, maintenance and thorough examination

Chapter 15 discusses general issues to do with routine inspection, maintenance and thorough examination of lifts. This section looks specifically at further guidance in relation to firefighting lifts.

The Regulatory Reform (Fire Safety) Order 2005 (RRO) (TSO, 2005) came into force on 1 October 2006, replacing many earlier pieces of fire safety legislation, and applies in England and Wales. The Fire Safety (Scotland) Regulations 2006 (TSO, 2006) and The Fire Safety Regulations (Northern Ireland) 2010 (TSO, 2010) have similar requirements in Scotland and Northern Ireland. These regulations apply to a very wide range of buildings and require that lifts used in the event of fire are subject to a suitable system of maintenance and are maintained.

The legislation applies to almost all buildings except single private dwellings. It places duties on the person responsible or duty holder for premises ('responsible person' or 'RP' although this term is not used in the Scottish or Northern Ireland Regulations) to provide and maintain sufficient fire precautions so that people can live or work in safety, and escape safely in the event of fire. The RP must carry out a fire risk assessment, make an emergency plan and undertake other fire safety duties related to these.

The legislation includes articles placing responsibilities on the RP (or duty holder) to maintain equipment. The regulations have articles with implications for maintenance of lifts, requiring that any facilities, equipment and devices provided in respect of the premises for the use by or protection of firefighters are subject to a suitable system of maintenance and maintained in an efficient state, working order and good repair. This is understood to apply to lifts for use by the fire service e.g. fireman's, firefighting and firefighters' lifts.

These articles not only require the maintenance of such lifts as part of the facilities and equipment of the building but also imply that their level of safety must not be reduced.

Further reading and guidance can be found at:

- the Department for Communities and Local Government website (www.communities.gov.uk/fire/firesafety)
- London Fire Brigade's *Fire Safety Guidance Note GN66: Regulatory Reform (Fire Safety) Order 2005* (LFB, 2011)
- BS 9999 and BS 9991 have recommendations and guidance on the maintenance.
- BS EN 81-72: 2015 contains an annex with recommendations for maintenance and firefighters lifts.

Irrespective of such specific legislation and other applicable legislation, the building owner should make provision or ensure that:

- regular checks are made of the lift including a check that, on operation of the firefighting lift switch, the lift recalls to the fire service access level and goes into firefighting control
- there is a suitable maintenance contract in place which covers the lift including its firefighting lift switch and firefighting lift features to ensure reliability
- the features of the firefighting lift are included within the scope of thorough examination by a competent person and, where these cannot be examined by the competent person (e.g. fire alarm interface or operation on a secondary power supply, supply changeover arrangements etc.), the competent person should call for supplementary testing
- labelling and notices specified in the various applicable standards are displayed
- where the lift is repaired or modernised, the firefighting features are retained or, where relevant, improved to keep the equipment to current standards.

Table 6.1 Routine checks

Check	Requirement
Weekly check	Operation of the firefighting lift switch by the building maintenance staff who should check that the lift returns to the lobby and parks with its doors open. Failure in this simple test should be reported immediately to the lift maintenance company.
Monthly check	Building maintenance staff to simulate failure of the primary power supply. Building maintenance staff should then operate the firefighting lift switch and observe its operation by entering a few calls. The lift maintenance company may be asked to be present at these tests but their presence can incur additional charges.
Six monthly check	Inspection and testing of the operation sequence of the lift should be made by the lift maintenance company.
Annual check	A full operational test of the lift should be performed at least once per year. A record of this test should be retained by the building management. This test is not normally part of a regular maintenance contract and this point should be clarified whenever a maintenance/ service contract is agreed, otherwise additional charges may be incurred.

For the lift, the checks shown in Table 6.1 are recommended.

For more guidance to lift owners, including guidance on thorough examination and on LEIA's code of practice for maintenance, refer to the lift owners section of the LEIA website (<http://www.leia.co.uk/index.php?cid=25>).

6.5 Evacuation lifts for persons with limited mobility

6.5.1 General

While planning fire prevention and escape routes for a building, consideration should be given to the evacuation of persons with limited mobility, who use the building or those who may be injured during an emergency. In the event of a fire, the occupants should usually evacuate a building by means of stairways. However, alternative provisions for the evacuation of people with limited mobility must be considered. This section provides guidance for the design of lifts intended to be used for the purposes of escape as incorporated within BS 9999.

CEN/TS 81-76: *Safety rules for the construction and installation of lifts. Particular applications for passengers and goods passenger lifts. Part 76: Evacuation of disabled persons using lifts* is not currently a standard but a Technical Specification (TS), and so does not have the same standing as a full European Standard (EN). The TS is published in the UK as DD CEN/TS 81-76 (BSI, 2011b) the national forward of which makes clear that the relevant requirements for lifts for the evacuation of disabled persons in the UK are contained within BS 9999, Annex G.

The scope of CEN/TS 81-76 is for the assisted evacuation of persons with disabilities (it does not include for the general evacuation of buildings and self-evacuation) and so has a similar application to the requirements discussed above.

At the time of writing, the European standards-making body (CEN) has work in hand for the development of a European Standard based on CEN/TS 81-76. Publication of a full EN standard is, at the time of writing, some way off. However, if a harmonised European Standard EN 81-76 is published, the requirements of BS 9999 and other UK requirements would need to be brought into line with the harmonised standard. Readers are advised to check the status of these documents and be guided by the contents of them, if and when they are revised.

6.5.2 Access/egress for persons with limited mobility

It is a requirement of UK legislation that access provision should be linked to egress provision and, since lifts were already being used to provide access for persons with limited mobility, concern was expressed over the possible use of such lifts for escape. In response to this BS 5588-8 was first published in 1988 with recommendations that are now contained in BS 9999. This standard provides detailed guidance for evacuation procedures and on the types of lift or other provisions that may be required. Although

wheelchair and stair lifts fitted to a stairway may be suitable for access, they are not specifically mentioned as a suitable means of escape. Furthermore, stair lifts may impair evacuation if they reduce the usable width of stairways. Escalators are also excluded as a suitable means of escape, both for disabled and able-bodied persons other than in the most unusual and specialised situations such as airports and underground railway systems.

BS 9999 recommends that the lift be operated under the direction and control of authorised persons using an agreed evacuation procedure and the successful operation of escape lifts is very dependent upon the competence of the lift operator and the effectiveness of the building management procedure. Only disabled persons should use the lift because fixed stairs are still considered as the appropriate means of escape for able-bodied persons. It is not intended that persons with limited mobility should evacuate themselves from the building unaided, even where a lift is provided, and other means such as the provision of a refuge may need to be considered.

Fire evacuation procedures should not include the isolation of electrical circuits that supply the lift or its lighting, communication or ventilation. Evacuation plans should consider the early evacuation of disabled persons i.e. at the first sign of an emergency. At this first stage of evacuation the need to evacuate able bodied persons might not yet have been identified. This is a short period when valuable time can be used to evacuate persons with a disability in an organised manner.

6.5.3 Evacuation lifts for healthcare buildings

In hospitals and similar buildings, not all the occupants can use the stairs or lifts in the conventional manner. Some patients may be compelled, for medical reasons, to remain in their bed. In such buildings evacuation may need to be made horizontally instead of vertically at least in the initial stages of an emergency.

Horizontal evacuation involves moving beds and their patients horizontally through the buildings from a fire risk area to another safe area away from the emergency. The patients are then retained in this area until the emergency has passed or, if conditions deteriorate they may be taken down and out of the building, if necessary by lift.

The Department of Health has published a number of specifications for such buildings and their lifts as Health Technical Memoranda (HTMs). These include the following:

- HTM 08-02: *Lifts* (DoH, 2010)
- HTM 05-01: *Managing health care fire safety* (DoH, 2013)
- HTM 05-03: Part E: *Escape lifts in healthcare premises* (DoH, 2008)

These documents call on the use of standards such as BS EN 81-1, BS EN 81-2 and BS EN 81-72, as well as referring to BS 9999.

In addition to a normal evacuation lift as described in BS 9999, evacuation and escape bed lifts are required for the evacuation of bed-bound persons, in the case of an

emergency, under the direction of either the building management, or the rescue service in line with BS 9999.

The needs, requirements, mode of operation and control (lift warden) of an evacuation lift are determined by the fire strategy of the healthcare building. Refer to HTM 05-03.

The basic requirements for the lift are similar to those called for under BS EN 81-72 but there are differences such as a roof trap door in lifts serving operating theatres to enable medical access in the event of a stoppage, different communication system, larger car and doors sizes etc.

As Health Technical Memoranda (HTMs) are under continuous revision, the information provided here should be checked against the latest available editions.

6.6 Design considerations for evacuation lifts

6.6.1 General

BS 9999 makes recommendations concerning the provision of lifts suitable for the evacuation of persons with limited mobility. These recommendations are based on the primary provision of an evacuation lift to BS EN 81-1 or BS EN 81-2. As noted earlier, BS EN 81-1 and BS EN 81-2 will be withdrawn on 31 August 2017. The new standard, BS EN 81-20 is not yet referenced by standards such as BS 9999 but this should not preclude their use.

The recommendations in BS 9999 for evacuation lifts include:

- The lift car should be of at least 630 kg rated load, 8-person capacity and the internal dimensions of the car should be at least 1100 mm wide by 1400 mm deep.
- Power-operated doors should be fitted, providing an opening of at least 800 mm by 2000 mm. The landing doors should provide at least half an hour fire resistance or as required by the fire resistance of the building and by building regulations.
- There should be two separate fire-protected power supplies although an alternative circuit fed from the main building intake could also be used. See section 6.6.3. However, two-stop hydraulic lifts may not require an alternate means of supply since they can be manually lowered and may not require a special switch to enable the lift to be quickly brought to the main lobby.
- The lift should conform to BS EN 81-70 for access for persons including those with disabilities.
- A separate communications system should be provided between the car, machinery space emergency and test panel, the main lobby and storeys where there are persons requiring evacuation.
- A switch, such as a triangular-key type switch, marked 'Evacuation Lift', should be located at the final evacuation floor. Where required to prevent unauthorised use, the switch can be key-operated or a break-glass type. Operation of this switch should

cause the lift to slow down, stop and return to the main evacuation floor without undue delay. While returning it should be prevented from answering any landing calls and once at the lobby, it should park with its doors open and then respond only to car calls. The lift should be under the sole control of the appointed user (fire warden).

Where evacuation lifts are installed, these should be clearly signed at the fire service access level; relevant information should be available detailing the locations of the main switch, rescue controls and machinery spaces.

BS 9999 allows alternatives to a separate evacuation lift, as follows:

- A firefighting lift (i.e. a lift to BS EN 81-72) that the fire and rescue service has agreed may be used prior to their arrival, as it should already have the main features required. Different fire and rescue services have different operational procedures regarding the use of firefighting lifts for disabled evacuation. These should be agreed as part of the building design including the fire and rescue service. *Note:* for a firefighting lift, a communication system is not required to each landing but this is required for an evacuation lift so should be provided where a firefighting lift is intended to be used for evacuation.
- In some circumstances a lift not designed for evacuation may be usable for evacuation in certain situations. If this is to be considered then a suitable fire risk assessment should be undertaken to evaluate whether the lift meets the functional recommendations of an evacuation lift. Refer to BS 9999 for some issues that should be included in the risk assessment and more guidance.

6.6.2 Operation of the communication system

BS 9999 recommends that, except in two-storey buildings, some form of communication system should be provided to enable the rapid and unambiguous identification of those storeys where persons with limited mobility are present who may require evacuation, and the relaying of this information to the persons operating the evacuation or firefighting lift. Alternatively, requests may be made by the persons requiring assistance to the person controlling the evacuation using visual indicators or by telephone, and these may then be relayed to the lift operator by telephone, intercom or radio transceiver.

Communication is a key item during a fire and simple systems generally prove the most reliable. For example, at each landing, adjacent to the lift, there could be a telephone system which connects it to the lift main evacuation lobby. When the lift is required for a particular floor, the person responsible for the evacuation of persons with limited mobility from that floor can request the person in charge of the main lobby to despatch the lift, who relays the message to the lift driver by means of the lift intercom system.

The provision of complex automatic systems is not recommended, and is unnecessary because it is not intended that persons with limited mobility should evacuate themselves from the building.

6.6.3 Other considerations

BS 9999 (BSI, 2008) includes recommendations for evacuation lifts in Annex G. There is a number of issues which are worth noting in this discussion.

BS 9999 recommends that the primary electrical supply for an evacuation lift should be obtained from a sub-main circuit exclusive to the lift and independent of any other main or sub-main circuit. It allows for other lifts in the same well to be fed from the same primary supply, provided that the supply is adequate for the purpose. These requirements are similar to those in BS 5655-6 and discussed in section 12.2 of this Guide.

As noted above, except for hydraulic lifts serving two storeys only (the lower of which contains a final exit to a place of ultimate safety), an alternative power supply is recommended for an evacuation lift. Secondary power supplies are often provided for evacuation lifts to satisfy clause G.2.2 of BS 9999, which also allows the provision of a separately fused protected circuit fed directly from the main incoming electrical supply to the building located in a fire protected enclosure. Where an automatically started generator is used, the discussion in section 12.5 is relevant. Generally, for the considerations for a secondary power supply and protection of the cables for an evacuation lift, much of the guidance in 12.6 is relevant. However, as noted above, BS 9999 also includes the possibility of an alternative supply cable from the building's main intake.

It should be noted that clause G.2.2 of BS 9999 recommends that a battery inverter is not normally acceptable as an alternative power supply, unless it can be demonstrated that it is:

- capable of operating the lift at normal speed, and
- of sufficient capacity to enable the lift to operate for a sufficient number of complete cycles to serve and evacuate every refuge associated with the shaft.

This would clearly require something like an uninterruptible power supply (UPS) of considerable capacity. The design of such a system involves complex issues including considerations of, for example, battery capacity as the system ages, periodic testing, and some means of informing the building management and maintenance personnel of the health of the batteries.

For details of other considerations, although not explicitly recommended by BS 9999, these could be considered by analogy to those discussed for firefighting lifts for the machine room location in section 6.3.3, protection from water in section 6.3.4.

6.6.4 Routine inspection, maintenance and thorough examination

Chapter 15 discusses general issues to do with routine inspection, maintenance and thorough examination of lifts. This section looks specifically at further guidance in relation to evacuation lifts.

The background to The Regulatory Reform (Fire Safety) Order 2005 (RRO) (TSO, 2005), The Fire Safety (Scotland) Regulations 2006 (TSO, 2006) and The Fire Safety

Regulations (Northern Ireland) 2010 (TSO, 2010) were discussed in section 6.4.2. In addition to the implications for firefighting lifts described there, the legislation also places responsibilities on the responsible person (RP) or duty holder; requiring that any facilities, equipment and devices provided in respect of the premises are subject to a suitable system of maintenance and maintained in an efficient state, working order and good repair. This is understood to apply to evacuation lifts and lifts with a fire recall function.

Irrespective of such specific legislation and other applicable legislation, the building owner should make provision or ensure that:

- regular checks are made of the lift including a check the fire recall feature and that, on operation of the evacuation lift switch, the lift recalls to the exit floor and goes into evacuation control
- there is a suitable maintenance contract in place which covers the lift including its evacuation switch and evacuation lift features to ensure reliability
- the features of the evacuation lift are included within the scope of thorough examination by a competent person and, where these cannot be examined by the competent person (e.g. fire alarm interface or operation on a secondary power supply), should call for supplementary testing
- labelling and notices specified in the various applicable standards are displayed
- where the lift is repaired or modernised, the evacuation features are retained or, where relevant, improved to keep the equipment to current standards.

For more guidance to lift owners including guidance on thorough examination and on LEIA's code of practice for maintenance, refer to the lift owners section of the LEIA website (<http://www.leia.co.uk/index.php?cid=25>).

6.7 Using lifts for general evacuation

Since the destruction of the World Trade Centre in New York on 11 September 2001, there has been considerable discussion relating to the merits of allowing all building occupants to use lifts during an emergency. The International Standards Organisation (ISO) has carried out a major study of the possible implications of using lifts for the evacuation of everyone from a building. The study contained in PD ISO/TR 25743 (BSI, 2010) indicates that whilst it is possible to design a building using lifts for evacuation the problems to be addressed are complex and in many instances expensive to implement. PD ISO/TR 25743 provides a tool to assist all parties in the design team. It indicates major issues to be addressed and hints at how they may be addressed.

Further work by ISO resulted in ISO/TS 18870: *Requirements for lifts used to assist in building evacuation* (ISO, 2014), which establishes requirements for lifts to provide an automatic evacuation service albeit with the 'intelligent' control of the evacuation and scheduling of the lifts from outside the lift installation. As for the earlier PD ISO/TR

25743, the specification of lifts to assist with the general evacuation of the building population is still generally limited to high rise buildings where a detailed study and design can be made using these techniques.

In the UK, ISO/TS 18870 has not been published as a standard but as a 'published document': PD ISO/TS 18870 (BSI, 2014b). Therefore it does not have the status of a standard and has not been developed in line with UK Building Regulations. It can be used for ideas but will have to be discussed in detail with either fire engineers or building control before serious consideration of its use. Potential users of ISO/TS 18870 are advised to consult it and should note the following:

- The existence of ISO/TS 18870 does not indicate if it is acceptable or permitted to use lifts for building evacuation. It only provides guidance on measures required should those persons responsible wish to make such a decision.
- The decision to use lifts for building evacuation is one which is essentially a building design issue. Although lift engineers can advise on lift-related issues, they are not building design or fire engineering experts.
- The requirements for evacuation lifts for persons with disabilities and impaired mobility were referenced in the earlier discussion. Careful consideration should be made to integrating these with those of a general building evacuation using lifts as considered in the ISO document discussed above.
- Careful consideration should be made of the requirements of ISO/TS 18870, since some of these may deviate from the requirements of harmonised standards such as BS EN 81-1 and BS EN 81-2 (until 31 August 2017), and BS EN 81-20. Where there are deviating requirements, these should be resolved and a notified body approval obtained for the design solution.
- Research work into the behaviour of people during evacuation of a building suggests that many people would be reluctant to use lifts, especially faced with crowded lobbies/refuges and lengthy waits for lift service. This is, no doubt, partly a consequence of for many years being told 'in the event of fire, do not use the lifts'.

The UK government has recognised that it may be possible to include lifts as part of an evacuation strategy in very high rise buildings but if this is done there should be no permitted reduction in the number of escape stairways or other provisions; in other words the lifts can be an addition to all the standard provisions.

In buildings with less than 25 floors there is unlikely to be any reduction in the time to evacuate if lifts are used and the time may well be increased above that which can be achieved by using stairs.

These and many other issues should be addressed by the building design team who must determine what strategy to adopt in the building for a given emergency and how the lift should respond. The use of lifts should not be considered as an option without at first detailed discussions taking place between the design team (that should include a fire engineer, lift contractor) and building control.

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7 Lift components and installation

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7 Lift components and installation

7.1 Introduction

The Lift Directive 1995 (OJ, 1995) opened the doors to much innovation in lifts. This has come about as there is no longer a legal requirement for any particular standard to be followed when designing a lift. Instead, the manufacturer is legally obliged to meet the requirements of the Lift Directive (implemented in the UK under the Lift Regulations 1997 (TSO, 1997)) by some suitable means. This freedom has resulted in the introduction of new components and technologies into the lift market. The legislative freedom combined with requirements for ever-safer products has resulted in a number of new or improved components being introduced.

This chapter describes the main components used in modern lifts, both electric traction and hydraulic, and their basic installation requirements. The main components of a lift are its prime mover (traction machine or hydraulic pump, depending on the type of drive), the lift car, counterweight (if used), guide rails, entrances, safety gear and governor, buffers, ropes and fixtures (i.e. buttons, indicators and switches).

Typical arrangements and the main components are indicated in Figure 7.1 for electric traction lifts and in Figure 7.14 for hydraulic lifts. Many variations of these basic arrangements are possible but the component parts are fundamentally the same.



Caution: both BS EN 81-1 (BSI, 1998a) and BS EN 81-2 (BSI, 1998b) are referred to in the text. BS EN 81-1 covers electric lifts and BS EN 81-2 deals with hydraulic lifts. These standards will be withdrawn by 2017 and replaced by BS EN 81-20 (BSI, 2014a) and BS EN 81-50 (BSI, 2014b). BS EN 81-20 deals with both electric traction and hydraulic lifts whereas BS EN 81-50 deals with tests and basic calculations such as traction and buckling factors.

Between 2014 and the 2017 withdrawal date, either BS EN 81-1 or BS EN 81-2 may be used, or manufacturers or specifiers may elect to use BS EN 81-20 along with BS EN 81-50. All these standards (i.e. BS EN 81-1, BS EN 81-2, BS EN 81-20 combined with BS EN 81-50) provide a presumption of conformity with the Lift Directive until BS EN 81-1 and BS EN 81-2 are withdrawn.

7.2 Electric traction drives

7.2.1 General

Electric traction drives can be grouped into several categories based on the motor type and its control.

Geared traction drives systems:

- single speed AC
- two-speed AC
- variable voltage AC
- variable voltage, variable frequency AC
- variable voltage DC.

Gearless traction drives systems:

- variable voltage DC
- variable voltage, variable frequency AC.

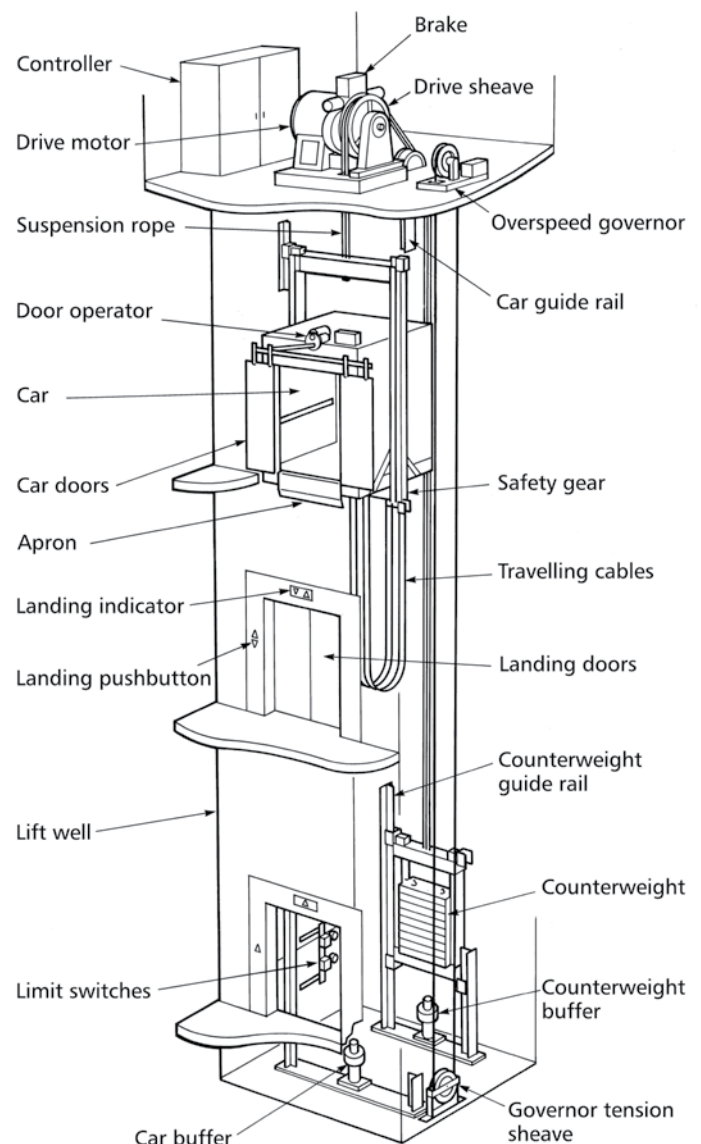


Figure 7.1 Electric traction passenger lift: principal components

To the above types should now be added linear induction drives, see section 7.2.9. Such drives have failed to become popular in the market for various reasons, not least of which is price.

Historically, the required lift speed and ride quality have determined to a large extent which type of drive is used for a particular application. Today, with solid-state control incorporating feedback techniques (see section 8.4), good ride comfort and levelling accuracy can be obtained for most types of electric traction lifts without large cost penalties.

In the past, DC motors have provided the best ride quality because the speed of the motor can be easily controlled using a DC generator with a variable output (see section 8.5.1). Consequently, DC motors have been used for the majority of applications requiring a smooth ride and accurate levelling. During the 1980s, static converters were replacing DC generators as the means of supply for large DC motors. Compared with DC generators, static converters are more efficient and provide improved control (see section 8.5.2).

Improvements in the control of AC motors mean that good ride quality may now be achieved using AC motors. Some manufacturers have used AC motors with helical or worm reduction gearboxes to attain speeds of up to 2.5 m/s. Advanced voltage and frequency control techniques have also led to the introduction of AC compact gearless permanent magnet drives. These provide ride quality to match DC gearless machines for any range of speeds.

Most modern drives use variable voltage variable frequency, (VVVF) control systems with or without regeneration. Many compact designs have been developed using. For guidance on the application of various drive systems refer to BS 5655-6 (BSI, 2011a).

7.2.2 Gearless machines

The assembly comprises a drive motor, drive sheave, brake, direct current armature (or rotor in the case of AC drives), supporting bearings and (possibly) bedplate, deflector, or double wrap sheave. Gearless machines have generally been used for high-speed lifts, i.e. speeds from 2.5 m/s to 10 m/s. They are, however, now used for all speeds, including low speeds.

Figure 7.2 shows a typical gearless machine. Size, shape and weight may vary considerably between manufacturers but the basic principles and components can be the same.

Until recently, the motor in gearless machines has always been of the DC type but, with the development of high-speed variable frequency drives, AC motors are being widely used. Whichever type of motor is employed, the power developed is transmitted directly to the driving sheave, which is located on the same shaft as the motor. Hence the sheave rotates at the same speed as the motor. The main shaft is supported on two large bearings that may be of the sleeve, roller or ball type. Sleeve bearing are rarely used these day but still found in older machines.

The brake drum is usually formed as an integral part of the driving sheave and this may be one of several types, depending on the type of brake, e.g. external calliper,

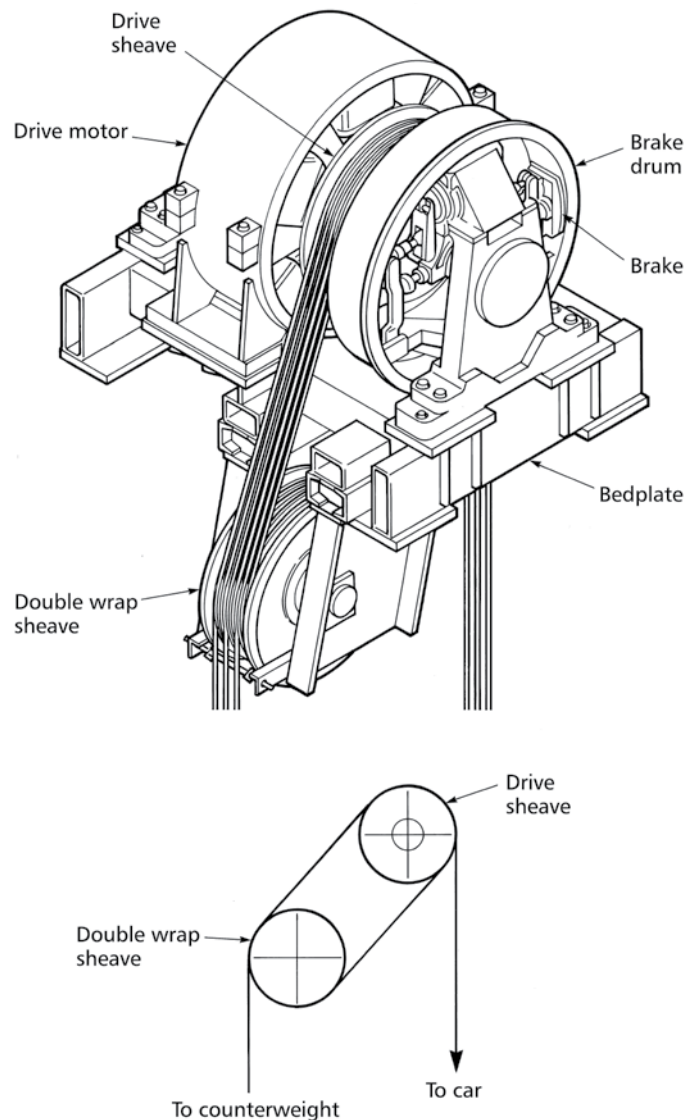


Figure 7.2 Typical gearless machine (courtesy of Otis Ltd.)

internal calliper or disc. Each type has advantages and disadvantages but the main consideration is that the type used should satisfy the relevant code requirements for the country in which it is to be installed. For Europe the requirement of BS EN 81-1 (BSI, 1998a) and BS EN 81-20 (BSI, 2014a) is that it should be capable of stopping the car when carrying 125% load at full speed whilst travelling down.



Caution: BS EN 81-1 will in time be superseded by BS EN 81-20, see section 7.1. The requirements for brakes remain unchanged. The basic requirements are that the brake is of a friction type that operates by loss of power (fail-safe) and, with the exception of the coil, has all of its components taking part in its application provided in at least two sets. With a failure of one brake set, the remaining set(s) must have sufficient braking effort to stop and hold the car, travelling down at rated speed with rated load and ascending with an empty car. The rate of retardation of the car shall not exceed that resulting from operation of the safety gear or buffer, $1 g_n (= 9.81 \text{ m/s}^2)$.

The brake is used only during emergency stopping and when at rest to hold the lift car. Under normal operating conditions, speed controls are normally employed to bring

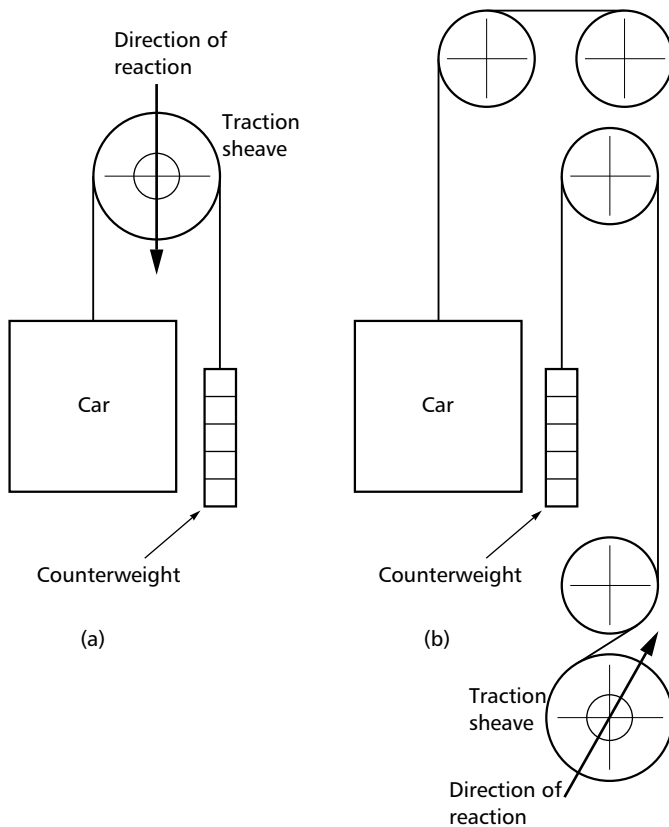


Figure 7.3 Sheave shaft load; (a) machine above with load acting directly downwards, (b) machine below with load acting upwards

the car to rest without the use of the brake. This means that the brake is little used and the linings can be slow to bed-in if hard materials are selected. For this reason, and because of the low rotational speed of such units, a relatively soft material is usually used.

7.2.2.1 Sheave shaft load

The load lifting capabilities of the machine are not limited by the power of the motor alone. During the design, certain bearings, bolts, steel section and grades of steel may have been selected for the construction of the unit. The materials used and the way in which the components are assembled can place a maximum limit on the load that the main shaft can support safely. This is referred to as the sheave shaft load, the value of which can be obtained from the manufacturer.

The sheave shaft load capability of the machine may vary depending upon the direction in which the load is applied. If the machine is located at the top of the building, with the load acting directly downwards, see Figure 7.3(a), the unit can generally support a higher load than if the ropes are deflected as shown Figure 7.3(b). Locating the machine at the bottom of the building usually results in an upward pull which can drastically reduce the sheave shaft load capability. This may necessitate the use of a much larger machine than was first envisaged. In the case of machines used in a double wrapped configuration, the sheave shaft load is approximately double the load of a single wrapped configuration. Standard layouts and other arrangements are considered in section 7.2.7.

7.2.2.2 Drive sheave

Gearless machines usually employ either a sheave cut with a specially formed traction groove, see Figure 7.4 (see also

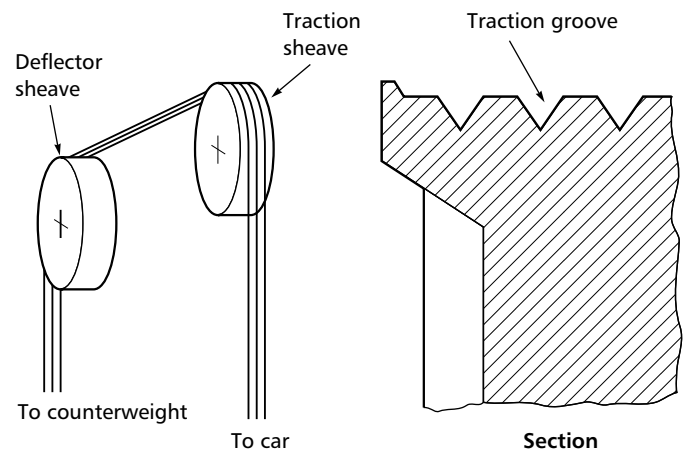


Figure 7.4 Single wrap arrangement with 'V' groove and detail of traction sheave

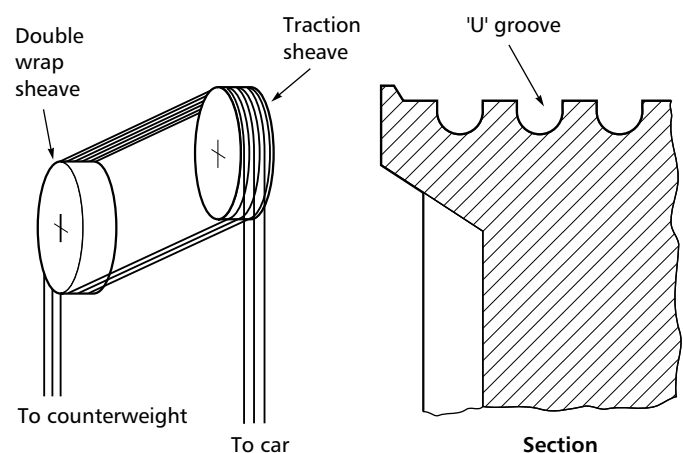


Figure 7.5 Double wrap arrangement with 'U' groove and detail of traction sheave

section 7.15.3, Figure 7.45), or are double wrapped, whereby the lift ropes pass over the drive sheave twice, see Figure 7.5.

Each method has its merits and can provide the required traction to move the car and ensure a long rope life, if properly designed. The main disadvantage of the double wrap method is that it takes up additional space since either a secondary level or pulley room should be provided or the unit should be raised to facilitate servicing of the double wrap sheave. However, with very large loads or speeds greater than 3.5 m/s, it is often the only method available.

As gear reduction is not employed, the rope speed is equal to the circumference of the drive sheave multiplied by the rotational speed (rpm) of the motor. A sheave diameter of 620 mm requires a motor of only 77 rpm to achieve 2.5 m/s. Large gearless units with slow rotational speed compared with geared machines often do not need sound isolation between the machine and structure. Small relatively light compact machines may require isolation and the manufacturer should be able to provide advice on this if required.

7.2.3 Geared machines

These comprise a traction sheave or drum, gearbox, brake, motor and possibly bedplate. It may also include a deflector sheave if mounted as an integral part of a bedplate assembly, see Figure 7.6. Strictly, however, the deflector sheave is not always part of the machine assembly.

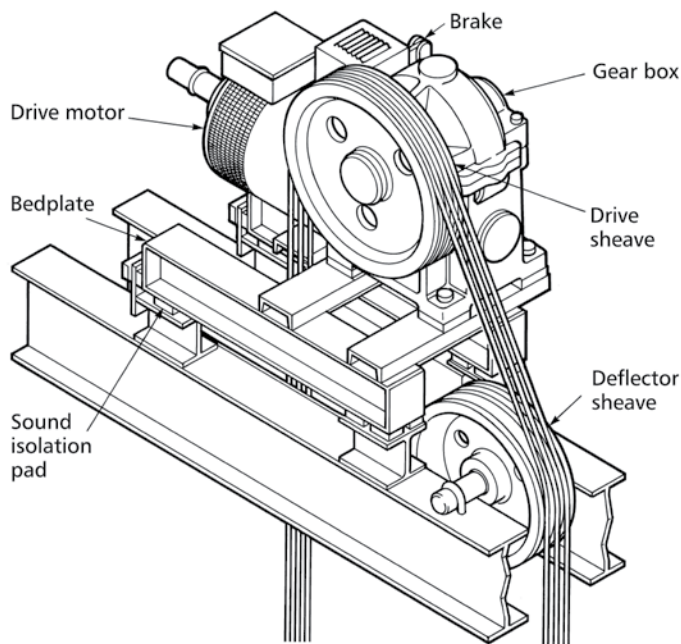


Figure 7.6 Typical geared machine (courtesy of Otis Ltd.)

Geared machines are generally used for speeds between 0.1 m/s and 2.5 m/s and are suitable for loads from 50 kg up to 10 000 kg or more. The size and shape vary considerably with load, speed and manufacturer, but the underlying principles and components are the same.

7.2.3.1 Motor

The motor may be of the AC or DC type, either foot- or flange-mounted. Foot-mounted types are available in a wide selection of sizes and makes, while flange mounting provides accurate alignment and, usually, a more compact design. There are no outstanding advantages for either type but for certain applications one particular type may be preferred. For example, for a lift on a ship, a foot-mounted motor would be preferred because of the greater availability of spare parts throughout the world. Whichever arrangement or motor type is employed, the motor transmits its power to the traction sheave or drum via reduction gear.

7.2.3.2 Gear box

Worm reduction gear, comprising a worm shaft, cut with a coarse helical thread, and a worm wheel, is still the most common worldwide although helical gears have started to appear.

The worm shaft has a high running speed compared with that of the worm wheel and therefore is made from either case-hardened or high-grade carbon steel. Both these steels have advantages and disadvantages, but the essential requirement is the smooth running and long-life of the finished assembly. Therefore manufacturers choose materials best suited to the particular application.

The worm wheel can be made from various materials but bronze is by far the most common and has considerable advantages over the alternatives. However the performance and reliability of the complete unit is more important than the materials employed for the component parts.

The worm may be cut with one, two, three or more threads or 'starts'. The number of teeth on the worm wheel divided by the number of starts on the worm determines the ratio of the gear. For example, 48 teeth on the wheel and 4 starts on the worm gives a ratio of 12:1.

By selecting different ratios a large combination of speeds and loads can be obtained from a single machine type. Each manufacturer has its own selection of ratios for a particular machine and it is not practical to specify a special ratio as any new design can require expensive retooling and extensive testing.

The worm may be mounted vertically or horizontally, either above or below the worm wheel. Again each arrangement has its merits but none has any significant disadvantage. The worm shaft is supported by two bearings of its own or utilise one of the motor bearings. Whichever arrangement is selected, one of the bearings acts as a thrust bearing to prevent the worm from moving horizontally or vertically, depending on the orientation of the worm. Depending on the design, a thrust movement of one or two thousandths of an inch may be allowed; in other cases no movement is tolerated. The manufacturer's requirements should always be met in this respect.

7.2.3.3 Worm wheel

The worm wheel may be supported on bearings, one of which may be either inboard or outboard of the traction sheave which is mounted on the same shaft. There is much argument as to the merits of inboard and outboard bearings. For example, the inboard bearing allows easy replacement of the sheave while the outboard bearing allows easy servicing of the bearing. The maintenance aspect, however, is insignificant since both components, if properly designed, can provide long service and neither arrangement should require frequent dismantling.

One of the main shaft bearings also serves as a thrust bearing to limit lateral movement of the shaft. Again, the manufacturer's clearances, if any, should be accepted. With the use of modern bearings, clearances are often required to be set at zero or less so as to preload the bearing.

7.2.3.4 Gear life

As with the gearless units described in section 7.2.2, the load lifting capabilities for geared machines may be limited by the motor size, the load capacity of the main shaft and its bearings (sheave shaft load), and the load and kilowatt capacity of the gearbox. The gears may have been designed to transmit a certain amount of power for a given life. The life can be reduced by the transmission of excessive power or extended if reduced power is transmitted. While worm gears may appear simple their design is complex and there is much debate on the calculation of gear life.

BS 721-1 (BSI, 1963) or BS 721-2 (BSI, 1983) provide a basis for such calculations, but need some modification to be realistic for lift gears. To make the calculation of gear life meaningful it is necessary to determine the load carried and the period for which it is carried. In a lift, the load is constantly varying between very light (i.e. empty car) and full load. The gear is not running in the same direction continuously and, for large portions of the day, it is not

running at all. Most lifts spend more time at rest, being loaded and unloaded, than running.

It is easy to 'over-engineer', adding unnecessary costs to the installation, by assuming worst-case conditions, such as full load for the life calculation.

At present, gear life is usually expressed in hours, with 15 000 to 20 000 hours being typical. This roughly equates to 15 to 20 years for a lift serving the average office building. It may be tempting to select a higher figure than this, but longer life is achieved by over sizing the gear which results in extra costs. In most commercial buildings, lifts are modernised or replaced after 15 to 20 years (see chapter 16). At that time, the main components of the gear can also be replaced. If a 25-year gear life is selected, it is likely that the gear can be overhauled at the time of modernisation of the lift even though it may not yet be near the end of its design life. It may, however, be more cost effective to replace the unit with a modern more efficient machine.

7.2.3.5 Drive sheave

The power transmitted by the gear results in rotation of the worm wheel shaft to which the traction sheave or drum is attached. These items are usually fixed to the main shaft by keys and bolts.

The sheave material is sometimes simple cast iron, but is more usually a complex alloy providing a combination of properties such as machine-ability, strength, coefficient of friction and durability. The aim of the traction system should be to provide sufficient traction to hoist the car whilst ensuring good rope life. These criteria are affected by the rope size, number and type, rope pressure, sheave material, sheave groove type (see Figure 7.45), acceleration rate, and the presence of pollutants and abrasives in the atmosphere.

Most manufacturers have, through experience, determined the best combination of these criteria for their particular design and should not be required to use particular materials or rope types that they do not usually employ.

Premature rope or sheave failure is more often due to unequal rope tension than any other single factor and good maintenance is therefore essential. It is not unreasonable to expect the sheave to last the life of the machine provided it is correctly serviced.

7.2.4 Brake

At some position along the motor or worm shaft a brake drum is usually be provided. The usual locations are between the motor and gear or on the opposite end of the gear to the motor, see Figure 7.6. The requirements for the brake vary according to the drive system. Figure 7.7 illustrates an electromagnetic brake with spring above.

Simple single-speed and two-speed drives may use the brake for stopping at floors and for emergency stops. With more sophisticated motor controls, the brake may be used only for emergency stopping and parking. Whichever braking system is adopted, it should satisfy the requirements laid down in BS EN 81-1 (BSI, 1998a), i.e. it should be capable of stopping the car when carrying 125% load at full speed whilst travelling down. BS EN 81-1 will in time be

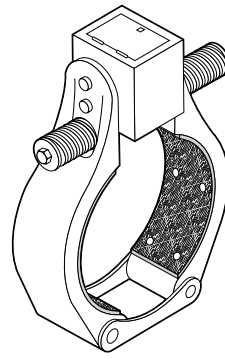


Figure 7.7 Electromagnetic brake with spring above

superseded, by BS EN 81-20 (BSI, 2014a). The requirements for brakes remain unchanged. The basic requirements are as described for gearless units in 7.2.2 above.

7.2.5 Machine bedplate

The gearbox, motor and brake may be assembled on a common bedplate. This fabricated steel structure serves to keep all parts in accurate alignment and allows one-piece shipment. It is important that the bedplate does not deflect under load thereby causing misalignment of the motor and gear. Some machines have the motor and brake as an integral part of the gear case, removing the need for a separate bedplate.

Properly designed and installed machines should be free from perceptible vibration and unusual noises. Worm rub marking on worm wheel teeth should be at or near the centre of the teeth. Any worm shaft float or worm-to-worm wheel backlash (running clearance between meshing teeth) should not produce audible knocking in the machine room or be felt within the lift car. The complete assembly can be

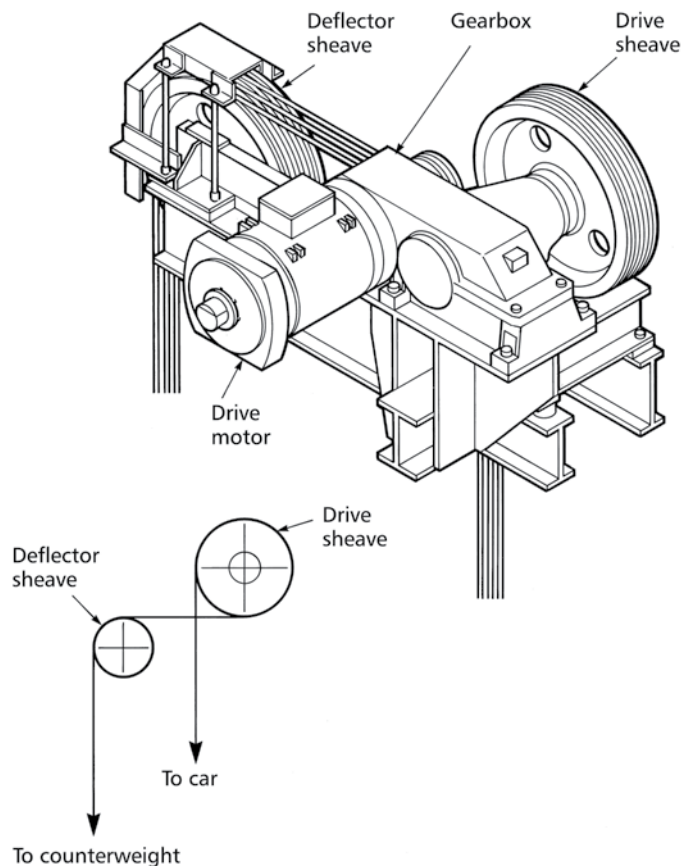


Figure 7.8 Typical longwrap machine and schematic showing rope path (courtesy of Otis Ltd.)

mounted onto isolation pads to separate it from the building structure. This may not be necessary in the case of bottom drive machines fixed to a solid foundation.

The unit should be installed with its sheave plumb and located within ± 2 mm of its required position. Some manufacturers may employ a roping system (i.e. 'overwrap' or 'longwrap') that requires the sheave to be at an angle to the vertical to avoid chafing of the rope, see Figure 7.8 (above). In this case the sheave angle should be as recommended by the manufacturer.

7.2.6 Planning and layout

Layout dimensions for electric traction lifts are detailed in BS ISO 4190-1 (BSI, 2010) and BS ISO 4190-2 (BSI, 2001). These dimensions should be used where possible because they are suitable for all lift equipment, excluding machine-room-less lifts. The dimensions, however, may be modified provided that careful appraisal of equipment and design is undertaken to ensure that the minimum clearances required by BS EN 81-1 (BSI, 1998a) or BS EN 81-20 (BSI, 2014a) are achieved. It should be noted that deviating from the dimensions given in BS ISO 4190 may result in additional costs because non-standard components may have to be fabricated.

The plan dimension of the lift well may increase if bottom drive and/or counterweight safety gear are to be incorporated, see section 7.6.3.

When a new lift is installed in an existing building and structural constraints prevent the provision of the refuge spaces required by the chosen design standard (namely BS EN 81-1, and/or BS EN 81-20), the need for any special derogation against clause 2.2 of the Lifts Regulations 1997 (TSO, 1997) is no longer obtainable having been replaced by either following BS EN 81-21 (BSI, 2009) or seeking a design examination from a Notified Body for lifts.



Caution: it should be noted that BS EN 81-20 defines new headroom and pit requirements. In some cases these may result in increased dimensions.

BS EN 81-21 defines the requirements where the headroom or pit dimensions are limited due to the structural constraints in an existing building. It is not intended that BS EN 81-21 be used to resolve space requirements in new buildings. If BS EN 81-21 is met by the installer, approval by a Notified Body is not required as this standard is harmonised under the Lift Directive and therefore provides a presumption of conformity with the regulations. However, derogation from the Department for Business Innovation and Skills (BIS) must still be sought if the required permanent refuge spaces are not available according to BS EN 81-21.

Whilst the most common issue with installing a new lift in an existing building is either lack of sufficient headroom or pit, other issues can exist such as limited well width or depth. BS EN 81-21 recognises this and permits a reduction in clearances between the car and counterweight, and also permits the reuse of a counterweight that runs in an existing separate well. Sheaves may also be incorporated in the well above the line of the car if provisions are made to retain the sheave in the event of a failure of its supporting shaft.

Where the pit or headroom is limited, provision must be made to ensure that sufficient safety spaces are created whenever a person enters the pit or accesses the car roof. These provisions can take many forms such as movable stops or a pre-triggered, bi-directional safety gear system etc.

If it is not possible to use a standard depth car apron a retracting or folding version is required.

Reduced machine room height, below 2.0 m, is permitted if all low areas are marked with yellow and black stripes as a safety warning.

In addition to the above additional safety notices are required to inform of the hazards that are present.

BS 5655-11 (BSI, 2005a) should also be consulted when modernising electric traction lifts in existing buildings.

Where a lift, which was installed before 1 July 1999, is modernised, see chapter 16, a derogation and Notified Body approval are not required since the Lifts Regulations 1997 apply only to new lifts installed after 1 July 1999.

Where a lift, which was installed after 1 July 1999, is modernised it should meet the requirements applicable at the date of its installation. This means that, after modernisation, it must still comply with the Lift Regulations applicable in 1999 and also meet any standards to which it was originally designed.

It is essential, however, that when any lift is modernised it is not made less safe as a result of the modernisation process. It is therefore advisable, as far as possible to bring the lift up to modern standards.

7.2.7 Machine position

BS ISO 4190-1 (BSI, 2010) and BS ISO 4190-2 (BSI, 2001) give standardised layouts utilising the traditional preferred top drive arrangement, i.e. where the lift machinery is positioned directly above the lift shaft, see Figure 7.9(a).

Other machine positions can be utilised to minimise headroom requirements. However each of the options may have implications in terms of additional costs, reduction in rope life, increased running noise or a poorer standard of ride quality. Roping systems are illustrated in Figure 7.44.

7.2.7.1 Top drive: machine adjacent

The machine is positioned adjacent to the shaft at high level; see Figure 7.9(b). A series of pulleys is utilised to achieve the correct rope alignment in the shaft below (see section 7.15).

7.2.7.2 Bottom drive: machine below

The machine is positioned directly below the lift shaft, see Figure 7.9(c). The ropes extend the full height of the lift shaft to overhead pulleys, which provide the correct rope alignment to the lift car and counterweight below. The overhead pulleys may be positioned in a pulley room directly above the lift shaft. Such pulley rooms require a minimum height of 1500 mm. However, the need for a

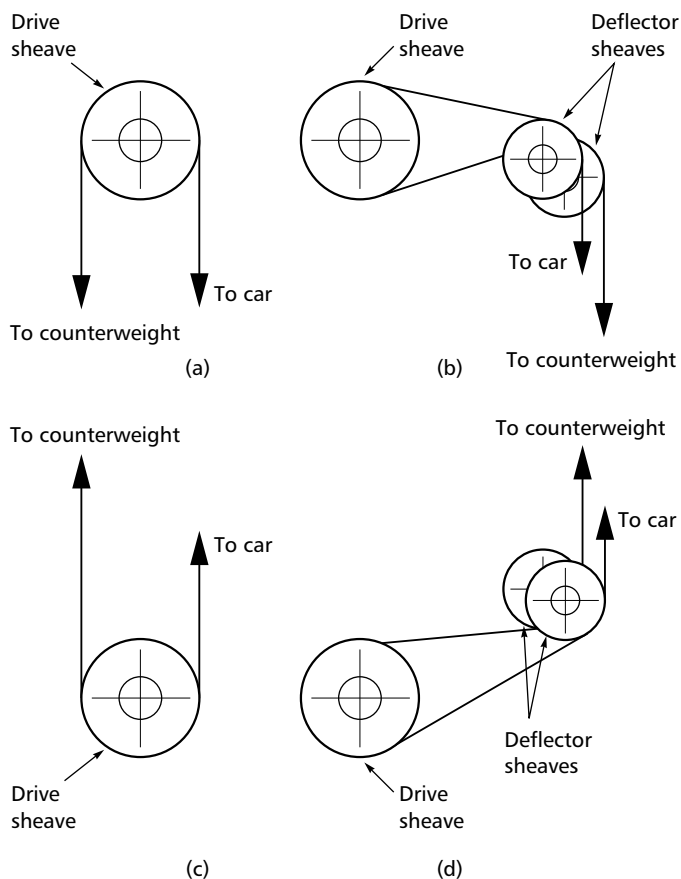


Figure 7.9 Machine position; (a) top drive, machine above, (b) top drive, machine adjacent, (c) bottom drive, machine below, (d) bottom drive, machine adjacent

pulley room may be avoided by using an underslung roping arrangement, see Figure 7.44(h). The top of shaft loadings are approximately double that involved where the machine is positioned overhead. Upthrust loads are also applied to the lift machine.

7.2.7.3 Bottom drive: machine adjacent

The machine is positioned adjacent to the shaft at low level, see Figure 7.9(d). The drive sheave can be supported on an extended gear shaft within the lift well or a series of pulleys can be utilised to achieve the correct rope alignment to the overhead pulleys. The pulley room arrangement is as described in section 7.2.7.2. The loadings at the top of the shaft are the same as for bottom drive with machine below. Openings for the sheave between the well and machine room should be boxed in as far as possible with fire resistant material, so that the remaining openings are as small as reasonably possible.

7.2.8 Machine-room-less lifts

Machine-room-less (MRL) lifts, see Figure 7.10, are now very common. In these lifts, the machine and other equipment that was traditionally placed in the machine room is located in the lift shaft or landing areas, see sections 5.2.5.3 and 5.3.7.3. With the lift machine placed in the lift shaft, special machines and servicing routines have been developed to make inspection of the equipment possible. It is very important for building designers to ascertain at an early stage exactly what may be the required to permit safe servicing and inspection of a given design. Each manufacturer may have their requirements that should be accommodated within the building design.

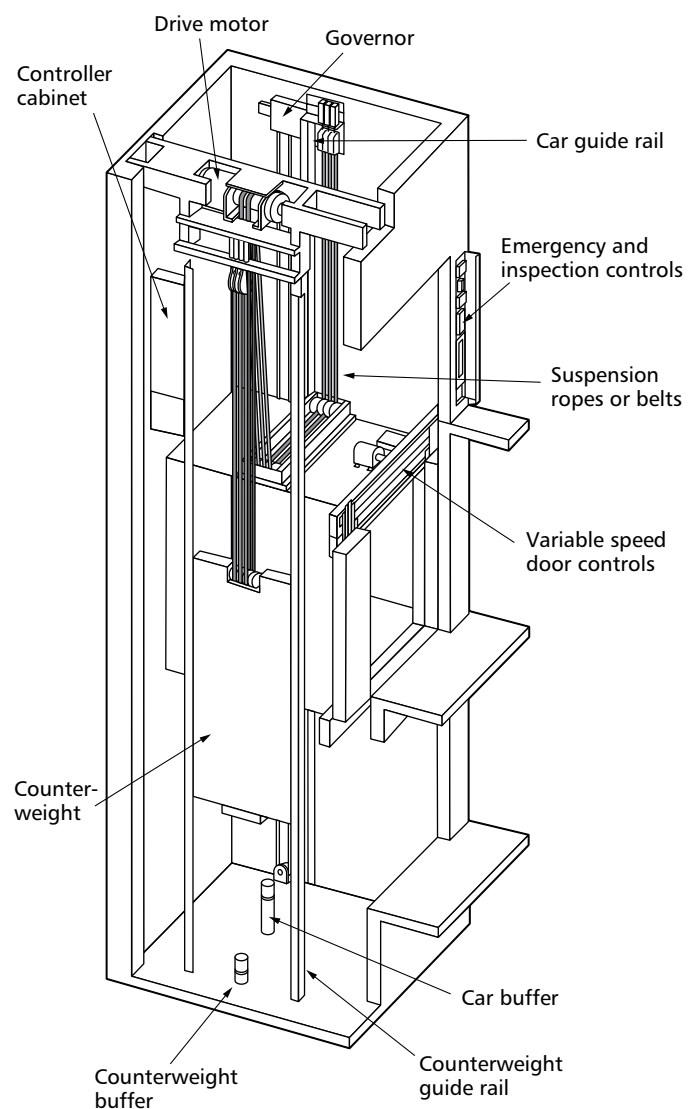


Figure 7.10 Configuration for a machine-room-less lift (courtesy of Otis Ltd.)

Amendment A2 (2004) to BS EN 81-1 (BSI, 1998a) introduced requirements for machine-room-less lifts to the BS EN 81-1. Until 2004 it was necessary for manufacturers to obtain a design examination certificate for each machine-room-less lift design because BS EN 81-1 did not recognise such lifts. Providing the manufacturer elected to follow BS EN 81-1+A2, Notified Body approval was not required. BS EN 81-1+A2 has since been replaced by BS EN 81-1+A3 and this is itself being replaced by BS EN 81-20 (BSI, 2014a) and BS EN 81-50 (BSI, 2014b), see section 7.2.6

The introduction of machine-room-less lifts has lead manufacturers to look at other possible changes in design. There are now some products for sales in Europe that have greatly reduced pit and or headroom requirement. It should be noted that putting such products into service in the UK was illegal even if the product had the approval of a recognised Notified Body for lifts. This is because Essential Health and Safety Requirement (EHSR) 2.2 under the UK Lift Regulations 1997 (TSO, 1997), enacting the European Lift Directive (OJ, 1995), required free space to be provided at the extreme positions. Derogation against this requirement was only available from the governments of EU member states and not from Notified Bodies. The EU governments could only provide a derogation under very special circumstances and then only on a job-by-job basis for their country and usually only for an existing building. In the UK, derogation had to be obtained by the owner

from the Department of Business Innovation and Skills (BIS), the government department responsible. If BS EN 81-21 (BSI, 2009) is followed, and being harmonised, some reduction in space is now permitted without a derogation under certain condition.

7.2.9 Linear induction drives

The principle of the linear motor is simple and has been known for many years. It may be regarded as a conventional AC motor 'unrolled' to lie flat. Such machines are sometimes referred to as 'flat-bed motors'. In principle, a linear induction motor could be mounted directly on the lift car but, in practice, this arrangement is ruled out by technical difficulties such as exposing the occupants to intense magnetic fields and, possibly, high noise levels.

Since the system may require a counterweight for reasons of efficiency, it is more logical to attach the motor to the counterweight. Figure 7.11 illustrates a typical modern lift design incorporating a linear induction drive in which the motor primary windings are within the counterweight frame. The secondary is provided by a vertical column for the full height of the lift travel. Note that the secondary is suspended from the top; the bottom fixing is simply to steady the column.

Such systems are in operation and have been proved to provide excellent service. Control is usually achieved by a variable voltage variable frequency drive as described in chapter 8. For various reasons, not least of which is cost, few if any of these lifts have been sold in Europe.

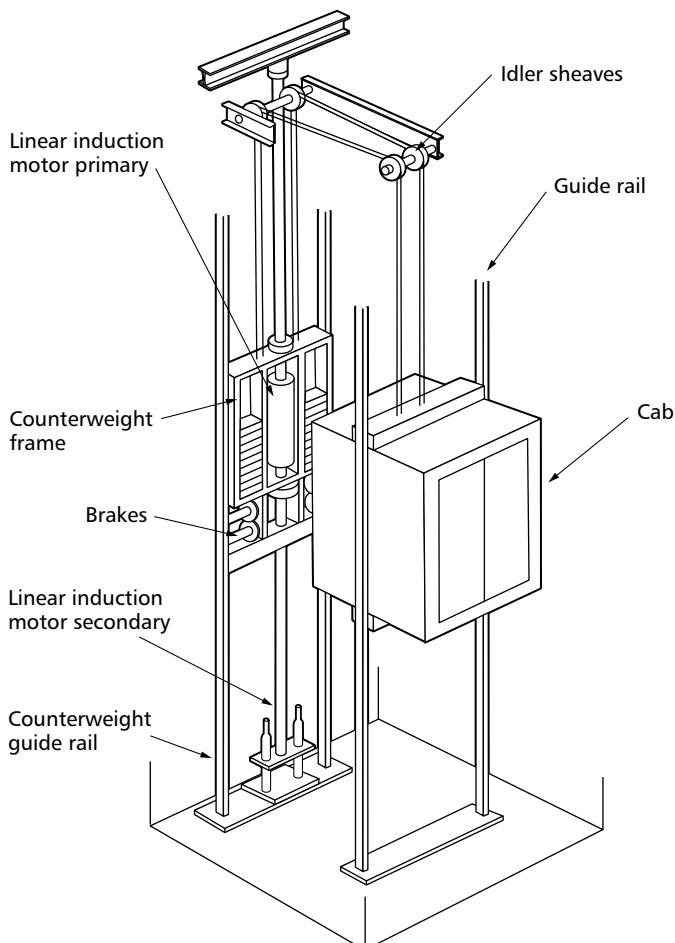


Figure 7.11 Arrangements for a lift using linear induction drive (courtesy of Otis Ltd.)



Caution: there appear to be no manufacturers offering products with a linear drive at this time in the European market. Any product coming from outside Europe with claims of compliance to standards or regulations should be checked with great care before purchase to ensure it will be legally accepted in Europe. At the time of writing (June 2015) linear drives are not addressed by any European standard and therefore require notified body approval.

7.2.10 Permanent magnet synchronous motors

Permanent magnet synchronous (PMS) motors are synchronous motors ideal for use where accurate control of speed and torque are required such as in a lift. They have high overall efficiency excellent controllability, fewer component parts as speed can be reduced without the use of a gearbox, a smaller size and therefore are capable of being installed in limited space. Such motors can typically replace existing machines where a motor and gearbox was previously used and are ideal for control by variable voltage variable frequency systems.

In a conventional squirrel cage AC motor the stator, when energised, creates high current in the rotor. In the PMS motor, permanent magnets are installed in the rotor so that it has a permanent magnetic field and does not require high currents to be induced in the rotor to operate. This arrangement results in a lower magnetising current demand from the supply compared to a squirrel cage motor with the same nominal speed. In practice this means smaller frequency converters and supply demands.

These motors regenerate power under any overhauling load condition such as empty car up or full load down. This may be regenerated back into the building or dissipated by some other load such as a resistor network.

Systems designed to regenerate to the building are a little more complex and hence more costly as the regenerated power will normally need some 'cleaning' and therefore on small or non-intensively used lifts, any power saving gained may be unworthy of the initial cost increase required for a fully regenerative drive.



Note: if it is thought that regenerated power is likely to be absorbed by building systems, this assumption needs to be checked by the building electrical system designer who should not assume that all building systems, such as air conditioning and lighting, are always available. This is especially true where lifts are intended to go into service prior to completion of the entire building, a common practice for very high-rise buildings. In such circumstances other provisions must be made to use or dissipate regenerated power. See chapter 8.

7.2.11 Car arrest systems

7.2.11.1 Rope brake

These devices usually consist of a pair of pads which the main suspension ropes pass between, see Figure 7.12. The pads have a material similar to a car brake lining that will

grip the ropes without damaging them. If the lift car speed exceeds a preset value, up or down the pads of the rope brake will be forced against the suspension ropes with sufficient pressure to cause the lift to be brought to a controlled stop. The force is usually pneumatic and generated by an air compressor.

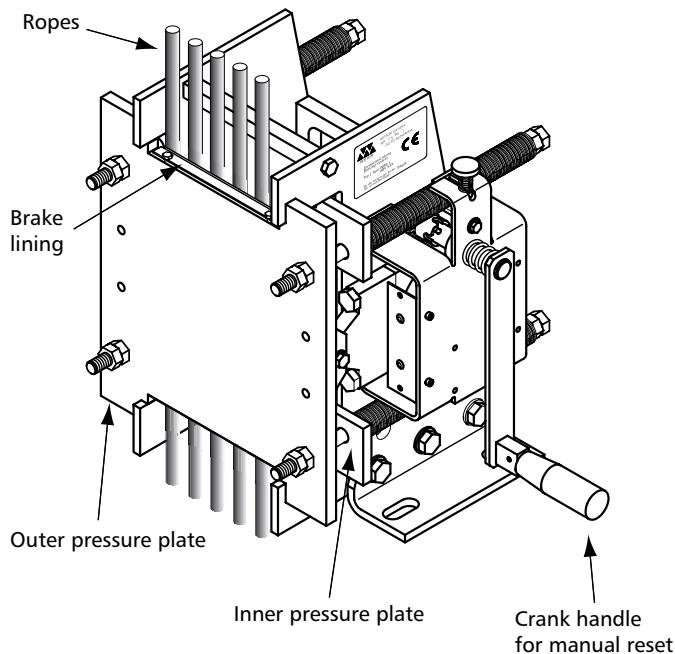


Figure 7.12 Rope brake (courtesy of Wittur K+S GmbH)

It can be made to operate on the car or counterweight side of the ropes although the car side is more often used. In addition to preventing excessive speed many such devices can be used to provide extra security of the car against movement during loading or during maintenance activities.

These devices are required to be type tested, CE-marked and provided with a declaration of conformity as safety components under the Lifts Directive (OJ, 1995).



Caution: according to the Pressure Equipment Regulations 1999 (TSO, 1999), where devices use a compressor to compress the air for operation and the stored energy is less than 250 bar/litre, the stored energy is considered relatively small and therefore does not requires a written scheme of examination by a competent person to ensure it remains safe. In the event the pressure vessel has a capacity greater than 250 bar/litre, it is subject to inspection by a competent person or a written scheme of examination. 'Competent' in this instance means someone competent in the inspection of pressure equipment.

7.2.11.2 Sheave brake

These devices normally act on the traction sheave or a disc directly adjacent to the sheave in much the same way as a disc brake on a motor car, see Figure 7.13. The device is usually held clear of the sheave by a magnet or other mechanical means and applied by spring force. In the event of the lift over-speeding up or down the device is activated and grips the sheave or sheave disc bringing the lift to a controlled stop.

These devices are required to be type tested, CE-marked and provided with a declaration of conformity as safety components under the Lifts Directive (OJ, 1995).

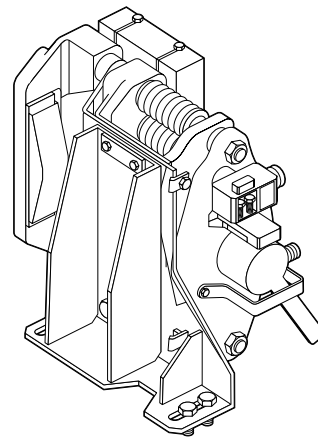


Figure 7.13 Sheave brake

7.3 Hydraulic drives

7.3.1 General

For certain applications hydraulic drives have many advantages over electric traction. However, when mis-applied, hydraulic drives can cause major problems for the building owner and users.

In its simplest form the hydraulic lift comprises a cylinder and piston located directly below the car. Oil is pumped from a tank by an electric motor. This raises the lift car. To lower the lift a valve is opened that allows the oil in the cylinder to exhaust back into its tank. See Figures 7.14 and 7.15.

Low-traffic passenger and goods, vehicle and bullion lifts are all suitable applications for hydraulic drives. For applications that involve very large loads, hydraulic drives often provide the best solution because the floor of the well carries the load of the lift and its contents. Hydraulic drives, with the cylinder in a borehole (see Figure 7.14), are often specified for observation lifts in low rise commercial buildings for aesthetic reasons, see section 5.5.2.

Hydraulic lifts are occasionally the only type suitable for installation in older buildings, originally designed without a lift, owing to restricted building height and possibly limited structural strength.

The practical maximum travel is typically 18 m. This is due to the strength and length of the hydraulics piston. As travel increases, larger diameter pistons have to be used to resist the larger buckling forces. This increases equipment costs and makes the use of the hydraulic drive less attractive when an alternative drive is available. Although rated speeds up to 1.0 m/s are available, the normal limit is 0.63 m/s.

Mechanical anti-creep mechanisms may be used where very heavy loads (i.e. greater than 3200 kg) are carried or forklift trucks are moving in and out of the lift. Active re-leveling systems may cause problems in these circumstances especially where small-wheeled trolleys are used.

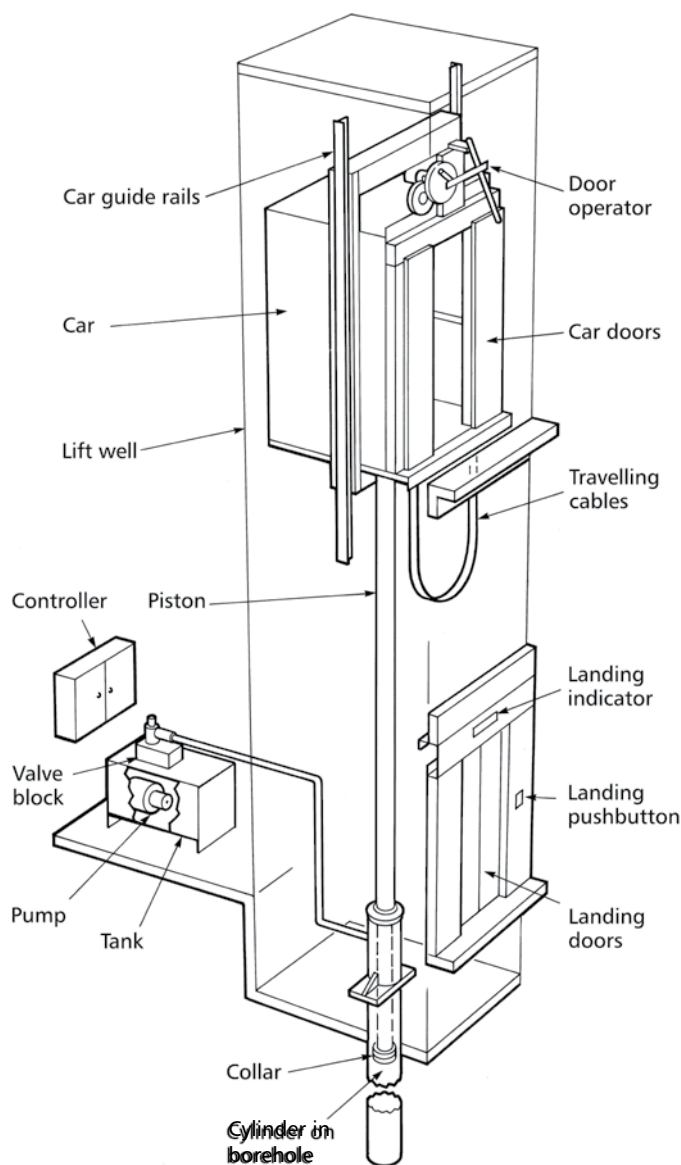


Figure 7.14 Hydraulic passenger lift; principal components (courtesy of Otis Ltd.)



Caution: care should be taken when considering hydraulic lifts for commercial buildings where continuous heavy traffic is expected since this may require lift speeds of 1 m/s or greater. Cooling is often essential under these circumstances since rated speeds greater than 0.63 m/s is generally accepted as the maximum operating speed for hydraulic lifts without cooling. This cooling requirement is often neglected in the design of the building and/or lift. Where two or more lifts are grouped together, overheating is likely to occur when one lift is removed from service, placing all work on the remaining lift.

Most hydraulic drives are not suitable for intensive use or for groups of lifts. Even duplex lift groups (i.e. two lifts) may exceed the recommended maximum number of motor starts per hour (i.e. 45) without additional cooling. Such cooling may be costly or impracticable. However, a hydraulic drive is sometimes the only solution, even in high traffic situations, due to building structure constraints. In these circumstances, extra cooling for the drive unit and oil should be provided.

For private residential buildings of up to eight storeys, hydraulic lifts may be used due to the low traffic levels in such buildings.

Simple hydraulic drives, which do not use a balance-weight, have the following attributes:

- low loads imposed on the building, therefore suitable for large goods lifts
- lift machine room normally positioned in the basement, or other low-cost area of the building
- economic for low-traffic, low rise applications with either single lift or a group of not more than two lifts
- a borehole location for a hydraulic cylinder may provide a visually attractive feature for low-rise observation lifts.
- depending on the layout and number of cylinders, the lift well area may be smaller than that for the equivalent electric traction lift.

Hydraulic lifts that use a balance-weight save energy but the major advantages of the simple hydraulic lift can be lost due to the increased loads on the building and the cost of fabricating and installing the additional mechanical components. Balance weights are one means to reduce power requirements although in recent years other devices have appeared such as gas-charged or hydraulic accumulators. See chapter 8. These devices store energy when the lift is descending and discharge when the lift is ascending. They help reduce energy consumption but do bring some points to consider depending on the operating pressure and energy storage fluid or gas used and location of the storage vessel.

The type of fluid or gas used should be checked with the manufacturer and a hazard chemical data sheet obtained in order to check its safety. Also the volume of the pressure storage vessel should be checked as it may be subject to the Pressure Equipment Regulations 1999 (TSO, 1999). Where devices use a compressor to compress the air or fluid for operation and the stored energy is less than 250 bar/litre, the stored energy is considered relatively small and therefore does not require a written scheme of examination by a competent person to ensure it remains safe. In the event the vessel has a capacity greater than 250 bar/litre is to be subject to inspection by a competent person or a written scheme of examination. 'Competent' in this instance means someone competent in the inspection of pressure equipment. It can increase maintenance charges and if located within the confines of the lift well may render the area subject to the confined spaces regulations. See chapter 8.

Pump rooms for hydraulic lifts should have adequate ventilation to prevent extremes of oil temperature (see section 12.10.1). In some cases air conditioning is required. The heat dissipation of the drive into the pump room can be obtained from the lift supplier.

With all hydraulic lifts the control equipment and pump unit can be positioned remote from the lift in a more suitable area of the building. In such situations great care is required as there are limitations on the maximum pipe work run that is possible. The supplier must be consulted where there is any intention to use a remote machine room and additional costs will be incurred.

When a new hydraulic lift is installed in an existing building and structural constraints prevent the provision of the refuge space required by BS EN 81-2 (BSI, 1998b), compliance with BS EN 81-21 (BSI, 2009) provides a possible solution. If this solution is not adopted the approval of a Notified Body for lifts is required for any proposed design. A special derogation against EHSR 2.2 of the Lifts Regulations 1997 (TSO, 1997) is no longer available other than in the most extreme cases. Any advice regarding a derogation should be directed to the Department of Business Innovation and Skills (BIS). Responsibility for obtaining the derogation rests with the building designer, however BIS will almost always insist on BS EN 81-21 compliance.

BS EN 81-21 defines the requirements where the headroom or pit dimensions are limited due to the structural restraints. If a derogation is granted and the requirements of BS EN 81-21 are met by the installer, approval by a Notified Body is not required as this standard is harmonised under the Lifts Directive (OJ, 1995) and therefore provides a presumption of conformity with the Directive.

Whilst the most common issue with installing a new lift in an existing building is either lack of sufficient headroom or pit, other issues can exist such as limited well width or depth. Where the pit or headroom is limited, provisions must be made to ensure that sufficient safety spaces are created whenever a person enters the pit or car roof. These provisions can take the form of movable stops or a pre-triggered, bi-directional safety gear system etc. as defined in BS EN 81-21.

Pulleys may also be incorporated in the well above the line of the car if provisions are made to retain the pulley in the event of a failure of its supporting shaft.

If it is not possible to use a standard depth car apron a retracting or folding version is required.

Reduced machine room height, below 2.0 m, is permitted if all low areas are marked with yellow and black stripes as a safety warning.

In addition to the above additional safety notices are required to inform of the hazards that are present.

BS 5655-12 (BSI, 2005b) should be consulted when modernising lifts in existing buildings.

Where a lift, which was installed before 1 July 1999, is modernised, see chapter 16, a derogation and Notified Body approval are not required since the Lifts Regulations 1997 apply only to new lifts, installed after 1 July 1999.

Where a lift, which was installed after 1 July 1999, is modernised it should meet at least the requirements applicable at the date of its installation. In reality it should be upgraded as much as possible to align with modern standards.

It is essential, however, that when any lift is modernised it is not made less safe as a result of the modernisation process.

7.3.2 Cylinder arrangements

7.3.2.1 Direct-acting

The cylinder is connected directly below the lift car, see Figure 7.15(a). A lined borehole is required to accommodate the cylinder. A central cylinder is ideal for heavy loads and low rise applications. Effectively there is no limit on the car size or on the rated load capacity. The central cylinder arrangement makes optimum use of shaft space because there is no counterweight or hydraulic cylinder alongside the lift car.

The limitations of this arrangement are:

- provision of a lined borehole can prove expensive
- inspection of the cylinders is restricted and, on rare occasions, the unit may have to be lifted out of the borehole for examination
- problems may be encountered creating bore holes with underground rock and/or water
- travel is limited to approximately 18 m by the buckling factor for the piston.

7.3.2.2 Single side-acting

Side-acting cylinders can be connected either directly or indirectly to the lift car.

With a direct side-acting cylinder, the cylinder is located within the shaft structure alongside the car, see Figure 7.15(b). In this arrangement the car applies a lateral force to the rails and structure. The cantilever loads imposed on the shaft wall (approximately 1600 kg) restrict the single side-acting arrangement to light loads only. The lift travel is limited by the piston length, usually 3.5 m.

The indirect side-acting cylinder arrangement is similar to the direct side-acting, except that the connection between the piston and lift car is achieved by means of a rope/chain and pulley arrangement, see Figure 7.15(c). This arrangement gives a 2:1 ratio of car travel (for every 1 m of piston stroke the car travels 2 m). Safety gear is required with this arrangement, see section 7.11.

7.3.2.3 Twin (tandem) cylinders

As with single side-acting cylinders, the twin cylinder arrangement may be either direct or indirect acting.

The limitations of twin cylinders are:

- increased shaft size
- increased installation and running costs due to the use of two rams
- load limited to approximately 20 000 kg.

In the direct-acting arrangement, a cylinder is positioned at either side of the lift car, see Figure 7.15(d) and this arrangement can accept heavier loads than a single side-acting cylinder.

The indirect-acting twin cylinder arrangement is similar to the direct-acting twin cylinder arrangement, except that the car is connected to the pistons by a rope/chain and

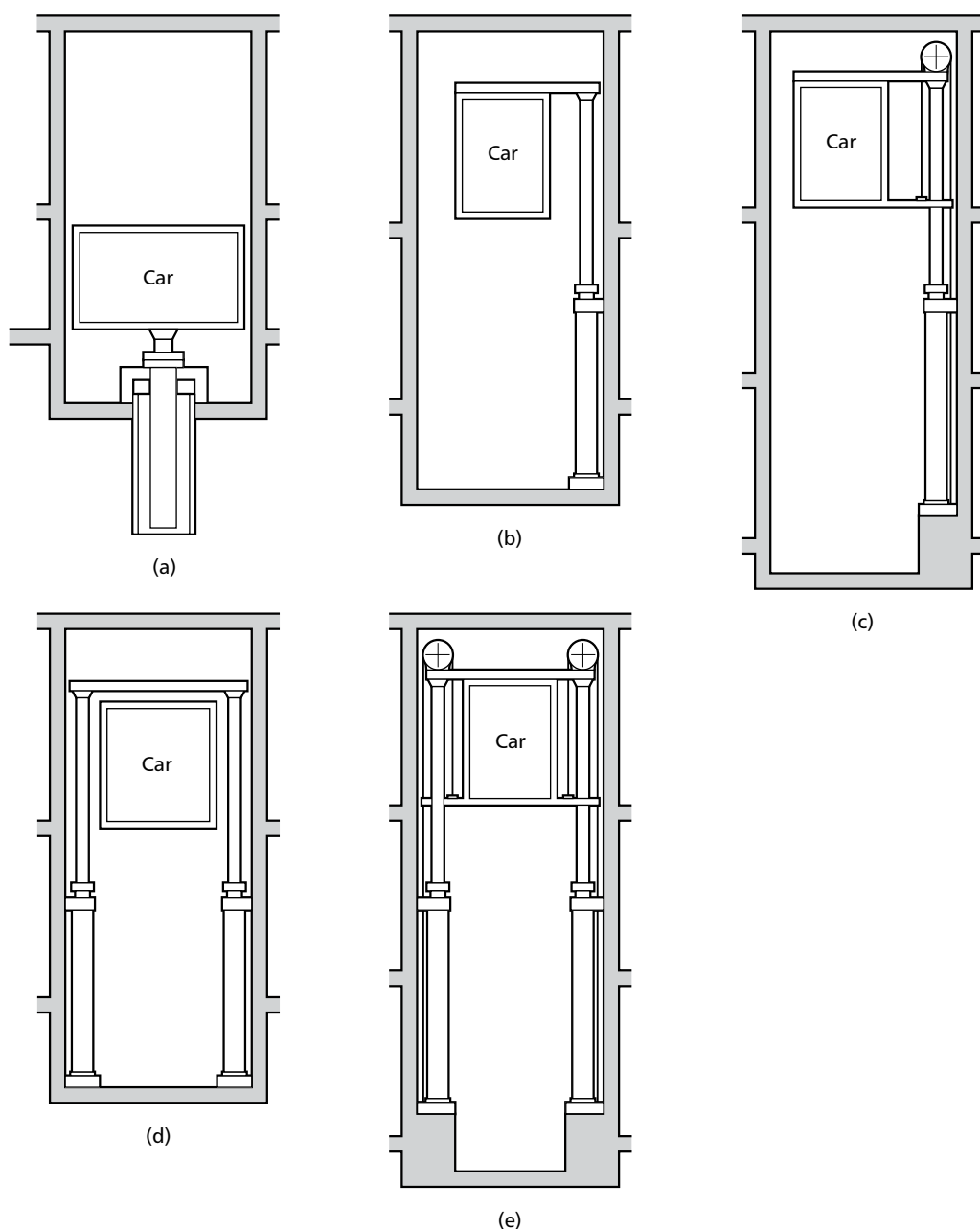


Figure 7.15 Hydraulic jack arrangements; (a) single, central, (b) single side-acting (direct), (c) single side-acting (indirect), (d) twin side-acting (direct), (e) twin side-acting (indirect)

pulley arrangement, see Figure 7.15(e), giving a 2:1 ratio of car travel to piston stroke travel (for every 1 m of piston stroke the car travels 2 m). Safety gear is required with this arrangement, see section 7.11.

7.3.3 Power units

There are two basic types; exposed and enclosed. In both cases the components and principles of operation are the same. The main components are as follows:

- tank or oil reservoir
- pump
- pump motor
- flow control valve block.

In exposed types, these items are mounted on a frame for easy installation. However, the enclosed type is now most common in which the pump and motor are submerged in the oil tank, see Figure 7.16. The control valves may sit either inside or on top of the tank unit.

The pump unit should be located as close as reasonably possible to the base of the cylinder to avoid an excessive pressure drop between the cylinder and the pump unit.

7.3.4 Pump and pump motor

The most common motor is the single-speed AC induction type. It is usually flange-mounted to the pump on the enclosed versions but may be foot-mounted and belt-driven on exposed types. In enclosed types, open-frame motors are used to ensure that the oil circulates throughout the motor to provide cooling. This has distinct cost advantages because it enables high power outputs to be obtained from relatively small motor frame sizes. However, the heat rejected by the motor heats the oil and thus causes its viscosity to change.

The motor drives the pump, of which the multi-screw type is most common since screw pumps are generally less noisy than other types.

A means should be provided within the lift controller to ensure the pump cannot be run in the wrong direction for

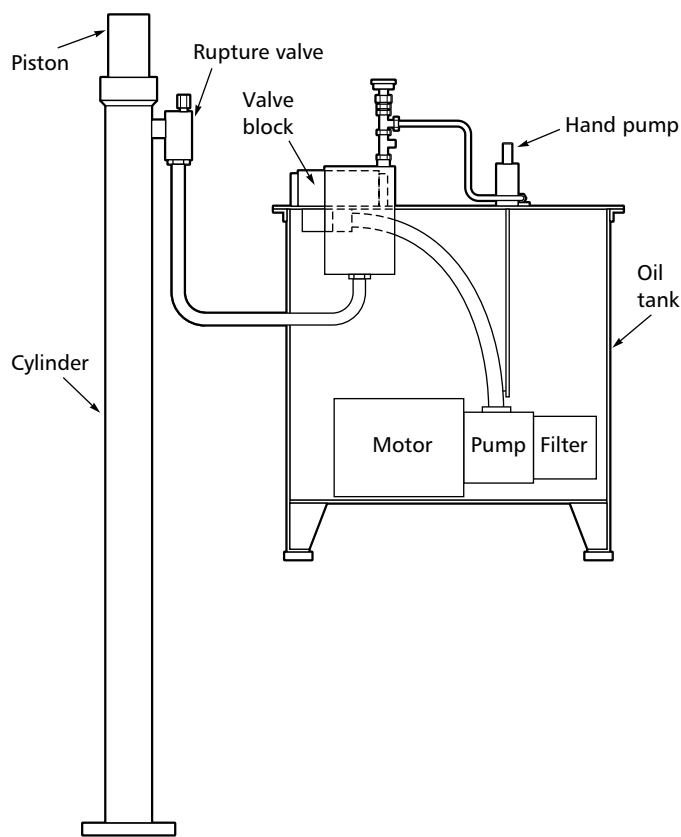


Figure 7.16 Enclosed hydraulic system

any length of time if a fault develops. Submerged pumps use the hydraulic fluid as a lubricant and, if reversed, this lubricant may be pumped away causing the pump to seize. Motor protection in the form of thermistors embedded in the windings is essential and an oil temperature sensor is good practice. This checks the oil temperature and ensures that the unit is shut down if a certain temperature is exceeded. The tank should be provided with a gauge or dipstick to determine fluid level.

7.3.5 Control valve

When upward movement of the lift is required oil is pumped to the flow control valve block at a constant rate. The valve block allows either all the oil to flow to the cylinder or diverts some back into the tank depending on the lift speed required. Many valve systems still use this simple system of speed control, although construction of the valve blocks vary considerably.

A silencer may be provided, either between the pump and valve block or after the valve block. These devices usually reduce noise by about 2–3 dBA. Most noise occurs when the valve block is bypassing oil to the tank and under such conditions noise levels of 80–85 dBA is common.

There are many new systems on the market that use a motor controlled by a variable frequency drive and or flow controlled valves. The motor is gradually accelerated to full speed thus avoiding the need for oil to be by-passed to the tank during acceleration. This saves energy and reduces waste heat and noise. Energy dissipated during down travel can in some systems be stored or regenerated to the supply.

A shut-off valve should always be provided on the output of the valve block so that it can be isolated from the cylinder

for servicing. A pressure gauge connection point is essential although the gauge itself may not be permanently fitted.

The complete assembly should be mounted on isolating pads. It should be installed plumb and level but absolute accuracy of alignment of the assembly is not essential. The items requiring critical alignment are generally the pump and the motor. This is usually carried out by the manufacturer at the factory.

7.3.6 Hydraulic cylinder

In a hydraulic system, power is transmitted to the lift car either directly or indirectly by a hydraulic piston or pistons, see Figure 7.15. Various names are given to this component such as jack, ram, plunger or piston. The main parts of the assembly are the cylinder, piston, seals and collar. Whichever system is provided, the piston and cylinder assembly should stand perfectly plumb and be securely fixed.

The cylinder is made from steel tube and may be in several sections depending on its length. The piston is made from steel ground to fine tolerances. Chromium plating provides a longer seal life and gives protection against certain environmental conditions. However, this is costly and usually not essential.

Like the cylinder, the piston may be made in several sections and various methods of jointing are used. The only criteria for jointing, apart from mechanical strength, should be the accuracy of the joints. Properly made joints should be imperceptible to the touch. At the bottom of the piston, there should be a collar to prevent the lift from striking the top of the building structure in the event of over-travel and to prevent the piston from leaving the cylinder. The top of the cylinder (or the top of each section in the case of telescopic pistons) should have a gland or seal to retain the oil. This gland should seal by the force of the oil acting upon it rather than by being crushed by its retaining plate. When working properly the piston should be covered by a very thin film of oil; anything more than a film indicates a problem. A scraper ring protects the seals from damage by abrasive particles, and the foils guide the piston through the seals.

The piston should satisfy the buckling factor and other requirements stated in BS EN 81-2 (BSI, 1998b) or BS EN 81-20 (BSI, 2014a). Obviously the higher the lift travel, the stronger and heavier the piston can become and this may require solid piston sections. For this and other reasons, hydraulic systems are not normally considered practicable for heights greater than 18 m.

The actual piston length depends on travel distance of the lift and the system employed. For direct-acting systems, the length is approximately equal to the travel plus the top and bottom over-travel, see Figure 7.17(a). For indirect-acting systems, the piston length is approximately equal to half of the sum of the travel and the total (i.e. top and bottom) over-travel, see Figure 7.17(b).

Cylinders and pistons cannot easily be altered in length. Therefore, it is essential to ensure that the cylinder assembly is manufactured accurately and it is vital to ensure that the lift travel is not altered by the builder or architect without first consulting the supplier. Very little tolerance is

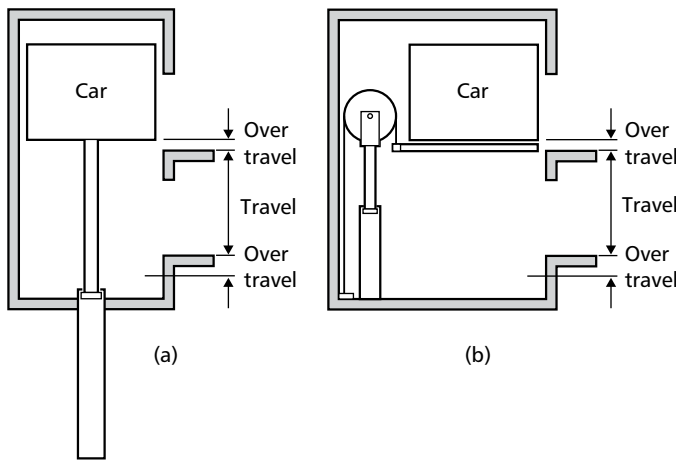


Figure 7.17 Over-travel; (a) direct-acting arrangement, (b) indirect-acting arrangement

provided and a variation of travel of as little as 20 mm can have serious consequences. (Note that the tolerances on the building dimensions may be considerably greater than the tolerance on the piston stroke.) With indirect-acting arrangements the travel is still critical, see Figure 7.17(b), as is the pit depth. No variations should be made, however small, without first consulting the supplier.

The most common problem associated with cylinders is premature failure of the seals. This can be caused by long-term storage in a horizontal position, defective scraper ring or impurities in the oil, misalignment of the cylinder, incorrectly installed seals or piston joints of poor quality, damage to the piston surface resulting from builders' debris. Dressing of joints is something that should be done with great care and only if essential.

After manufacture the assembly should be pressure tested to comply with BS EN 81-2 (BSI, 1998b) or other codes such as BS EN 81-20 (BSI, 2014a) as specified. The assembly is installed to ensure that, when in the fully extended position and against its collar, the car does not strike any part of the structure. When the lift is at the bottom, fully compressing its buffers, the piston should not be touching the bottom of the cylinder. These conditions should be checked as part of the lift testing procedure.

7.3.6.1 Rupture/restrictor valves

Hydraulic cylinders are usually connected to a pump by way of flexible or solid tubing that employs joints. As a result, rupture is always a possibility. Hydraulic lifts are therefore required to have a device to prevent uncontrolled decent of the car in the event of a hydraulic circuit rupture.

Prevention of uncontrolled decent of the car can be provided by various means. In the case of a rope suspended lift a safety gear may suffice, but if the lift is being supported solely by a piston a rupture or restrictor valve can be used connected directly to the cylinder (or connected by means of a solid pipe) so as to be between the cylinder and its pipework. These devices, when used as described above, are classified as safety components under the Lift Regulations 1997 (TSO, 1997) and therefore subject to type testing and CE-marking.

In the case of a rupture valve, normal lift operation is allowed provide the pressure on either side of the valve is approximately equal. In the event of a pipe joint, or other rupture the pressure on one side of the valve drops whilst

the pressure the other side (piston side) stays high. The result is the difference in pressure causes the rupture valve to slam shut so as to stop further decent of the piston and hence car. A restrictor valve works in the same way although instead of stopping the oil flow and car decent, it restricts the flow of escaping oil thereby allowing the car to descend slowly to its buffers at not more than 0.3 m/s. In the UK, for historical reasons it is more likely to find a rupture valve than a restrictor valve. Either type is acceptable.

7.4 Controller cabinet

The controller cabinet contains the equipment necessary to control and monitor the operation of the lift installation. The drive and control systems are considered in chapter 8 and traffic control in chapter 9.

Controller cabinets vary in size according to the complexity of the installation. Typical heights range from 0.5 to 2.5 m. They should be securely fixed, square and plumb, to the machine room wall or floor and in such a position as to ensure easy access for maintenance. Adequate lighting should be provided. Detailed requirements for safety clearances and lighting are given in BS EN 81-1/2 (BSI, 1998a/b) or BS EN 81-20 (BSI, 2014a) as applicable.

Ambient environmental conditions should be maintained as specified by the controls manufacturer, see chapters 8 and 12. In some cases it may be necessary to provide coolers on the cabinet to reject the heat generated, see chapter 12. Where cooling of cabinets takes place it is essential to ensure the area in which heat is dumped is also suitably cooled.

7.5 Guide rails

7.5.1 General

Some form of guide rails is required for the car and counterweight (where provided) to ensure travel in a uniform vertical direction. The position and alignment of the guides is very important and, with the exception of the drive, no other component has such a significant effect on the ride quality. Although round and other sections have been used, T-section rail is now used almost exclusively.

7.5.2 Position of rails

The relative position of the guide rails depends upon such factors as location of the entrance, shape of the car and centre of gravity of the car. The actual location may have been determined during the design stage and lift manufacturers can advise on what is and what is not possible.

Guide rails should be kept as near to the centre of gravity of the car as possible. A cantilevered arrangement may be acceptable at speeds up to 1 m/s but ride quality may be difficult to maintain when speed is increased beyond this level. Where possible, the guide rails should be located on either side of the car, see Figure 7.18.

The number of guide rails depends upon the loads to be handled and the sizes available for use. Two rails for the car

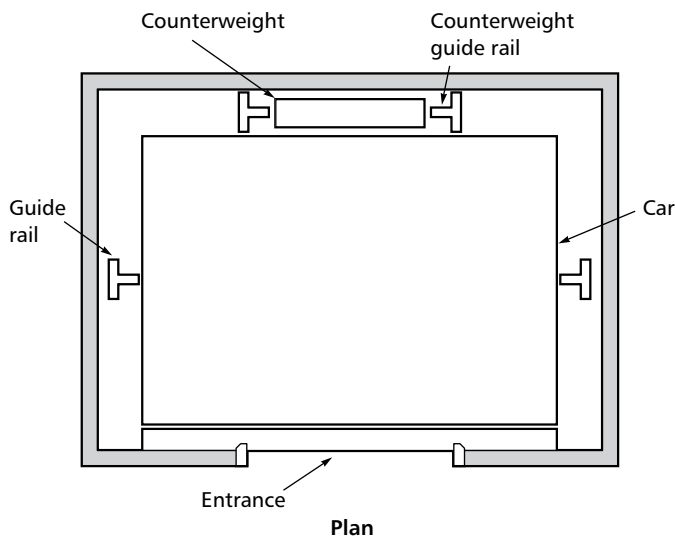


Figure 7.18 Position of guide rails

and two for the counterweight is the most common arrangement but there is no real limit on the number that can be used. The guides are drawn from steel and the running blade is usually machined to a finish, though not in all cases.

7.5.3 Size of rails

The size of the rail selected depends on the forces that it is required to withstand. During lift travel, the forces may be comparatively low, especially if the car is well balanced and the load is well distributed. During loading of the car, however, large loads may be exerted upon the rails. This is especially true of goods lifts being loaded using fork-lift trucks. These loads can produce a twisting moment in the rails. Under extreme conditions, it may be necessary to provide a means of locking the lift to the structure to relieve the rails of some of this load.

The other loads exerted on the rails occur on the application of the safety gear under emergency conditions. This can result in a large compressive load being transmitted to the rails as well as a bending stress. The means of calculating these forces, and thereby selecting rail size, is laid down in BS EN 81-1 (BSI, 1998a) or BS EN 81-2 (BSI, 1998b) and BS EN 81-50 (BSI, 2014b) as appropriate.

7.5.4 Alignment of rails

The need for accuracy in the installation of the rails cannot be overemphasised, especially for lift speeds of 2.5 m/s and above. At speeds greater than 4 m/s, rail alignment becomes critical. Manufacturers of rails usually offer two grades of finish, first grade being recommended for speeds greater than 2.5 m/s.

It is very difficult, if not impossible, to align rails correctly once the lift car is in the shaft. They should therefore be checked before the car is installed so that any error may be corrected. It is also common practice to use the rails as working centres for all dimensions. Therefore if these are wrongly aligned almost everything else may be wrong. Figure 7.19 provides a guide to installed accuracy. It is often not appreciated that the accuracy of alignment of the rails for the counterweight is as important as the alignment of the car rails to ensure good ride quality.

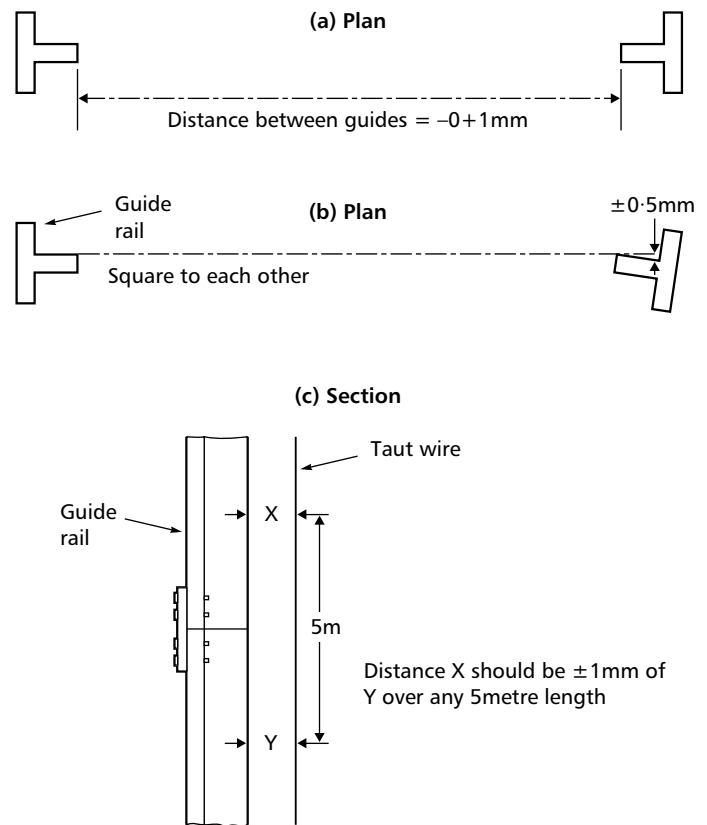


Figure 7.19 Alignment of rails; (a) tolerance on distance between guides, (b) tolerance on accuracy of angular alignment, (c) tolerance on vertical alignment

7.5.5 Rail fixings

Guide bracket and clip design is important as these items provide the means of holding the rails in alignment. For low-rise installations, forged steel clips may be used to hold the rails rigid. For travels of more than 20 m, spring clips are favoured because they allow for building compression. All buildings expand, contract and move to some degree and rail alignment obtained during initial installation should be maintained while this occurs. Again the taller the building and the faster the lift, the more critical this aspect becomes.

At speeds up to 2.5 m/s, it is good practice to clean the back of rails and face of brackets and to apply a small amount of grease to facilitate movement. At 2.5 m/s and above, most manufacturers provide more sophisticated arrangements to enable movement to occur, e.g. by employing brass shims between the brackets and the back of the rail.

7.5.6 Length of rails

While the rails should be long enough to ensure that the car and counterweight never leave the rails during over-travel, clearance should be left between the top of the rails and the structure. This is to ensure that when the building compresses it does not compress the rails. The dimension is approximately 3 mm for every 3.5 m of travel. For travel above 100 m the structural engineer should be consulted regarding the anticipated compression distances. In the absence of specific data, 5 mm per 3.5 m of travel should be allowed.

7.5.7 Guide shoes

The lift car, counterweight or balancing weight (as applicable) is provided with guide shoes. There are usually two shoes at the top and two shoes at the bottom, see Figure 7.20.

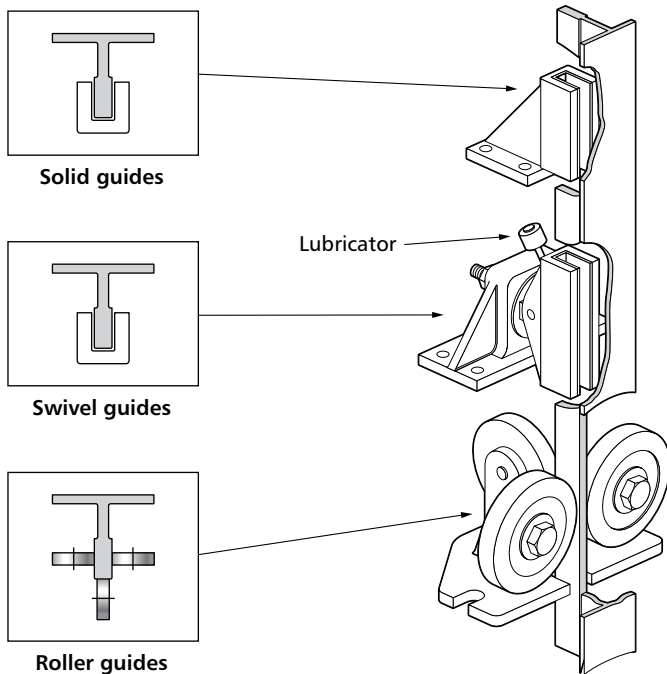


Figure 7.20 Guide shoes

The shoes, in their simplest form can be plastic, steel, iron or bronze. These shoes slide on the surface of the rails. Solid shoes are ideal for heavy goods lifts, but for passenger lifts the shoes are normally spring loaded, or resiliently mounted, to reduce noise in the lift car and to absorb small discrepancies in the guide rail alignment. The shoe is often made of steel with a nylon insert to form the running surface. The use of such materials improves noise and minimises the needs for lubrication. Sliding type shoes can be used at speeds up to 2.5 m/s, but are usually limited to 2.0 m/s.

Where the lift is required to operate at higher speeds than 2.5 m/s, roller guide shoes are used as shown in Figure 7.20. These are spring-loaded and at speeds of 5 m/s may be provided with shock absorbers to reduce lift car oscillation at speed. Roller shoes provided an excellent ride provided the car is well balanced to avoid high loads on the rollers, when the car is parked. If this is not the case, flat spots may develop on the rollers and these may not only create noise, but also produce a poor lift ride.

7.6 Counterweight

7.6.1 General

The counterweight provides traction between the ropes and sheave, by balancing the weight of the car and a proportion (normally 40–50%) of the load to be carried. Counterweights usually consist of a steel frame of welded or bolted construction, see Figure 7.21.

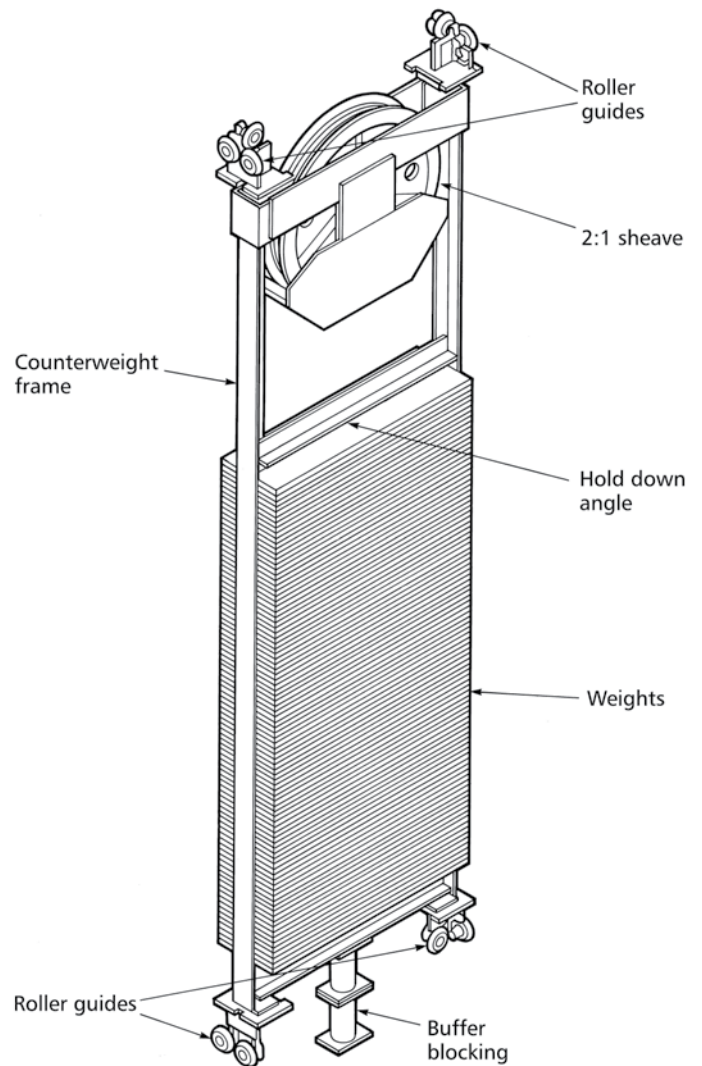


Figure 7.21 Typical counterweight (courtesy of Otis Ltd.)

The mass of the counterweight is provided by small weights, known as filler weights, made from steel, cast iron or concrete. The material selected is not critical provided its weight stays constant with age and atmospheric changes and does not burn. Some additional weights, known as makeweights, may be used for precise balancing. These weights are clamped into place in the frame with clips, rods or plates so that they cannot fall out. Wood or other blocks may be provided underneath the weight to allow for rope stretch adjustment. Sliding or roller guide shoes are fitted to the top and bottom of the counterweight to guide it smoothly along the rails.

The frame should be constructed to avoid undue distortion and should hang reasonably central of the rails of its own accord. This ensures that the shoes are subjected to minimum force and therefore minimum wear. This is particularly important for counterweights employing roller guide shoes; if the counterweight is forced into place by undue roller pressure the rollers may develop flats that result in noise and vibration.

Counterweights with rollers should, therefore, be statically balanced in the same way as lift cars with roller guide shoes. This involves arranging the filler and make-weights, along with the rope hitch-point, into such a position that the counterweight hangs centrally within the rails without the use of the rollers. The rollers are then adjusted to provide minimal pressure on the guide blade.

In addition to checking the static balance and roller or shoe adjustments, the main considerations during installation of the counterweight are to ensure that it does not strike the building structure when the car is fully buffered and to check that the safety gear, if provided, is operating correctly.

7.6.2 Counterweight sheave

A sheave or sheaves may be provided on the counterweight, depending on the rope arrangement employed. When provided, rope 'kick-off' guards should also be included to prevent ropes leaving the sheave during sudden stopping, or if some foreign object should become lodged between the ropes and sheave.

7.6.3 Counterweight safety gear

Safety gear (see section 7.11) should be provided if the counterweight is running above an area accessible to persons. This generally means that the size of the guide rail should be increased to take account of the load the safety gear applies to the rails during application. On a low-speed unit, the safety gear may be operated by the failure of the main ropes (e.g. a broken rope). On units running at 1 m/s or faster, governor actuated safety gear is required.

With speeds of up to 1 m/s the safety gear may be of the instantaneous type, but progressive types should be used above this speed.



Caution: according to BS EN 81-1 (BSI, 1998a), a solid pier may be used under the counterweight to avoid the need for a counterweight safety gear where accessible space exists. This pier option is no longer available within BS EN 81-20 (BSI, 2014a).

7.6.4 Compensation

The counterweight may also carry compensation ropes, see section 7.15.2. If tied-down compensation is used, the counterweight can be subjected to considerable stress when the car safety gear is applied, over and above the usual stress for which counterweights are designed, such as striking the buffers at full speed.



Caution: if a lift is modernised to a type requiring tied-down compensation it is likely a new counterweight will be required.

7.7 Lift car

7.7.1 General

Most lift cars today consist of two distinct assemblies: the sling or car frame and the car itself. The sling is a steel frame of welded or bolted construction that provides a cradle in which the car can sit. It has to be of sufficient strength to withstand the stresses applied to it when the car is accelerated and the compressive forces resulting from a fully laden car striking the buffers at speed or when the safety gear is actuated.

7.7.2 Car frame (sling)

The main parts of the car frame are the crosshead or crown bar, the uprights or side posts, and the bottom channels or plank channels, see Figure 7.22. Many designs and variations exist and on very large lifts more than one sling may be bolted together to provide the support the car requires. Ropes may be attached directly to the frame or pass around sheaves placed above or below it.

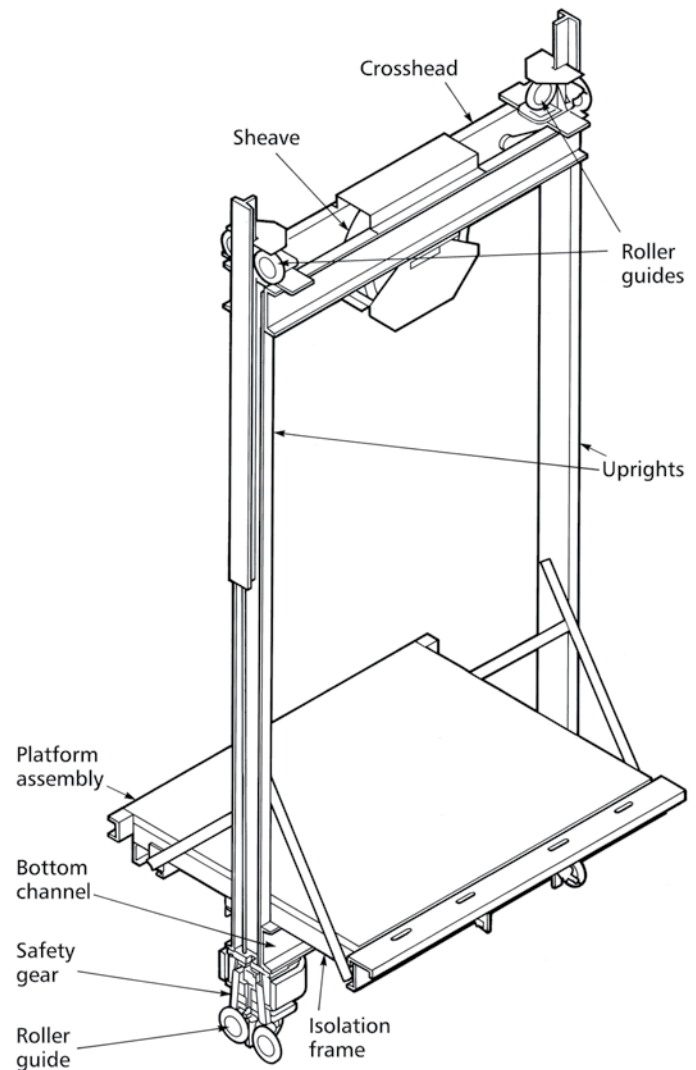


Figure 7.22 Typical car frame (courtesy of Otis Ltd.)

Shoes or rollers are provided at each of the four corners of the frame to guide it along the rails. The construction of the sling is important not just in terms of strength but of alignment. It should be assembled free of distortion, especially if roller guide shoes are to be used. Once built, distortions are difficult, but not impossible, to remove.

7.7.3 Platform/enclosure assembly

Passenger lifts usually have an isolation frame attached to the car frame, see Figure 7.22. The purpose of the isolation frame is to separate the passenger compartment from vibrations present in the car frame during running. The platform is supported by rubber pads fixed to the isolation frame. The platform should be levelled front to back and side to side before the walls are attached. The isolation pads

compress under load and can therefore be used to provide information on the load in the car.

For passenger lifts, the platform is usually made of steel and may have a timber overlay to reduce noise. If factory-assembled, the walls would then be installed, along with the car front, and finally the roof would be added. If assembly takes place on site, however, it may be necessary to install the roof and hang it temporarily from the crosshead while the walls are installed. The roof is often in one piece and therefore should be installed before the walls are in place. Whichever method is used, the walls should be plumb and square without being forced into position. If not, the car can quickly develop squeaks and rattles. Walls should not deflect beyond the limits indicated in BS EN 81-1/2 (BSI, 1998a/b) or BS EN 81-20 (BSI, 2014a), if chosen.

Materials used in the car construction according BS EN 81-20 to should use material non-flammable material for the supporting structure of the car body. Material for floors ceiling walls finishes are also required to be of limited combustibility.

Paint and laminates up to 3 mm thickness are excluded from these requirements.

Classifications as specified are as follows:

- Flooring: Cfl-s2
- Wall: C-s2,d1
- Ceiling C-s2.d0



Caution: BS EN 81-20 (BSI, 2014a) provides new strength requirements for car walls. Structural walls have to withstand 300 N applied over 5 cm² without permanent deformation greater than 1 mm or elastic deformation greater than 15 mm, and 1000 N over 100 cm² without permanent deformation greater than 1 mm.

The roof when installed should be able to support the weight of two persons without permanent deformation. The forces exerted on the platform during passenger transfer are not large and should be based upon the requirements of BS EN 81-1/2 or BS EN 81-20 as applicable. The top of the car is held to the frame by isolated steady devices so that at no point is it mechanically bolted to the car frame. Figure 7.23 shows a typical passenger lift car with the car shell constructed and the door tracks, sill and doors assembled.

For goods lifts, the platform isolation and resilient steady devices are normally omitted because it is important to hold the platform securely to withstand the forces applied during loading. For lifts intended to carry general goods, it is assumed that not more than 25% of the load can be placed in the car in a single operation. If the car is to be loaded using trucks (either hand or power operated), this intention should be made clear to the lift supplier since the combined weight of the truck and its load may exceed the maximum load for which the lift is designed.

Platforms for some passenger lifts may be provided with weights to ensure the finished lift car hangs in the guide rails without imposing large forces on the guide shoes. This features is known as static balancing and is normally only provided where roller type guide shoes are used as flats may

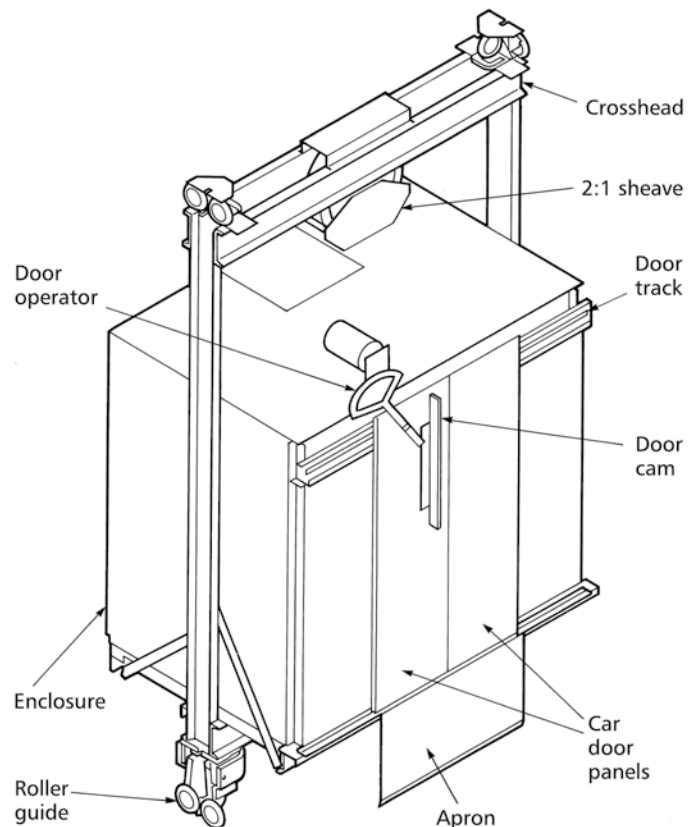


Figure 7.23 Construction of typical passenger lift car

develop on the rollers if they are continuously subjected to large forces.

7.7.4 Car safety gear

Safety gear should always be provided if the car is for passenger use, or is of a size that a person can enter for the purpose of unloading even if it is not primarily for passenger use (see also section 7.11). The requirements for the provision of a safety gear on passenger lifts are defined in BS EN 81-1 (BSI, 1998a) or BS EN 81-20 (BSI, 2014a) for electric traction lifts and BS EN 81-2 (BSI, 1998b) or BS EN 81-20 for hydraulic lifts.

7.8 Door operators

7.8.1 General

The function of the door operator, or door engine, is to open and close the lift doors in a safe and swift manner. Various methods are used, but the most common is an electric door operator mounted on top of the car, see Figure 7.24. When the lift approaches or arrives at a floor, a mechanical device couples the car doors to the landing doors. As the car doors open they also pull open the landing doors. This method has two distinct advantages. First, only one door operator is required for each car entrance regardless of the number of landing doors on that side of the car. Secondly, the landing doors cannot be opened if the car is not at a floor.

The disadvantage of this arrangement is that the operator may have to open and close doors of different weights. For

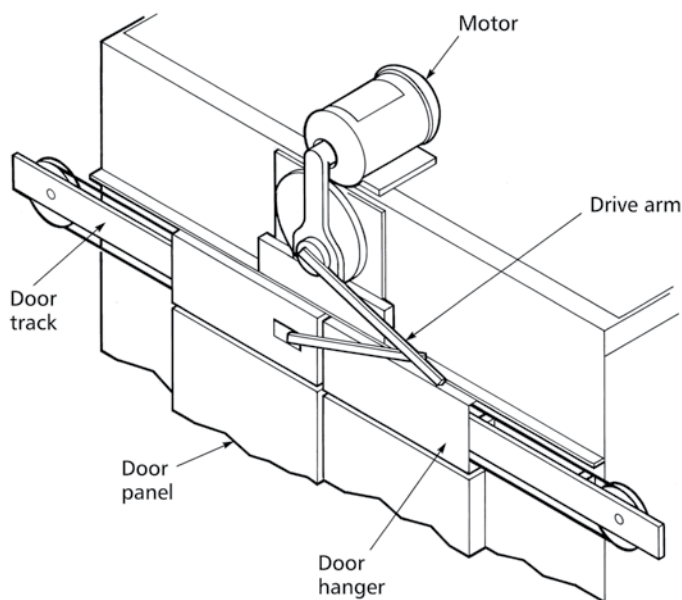


Figure 7.24 Typical door opener (courtesy of Otis Ltd.)

example, the main lobby may have heavy bronze doors while the doors on all the other floors may be of light panel construction. Under such circumstances the design of the operator might be a compromise; sufficiently powerful to open the lobby doors in a reasonable time but not so powerful that the doors on other floors are opened too fast since this may prevent smooth operation of the doors at all floors.

7.8.2 Principles of operation

To open the doors, the operator should accelerate the door from zero to full speed and back to zero in a smooth, quiet manner. This can be achieved by speed control of the drive motor, which drives an endless belt to obtain linear door movement or by a mechanical linkage that converts the rotational movement of the motor into a sinusoidal or harmonic door movement. The faster this operation is the better, as it saves time in loading and unloading. To open the doors smoothly at high speed requires good speed control, therefore high-speed door operators are generally more expensive than low-speed types. Today most operators employ VVVF technology to provide the precise control, see section 8.12.

Closing the doors raises different problems. While it may be desirable to save time by closing the doors quickly, BS EN 81-1/2 (BSI, 1998a/b) and BS EN 81-20 (BSI, 2014a) set limits on the maximum kinetic energy acquired by the closing doors in order to reduce the risk of injury to passengers. The current figure is 10 J provided that a safety device, such as a passenger detector, is in operation (see section 7.8.6). This limit applies at the average speed of the doors. In addition, the force necessary to prevent the doors closing should not exceed 150 N. If no safety device is provided, or an existing safety device is not operating, the maximum kinetic energy permitted is 4 J.

The most difficult control function, and the most mechanically severe, is the reversal of the direction of motion of the door whilst closing at high speed. Under such conditions the doors should be rapidly decelerated, stopped and then accelerated in the opposite direction. Poor design or incorrect adjustment of the system may result in premature

failure of the door drive and its bearings, a common fault with door systems. Bearing and drive failure may also be caused by adding too much weight to the doors, for example by applying a heavy finish to existing doors. The type of door should not be changed unless the capabilities of the door operator are known to be adequate to accommodate the extra weight.

Although initially more expensive than the simple sinusoidal operator, the principle of linear motion, whereby the door movement is linearly proportional to the motor rotation, provides better control of the door movement. With linear door operators, interruption of door closing does not generate such high mechanical forces and this ensures long-term quietness in operation.

7.8.3 Door operator motors

The operator itself may use:

- a DC motor driving through gears or a mechanical linkage system
- an uncontrolled AC motor driving through a gearbox
- an AC or DC motor with closed-loop speed control.

Until the 1980s, only DC door operators provided a means of adjusting the door speeds and therefore these were used for lifts with higher door speeds and wider entrances. AC operators, without any speed control, were restricted to smaller lift car entrances and had fixed opening and closing times. Most manufacturers now produce electronically controlled AC and DC door operators suitable for higher door speeds. Some of these use position and velocity control along with sophisticated passenger detection and logic control.

Single-speed AC door operators are most suited for entrances up to 800 mm wide where there is a low density of traffic. In other situations, lift efficiency and passenger comfort are improved by the use of DC and controlled AC operators.

DC door operators provide good all-round performance for most applications but variable frequency controlled AC operators are now replacing them, due to their excellent performance and low cost. In the case of AC motors, variable frequency control may also be used. Control of door operators is dealt with in section 8.12. The motors are usually designed for the function and, depending on the manufacturer, may be suitable for continuous stalled operation thereby eliminating the need for stall protection.

The operating times can often be adjusted to suit user requirements for comfort. It is difficult, however, to modify the speed of the doors in response to varying traffic conditions. Nudging, to close the doors slowly when obstructed or held open unnecessarily, is easily accomplished.

7.8.4 Door opening times

The selection of a suitable door operator usually depends upon the application. Generally, high-speed door operators should be used with high-speed lifts. There is little point in having a fast ride if this is followed by slow door operation.

Table 7.1 Door operating times

Operator and door type	Opening size† (mm)	Opening time (s)	Closing time (s)
Low speed:			
— two-panel opening	800	4.8	4.8
	900	5.1	5.1
— two-panel centre-opening	800	4.1	4.1
	900	4.7	4.7
Medium speed:			
— two-panel side opening	800	2.9	3.3
	900	3.1	3.5
	1000	3.3	3.7
	1100	3.5	4.2
— two-panel centre-opening	800	2.3	2.5
	900	2.4	2.6
	1000	2.5	2.7
	1100	2.7	3.0
High speed:			
— two-panel side opening	800	1.8	2.8
	900	1.9	3.4
	1000	2.0	3.6
	1100	2.2	3.8
— two-panel centre-opening	800	1.5	2.0
	900	1.6	2.2
	1000	1.7	2.5
	1100	1.8	2.9

† Door height taken as 2100 mm in all cases

Table 7.1 shows typical door opening and closing times and likely applications for door operators. The terms low, medium and high speed are not well defined and therefore the figures are given only as a guide. Note that low-speed operators are generally of low cost and usually cannot provide faster opening than closing. For a given width, centre-opening doors can have shorter opening and closing times than side-opening doors. The opening and closing times of the doors have a significant effect on the lift efficiency and cycle time: a one second saving on door operation gives approximately 5% greater traffic handling capability. High closing speeds increase the risk to users. To minimise this risk, limits are placed on the energy that a closing door can contain. In the case of doors without a passenger detection system to reverse doors the limit is 4 J. Where an automatic reversal system is employed this can be increased to 10 J. If heavy finishes are applied to doors it

may be essential to reduce closing speed to stay within the defined limits. This would reduce the traffic handling capacity and is best avoided.

7.8.5 Installation

With power-operated doors, the operator should be installed to the manufacturer’s recommendations. It may bolt directly to the car roof, with or without isolation, or it may be fixed to its own support frame, which is, in turn, bolted to the car frame. Following installation of the door operator, it should be checked thoroughly for smooth, quiet operation. Doors and operators often account for some 80% of breakdowns on lift systems therefore good quality installation is essential. Manufacturers should state opening and closing times, as well as noise levels, and these should be checked after installation. The kinetic energy of the doors when in motion should also be checked, see section 7.8.2.

7.8.6 Passenger safety devices

Passenger detection devices are necessary for the safety and comfort of lift users, when they are moving in and out of lift cars. They also provide controller inputs for the operation of the doors and in some cases, the lift drive. The time taken to react to an obstruction to door closure varies with the type of detector and several different types may be used. Figure 7.25 shows a typical mechanical safety edge and photocell passenger detector systems and Figure 7.26 shows a typical wide-field electronic safety edge.

A mechanical safety edge can be mounted on the leading edge of the car door. The safety edge moves when it strikes an object and this movement causes the doors to reverse direction. While simple to construct and reassuring to passengers, mechanical safety edges are easily damaged by trolleys etc. They are rarely used today.

Photocell detectors provide remote sensing across the complete door entrance. They can be a useful addition inside the car, either on the door returns or built into the detector edge, but they should be provided in addition to a safety edge or detector, not as an alternative. For goods lifts, a photocell detector built into the landing architrave is a

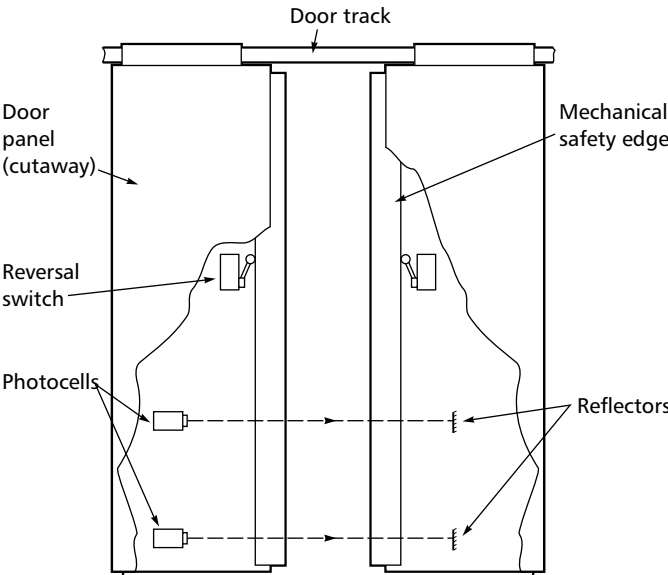


Figure 7.25 Schematic of typical mechanical safety edge

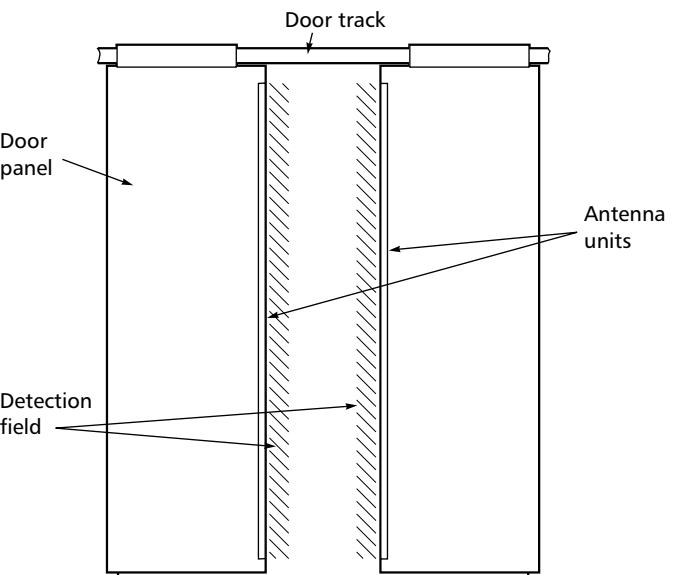


Figure 7.26 Schematic of typical electronic passenger detector

good way of protecting the landing doors. Despite the claims made by manufacturers, most car door detectors provide only partial protection to the landing doors.

A photocell detector can allow more efficient use of the lift, by acting as a 'door open' (dwell time) monitor. These devices modify the dwell time in response to passengers moving through the entrance. If an obstruction is present, door closure is delayed to prevent unnecessary reopening caused by safety edge operation.

More common today are electronic detector edges in which a solid-state detector is located on or beside the leading edge of the car doors. This produces a detection field that may extend for a short distance (say, 100 mm) in front of the door, or it may cover the whole opening width. When the field is interrupted the door reverses direction. This type of system has the advantage of reversing the door before it hits the obstruction. For this reason, electronic detectors are preferred to mechanical types. Modern electronic detectors are robust and stable, and their ability to sense obstructions without physical contact is more comfortable for passengers and provides better protection for the doors. In the event of failure of the detector, the doors should stay open or be permitted to close only at slow speed (nudging operation) with a warning buzzer sounding.

Optical passenger (obstruction) detectors provide even greater passenger protection in situations where heavy objects have to be moved through the entrance. Again, these detectors should be used in addition to electronic safety edges. Optical passenger detectors use simple video cameras with local image processing to detect passengers and objects approaching the lift entrance. Situated above the car doors, the landing doors or between the car and landing doors, the field of view can be angled to meet the requirements of the application. Typical situations where these devices have proved advantageous are in airport terminals and hospitals. They can, however, interfere with normal service if located above the landing doors by detecting persons passing the lift rather than those waiting to use it. The field of view should be carefully adjusted to avoid false sensing.

7.9 Door configurations

7.9.1 General

While various types of door exist, all serve the same prime function: to prevent persons or objects from entering the path of the lift. Each type, however, offers certain features or advantages. The mechanical strength required for doors and their locking mechanism is laid down in BS EN 81-1/2 (BSI, 1998a/b).



Caution: new strength requirements are specified in BS EN 81-20 (BSI, 2014a) for car and landing doors. These include the need for both hard and soft impact tests to be conducted on all door design. Door panel gaps are still limited to 6 mm, or 10 mm after wear. However, for glass door panels 6 mm is the limit. In a note it is suggested that sills be set with a slight counter slope to prevent water washing into the well. A further note states that, where additional doors are added in front of the landing

door trapping of persons in the space between doors is to be avoided.



It is suggested that, irrespective of what the standard may permit, whilst possibly acceptable in a single dwelling or apartment, it is unacceptable to have access to a lift via a private route where a lift (or lifts) serve multiple premises, and should be avoided for the safety of maintenance staff, security of the owner, and convenience of all building tenants.

BS EN 81-20 (BSI, 2014a) demands doors locked in their closed position to withstand a static force of 300 N distributed over an area of 5 cm² applied in any position, to withstand deformation greater than 1 mm, elastic deformation greater than 15 mm and that after such a test the function of the door shall not be affected. In addition, when a force of 1000 N is applied at right angles over an area of 100 cm² at any point they shall resist without significant permanent deformation affecting functionality and safety. These are static tests applying to all door types

Doors must also have a device to retain panels in position if the guiding elements fail. Doors with their retainers shall withstand a pendulum impact test at impacting points defined in a figure (see Figure 7.27). The impact force is considerable and is given in BS EN 81-50 (BSI, 2014b) with other details such as design of the test rig. One shock test is to be made with a soft shot bag of 45 kg mass, plus another hard shock test with mass of 10 kg.



Note: BS EN 81-20 can be misleading and needs to be studied with care, the intention is that these tests apply to a given door design, (a design test) car or landing, irrespective of material used in their construction. It does not apply solely to glass doors.

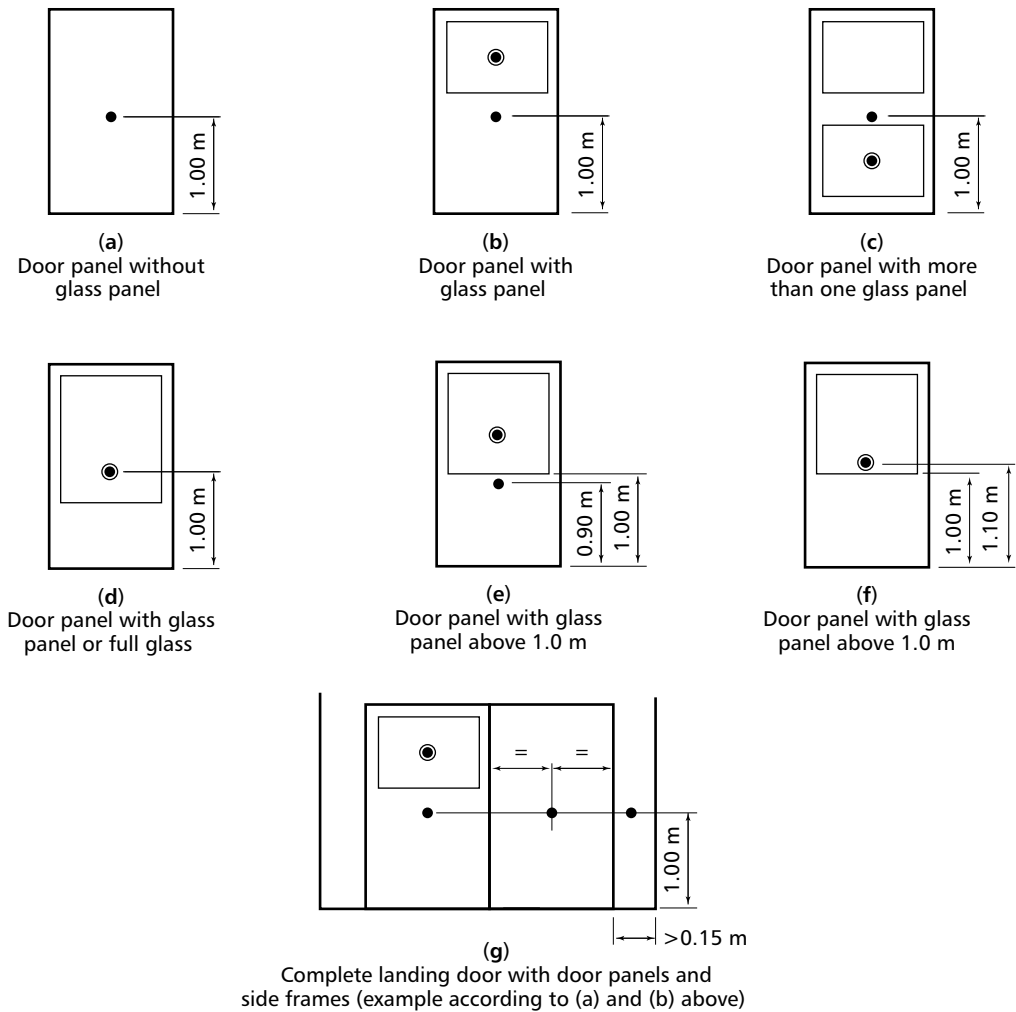
The completed panel assembly should be designed to be as free running as possible, with all clearances within the limits laid down by BS EN 81-1/2 or BS EN 81-20. The face of sliding doors should always be kept as flush as possible. While the standard permits recesses and projections up to 3 mm in the face of the door, these should be avoided if possible. Safety should always be the prime consideration.

7.9.2 Single-hinged, manual doors

The simplest, and generally the least expensive, type of landing door is the single-hinged, see Figure 7.28. In the past, these were frequently made from wood but, because of its flammability and tendency to warp, steel doors are now more common. Single-hinged doors require very little space in terms of width since they consist of only the door and a simple frame. The disadvantage is that they usually open out to a right angle with the wall and therefore obstruct corridors. They can be difficult to open for persons in wheelchairs or elderly or disabled people. They are, however, acceptable for simple, low-cost passenger lifts serving a small number of floors. Typical opening widths for these doors are 700, 800 and 900 mm.



Note: if single hinged wooden doors are to be provided by other contractors, as may be the case if wooden doors are part of the design, the lift supplier may agree to provide lifts without landing doors. In this case the lift is considered partly completed and the lift contractor is required to provide all neces-



Note 1: (e) and (f) are alternative solutions

The worst case shall be tested. If it is not possible to determine the worst case, both or all variants shall be tested.

Note 2: For striking points defined by 1 m, the tolerance is ± 0.10 m.

- Key**
- Striking point for soft pendulum shock test
 - Striking point for hard pendulum shock test

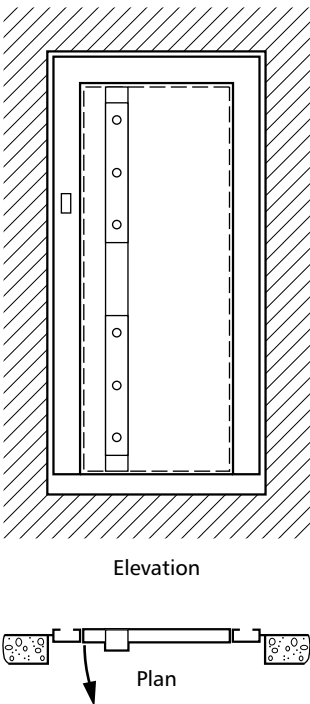


Figure 7.28 Single, hinged door

Figure 7.27 Landing door impact test points (reproduced from BS EN 81-20 (BSI, 2014b) by permission of the British Standards Institution)

sary information to enable the other contractor to design the doors. This information should include strength requirements of the door, requirements and need for impact testing and associated certificate, location of locks or beaks and method of fixing, warning that screwing into wood is not acceptable, lock strength when attached to door, etc.

7.9.3 Horizontal power-operated sliding doors

The most frequently used power-operated door for passenger lifts are horizontal sliding doors, see Figure 7.29. The simplest of these is the single-slide (single-panel) version, see Figure 7.29(a). The single panel is pulled open or shut by the car door operator. As only one panel is used the construction is simple and reliable but requires a greater shaft width in many instances for a given opening, i.e. approximately twice the opening width plus 300 mm. The typical opening width is 840 mm. These types of doors were commonly used for lifts in local authority housing during the 1960s and 1970s. They are still used for some applications but less frequently so.

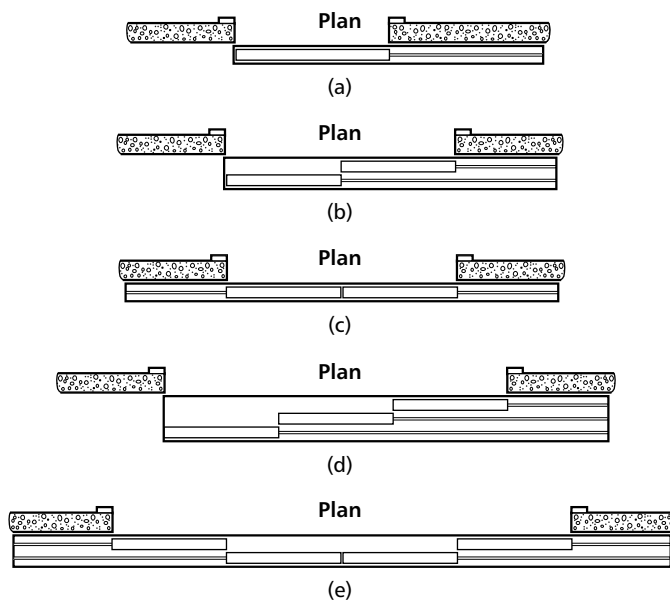


Figure 7.29 Horizontal power-operated sliding doors; (a) single slide, (b) two-speed side-opening, (c) single-speed, centre-opening, (d) three-speed, side opening, (e) two-speed, centre-opening

7.9.4 Two-speed, power-operated doors

Two-speed side-opening (two-panel side opening) door may be used where space is at a premium, see Figure 7.29(b). These doors are sometimes referred to as two-speed because while both panels close simultaneously, the leading panel travels at twice the speed of the trailing panel. This means that, although the leading panel has twice the distance to travel of the trailing panel, it covers the distance in the same time. The space required by these doors is approximately 1.5 times the opening width plus 400 mm. Opening sizes for these doors are generally between 600 and 1300 mm, the most common sizes being 700, 800, 900, 1100 and 1300 mm.

7.9.5 Centre-opening, power-operated doors

The most common entrance for passenger lifts is the single-speed centre-opening door (two-panel centre opening), see Figure 7.29(c). This arrangement is mechanically relatively simple, visually attractive and fast in operation because both panels move simultaneously, either away from or toward each other. For a panel speed during opening of 0.3 m/s, an opening of 900 mm may be created in approximately 1.6 s, whereas a two-speed door would require approximately 3.0 s. This time saving can be critical on large installations and groups of lifts. The space required by the doors is more than other types being approximately twice the opening width plus 200 mm. However, centre-opening doors are preferred to side-opening where the depth of the shaft is limited.

Opening sizes for these doors are usually between 800 and 1300 mm; larger sizes are possible but generally unacceptable because of the space required. The most common door opening widths are 800, 900, 1100 and 1300 mm.

7.9.6 Wide entrance doors

For special applications, such as very large passenger or goods lifts, other horizontal doors are available. For example, two-speed centre-opening (four-panel centre opening) or three-speed side-opening (three-panel side opening) doors are suitable for opening widths from 1200 to 2500 mm or greater, see Figure 7.29(d) and (e). However, these arrangements are generally costly and can be noisy because of the complexity of mechanical linkages.

7.9.7 Multi-leaf gates

For goods lifts, the requirements are generally different. Adequate space to enter the lift and within the shaft, combined with rugged, reliable operation are more important than speed of operation. Where cost and space are at a premium, manually operated shutter gates may be used, see Figure 7.30. These are simple and rugged. The space required is the opening width plus the bunching width plus 300 mm. The space required for bunching can vary according to the widths of opening and leaf size used.

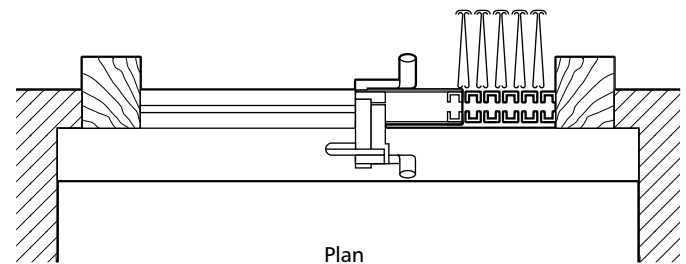


Figure 7.30 Multi-leaf gate

7.9.8 Vertical bi-parting doors

For very large goods lifts, where loading may be by powered truck, vertical bi-parting doors may be used, see Figure 7.31. These may be either manual or power operated. Space requirements vary between different manufacturers. The powered versions usually have an operator motor per entrance (i.e. on each floor served). This enables each entrance to be individually adjusted.

The two panels counterbalance each other. As the bottom panel moves down the upper panel moves up. When fully open, the top edge of the bottom panel forms a trucking sill. The doors are designed to accept different trucking loads and the intended load should be specified.

Although opening may be fully automatic, closing is performed by constant-pressure button operation. The door closing sequence may be interrupted if necessary by releasing the door close button. Fully automatic power closing of these types of doors is not permitted under BS EN 81-1/2 (BSI, 1998a/b) or BS EN 81-20 (BSI, 2014a) for safety reasons.

7.9.9 Materials and finishes

BS EN 81-1/2 (BSI, 1998a/b) and BS EN 81-20 (BSI, 2014a) sets limits on the closing force and kinetic energy of moving doors (see section 7.8.2), and these may have a bearing on the materials selected for the door. Most doors are made

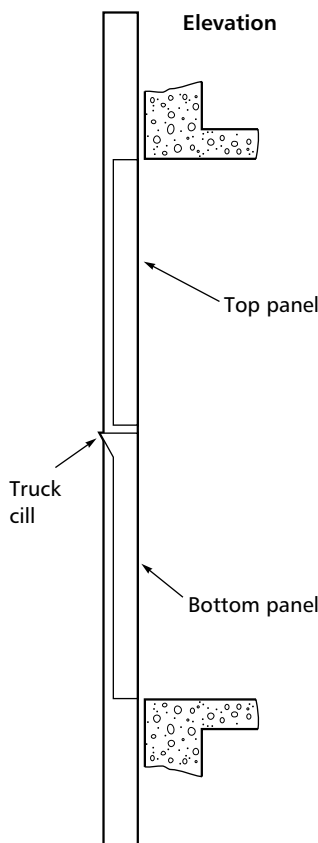


Figure 7.31 Vertical bi-parting door

from steel with either a painted or applied skin finish. While the finish is a matter of design choice, certain factors should be considered. For example, if heavy materials are used, door closing speed may have to be reduced to keep within the kinetic energy requirements. Some materials, especially those with heavy embossed patterns, may be difficult to form and may therefore increase costs. Finally, heavy materials may require that the door tracks, rollers, bearings and driving operators are all increased in size to handle the extra weight, this often results in a significant increase in cost.

7.9.10 Fire rating

Lift doors are often required to be fire rated. In the UK, testing of this property has historically been laid down in BS 476-22 (BSI, 1987). Unlike other fire doors, lift doors are tested from the outside only (i.e. the landing side) and the ability to stop fire from the lift shaft side is not a requirement. Doors are tested within their frames built into a typical structure in a test furnace. The test report obtained can be for a given duration, typically 30, 60, 90 or 120 minutes, and may cover both integrity and stability. Insulation properties are not required or tested nor smoke control.

A fire testing method is given in harmonised European Standard BS EN 81-58 (BSI, 2003b). In this test, carbon dioxide is introduced into the test furnace as a tracer gas and its rate of leakage through the doors is measured. Manufacturers of lift doors increasingly adopt this test method as it enables a door design to be recognised as acceptable in all European member states with only a single fire test.

It should be noted that modifying doors by removing entrance upright sections, changing the locking system, closing system or the addition of finish materials such as woods, plastics etc. would invalidate the report. The

addition of a skin may also render the report invalid if flammable materials are used and this should be borne in mind during the selection of finishes and adhesives for fixing skins. Where it is planned to make such changes a professional opinion should be sought from a Notified Body for lift who will take advice from the appropriate fire testing laboratory.



Caution: note that the BS EN 81 series of standards require testing of doors to BS EN 81-58 (BSI, 2003b). Any other test, irrespective of type or quality, will not offer a presumption of conformity with the Lift Regulations 1997 (TSO, 1997) and therefore would require a lift Notified Body approval.

7.10 Overspeed governors

7.10.1 General

Overspeed governors have been used on lifts almost since the first lifts were installed. The purpose of the overspeed governor is to activate a safety gear by stopping and holding the governor rope. It has to hold the rope with a predetermined force in the event of the descending car or counterweight exceeding a specified speed. The rope may be held by traction forces developed between the governor sheave and its groove or by a special rope-clamping device designed to hold the rope without damaging it. The force exerted on the rope should be at least 300 N or twice the force required to engage the safety gear, whichever is greater. For governors using rope traction to obtain this force, the force should be calculated in accordance with BS EN 81-1 (BSI, 1998a) or BS EN 81-20 (BSI, 2014a).

These devices are classified as a safety component by the Lift Regulations 1997 (TSO, 1997) and as such must be type-tested and issued with a declaration of conformity.

New governors are required to be type-tested and provided with a declaration of conformity. BS 8486-1 (BSI, 2007a) provides information for testing once installation is complete. For hydraulic lifts BS 8486-2 (BSI, 2007b) is applicable and sets down requirements for on-site testing. The general requirements for governors are laid down in BS EN 81-1/2 (BSI, 1998a/b) as applicable. If used, BS EN 81-20 (BSI, 2014a) defines requirements and BS EN 81-50 (BSI, 2014b) defines tests.

In the past, vertical shaft fly-ball governors were common but, although many still exist, their use is becoming less frequent. Horizontal shaft, centrifugal governors are now preferred, see Figure 7.32. The centrifugal governor consists of a sheave, flyweights and a rope clamping device. As the sheave rotates, the pivoted flyweights move outwards due to centrifugal force. At a predetermined speed, the weights strike a release mechanism that causes the rope-clamping device to grip the governor rope. The rope-clamping device is designed to allow the rope to slip through its jaws if the load on the rope is too great. This ensures that the safety gear stops and holds the car rather than the governor.

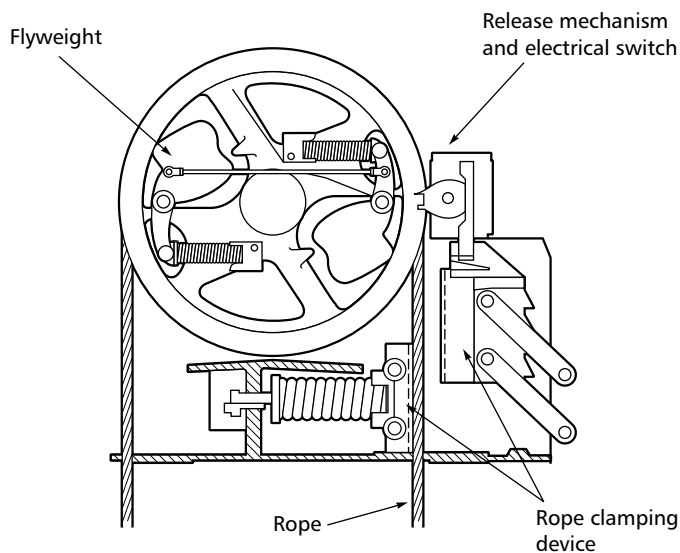


Figure 7.32 Centrifugal governor (courtesy of Otis Ltd.)

7.10.2 Governor activation

BS EN 81-1/2 and BS EN 81-20 requires that tripping of the overspeed governor for the car safety gear should occur at a speed at least equal to 115% of the rated speed and less than:

- 0.8 m/s for instantaneous safety gears except for the captive roller type
- 1 m/s for safety gears of the captive roller type
- $(1.25 v + 0.25/v)$ for progressive safety gear for rated speeds not exceeding 1.0 m/s (where v is the rated speed).



Note: safety gears with buffered effect have now been removed from BS EN 81-20.

A governor used to operate counterweight safety gear should be set to activate the safety gear at a speed not more than 10% greater than the speed at which the car safety gear is activated.

Governors are provided with an electrical switch, which removes power from the lift motor and applies the brake before the safety gear is activated. However, if the rated speed of the lift is 1.0 m/s or less, this switch may trip simultaneously with the safety gear. For speeds above 1.0 m/s the switch is set to operate prior to the operation of the safety gear to avoid unwarranted safety gear application.

7.10.3 Governor resetting

After operation, the governor can be reset either by raising the car or may require to be reset manually. The rope-gripping device should always be inspected for signs of wear after an application.

7.11 Safety gear

7.11.1 General

Safety gear is the term given to a mechanical clamping device located on the car and in some instances also on the

counterweight, the prime function of which is to grip the guide rails to prevent the uncontrolled descent of the car if the lifting ropes were to part. Any lift car designed for transporting passengers, or into which persons may enter to load or unload goods, and that is suspended by ropes, chains etc. requires the provision of safety gear. The safety gear may be located under the car frame but may be at the top or halfway up. The position is not important provided that the gear is fixed securely to the frame. Figure 7.33 shows a typical car frame with progressive gear located at the base of the uprights. All types of safety gear should be applied mechanically and not rely on the operation of electrical circuits. Activating devices for safety gear are considered in section 7.11.6.

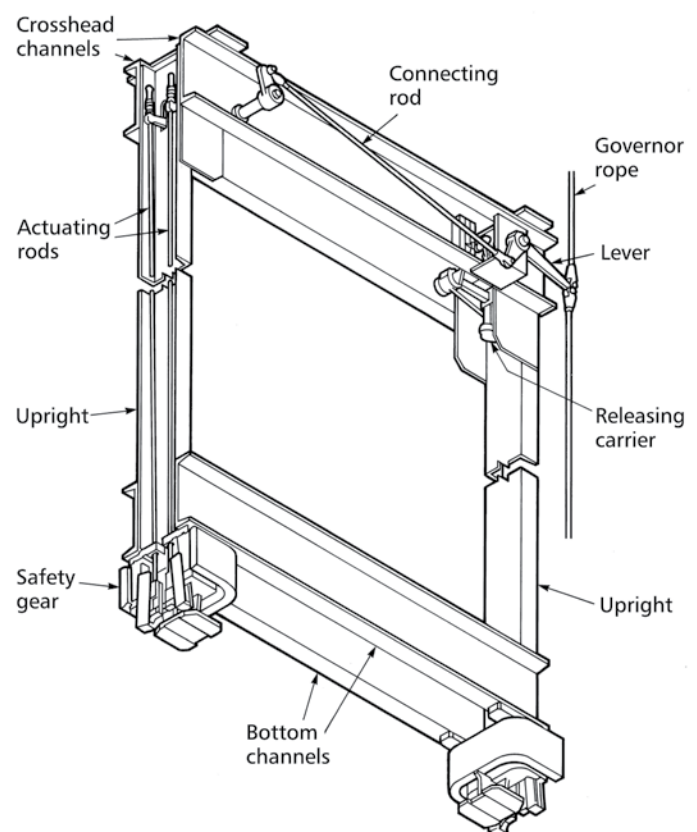


Figure 7.33 Car frame with progressive safety gear (courtesy of Otis Ltd.)

Safety gear may also be fitted to the counterweight, see section 7.6.3.

Safety gear is classified within 'safety components' according to the Lift Regulations 1997 (TSO, 1997) and as such must be type tested and provided with a declaration of conformity.

7.11.2 Instantaneous safety gear

This is the simplest type of safety gear, see Figure 7.34. It is almost instantaneous in operation but limited to lifts with speeds of not more than 0.63 m/s. This is because the small stopping distance results in heavy shock and strain, not only to the lift equipment but also to the passengers.

When fitted to a counterweight frame, the device may be used at speeds up to 1 m/s. Although the counterweight may be stopped instantly, the car may come to rest under the action of gravity.

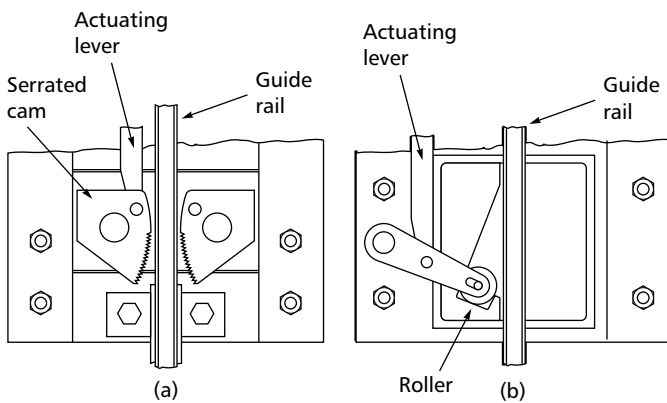


Figure 7.34 Instantaneous safety gear; (a) serrated cam, (b) roller type

These devices are required to be type tested, CE-marked and provided with a declaration of conformity as safety components under the Lift Regulations 1997.

7.11.3 Instantaneous safety gear with buffered effect

Instantaneous safety gear with buffered effect may be used on cars with speeds up to 1.0 m/s. The safety gear again applies a rapidly increasing pressure on the guide rails but oil-filled buffers, interposed between the lower members of the car frame and the safety gear, dissipate the energy and reduce the shock to passengers.



Warning: safety gears with buffered effect have been removed from BS EN 81-20 (BSI, 2014a) due to lack of use in recent years.

These devices are a safety component according to the Lift Regulations 1997 and must be provided with a declaration of conformity.

7.11.4 Progressive safety gear

For speeds in excess of 1 m/s, progressive safety gear should be used. This device clamps the guide rails by applying a limited constant pressure which brings the car progressively to a standstill, see Figure 7.35. These devices are also used where several safety gears are fitted to the car as is the case with some large goods lifts. Progressive safety gear may be used at speeds below 1.0 m/s, if required and designed for such speeds.

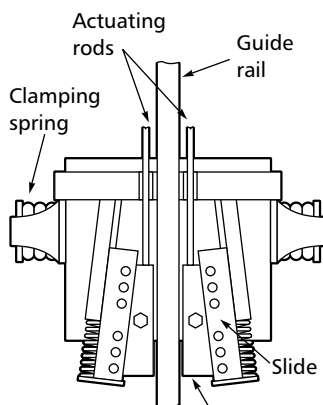


Figure 7.35 Progressive safety gear (courtesy of Otis Ltd.)

The gear is usually designed so that under free fall conditions the average retardation of a fully loaded car lies between 0.2 g and 1.0 g. The actual distance taken to stop

the lift depends upon its speed. Requirements for stopping distances and methods of testing vary depending on the design standard current at time of original installation. Testing of these older devices should be in line with testing requirements at time of design. New lifts should be tested to BS 8486-1/2 (BSI, 2007a/b) as appropriate.

Any new devices are required to be type tested, CE-marked and provided with a declaration of conformity as safety components under the Lift Regulations 1997 (TSO, 1997).

7.11.5 Resetting the safety gear

All modern types of safety gear are reset after application by upward movement of the car. This requires the intervention of a competent person not only to release the safety gear and check its condition after operation but also to determine the reason for its operation.

Contrary to common belief there is no requirement within BS EN 81-1/2 (BSI, 1998a/b) for the car to be able to be raised if the safety gear has applied, but if it is raised it should automatically reset.

7.11.6 Safety gear activating devices

The most common arrangement for activation of a safety gear is by way of an overspeed governor, see section 7.10. The linkage mechanism that operates the safety gear is connected to a steel rope of at least 6 mm diameter (the 'governor rope'), which passes from the safety gear linkage up the lift shaft, over a governor sheave, back down the shaft to the pit, around a tension sheave and back to the lift car or counterweight, see Figure 7.36. In the event of the car exceeding a predetermined speed, the governor operates a device that grips and holds the governor rope, causing the safety gear to be applied. The downward motion of the car, or counterweight, is then arrested by friction between the wedges, rollers or jaws of the safety gear and the guide rails. The safety gear should also operate an electrical switch which disconnects the motor at, or before, the instant of application of the safety gear, see section 7.10.2.

With progressive safety gear, the car may slide some distance before stopping, so the governor should allow the rope to move under force. This ensures that while the safety gear is properly engaged the weight of the lift is not directly placed on the governor or governor rope. The governor should grip and hold the governor rope with a force of 300 N or twice the force required to engage the safety gear, whichever is greater. Typically, the force required to engage the safety gear is 250 N whereas the force in the governor rope is 500–600 N.

7.11.7 Bi-directional safety gear

As the name implies this is a safety gear mechanism that will grip the guide rail in the event of the lift over-speeding in the up or down direction. Such safety devices are designed to apply a progressive force to the guide rail so as to give the lift a controlled stop.

These devices are required to be type tested, CE-marked and provided with a declaration of conformity as safety components under the Lift Regulations 1997 (TSO, 1997).

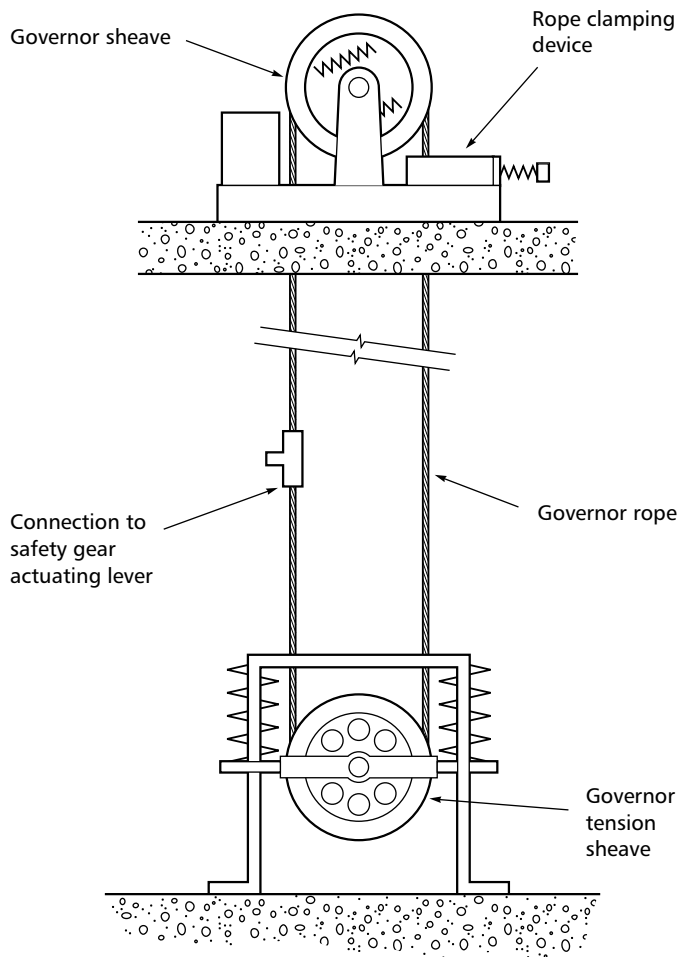


Figure 7.36 Governor rope; general arrangement

7.11.8 Type-tested safety gear

Any new safety gear is now required to be type tested 'type-tested'. This means they have been tested in accordance with BS EN 81-1 (BSI, 1998a) or BS EN 81-2 (BSI, 1998b), or in accordance with BS EN 81-50 (BSI, 2014b) as appropriate. The tests required on-site after installation are described in BS 8486-1 (BSI, 2007a) and BS 8486-2 (BSI, 2007b). Older non-type-tested devices should be tested to the standard to which they were designed.

7.12 Buffers

7.12.1 General

Buffers are placed below the car and counterweight to arrest them should they over-travel into the lift pit. In the case of positive drive lifts buffers are also required at the top of the shaft or on top of the car. The number of buffers can vary according to the design capacity of the buffers and the load to be stopped, but the stroke is dependent on the speed of the car or counter-weight. There are two basic types of buffers: energy accumulation types using springs or rubber, and energy dissipation types such as hydraulic buffers. These are illustrated in Figure 7.37.

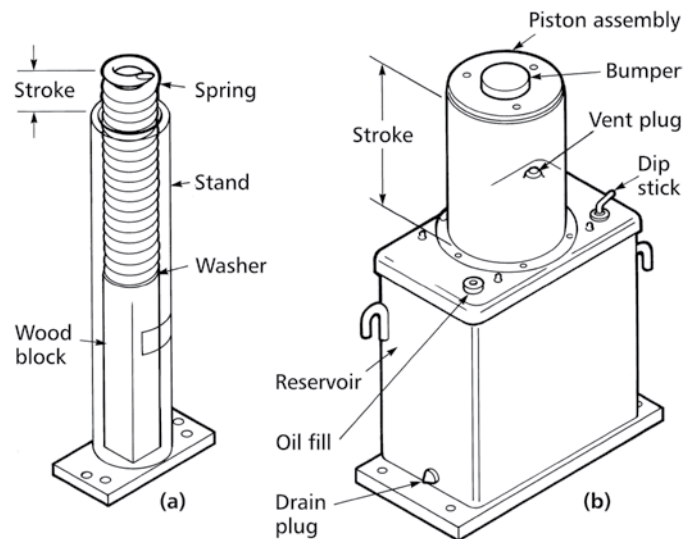


Figure 7.37 Buffers; (a) energy accumulation type, (b) energy dissipation type (courtesy of Otis Ltd.)

7.12.2 Energy accumulation buffers

The kinetic energy is stored in the gradual compression of springs or rubber blocks, which provides a progressive retarding force, see Figure 7.37(a). The range of speeds for which they can be used is normally limited to 1.0 m/s. For buffers with linear characteristics (springs), the distance the contact end of the buffer can move (i.e. the stroke) should be at least equal to twice the gravity stopping distance corresponding to 115% of the rated speed, i.e:

$$s = 2 \times 0.0674 v^2 = 0.135 v^2 \quad (7.1)$$

where s is the stroke (m) and v is the rated speed (m/s).

However, the stroke should not be less than 65 mm. The buffer should be able to cover this stroke under a static load of between 2.5 and 4 times the sum of the mass of the car and its load.

Energy accumulation buffers with non-linear characteristics (polymer buffers) are required to be type-tested. The test requires that when the car impacts the buffer at 115% of rated speed, its retardation does not exceed $2.5 g_n$ for more than 0.04 s, and that the average retardation does not exceed $1.0 g_n$ ($1.0 g_n = 9.81 \text{ m/s}^2$).



Note: in BS EN 81-50 (BSI, 2014b) the text has been changed slightly to preclude the use of these buffers at higher speeds, where the average retardation could be within the stated limits but peak values may be unacceptably high.

7.12.3 Energy dissipation buffers

The kinetic energy is dissipated by forcing oil through a series of holes or slots, see Figure 7.37(b). Energy dissipation buffers (hydraulic) provide a near constant rate of deceleration and are therefore suitable for all speeds.

The stroke (i.e. the distance moved by the buffer piston or plunger) required should be at least equal to the gravity stopping distance corresponding to 115% of the rated speed,

see BS EN 81-1/2 (BSI, 1998a/b) or BS EN 81-20 (BSI, 2014a), i.e:

$$s = 0.0674 v^2 \quad (7.2)$$

It is permissible to reduce the stroke so as to avoid excessive pit depth, provided that additional speed monitoring equipment is installed to ensure that the car speed is reduced even under fault conditions at terminal floors. If such equipment is provided, the speed at which the car strikes the buffer may be used in the calculation instead of the rated speed. However, the stroke cannot be less than 50% of that resulting from equation 7.2 for lift speeds up to 4.0 m/s and never less than 420 mm. For rated speeds above 4.0 m/s the stroke cannot be less than 33 1/3% of that resulting from equation 7.2 and never less than 540 mm.

7.12.4 Type-tested buffers

Buffers for new lift installations are required to be type-tested and final testing at site can therefore be carried out in accordance with BS 8486-1 (BSI, 2007a) or BS 8486-2 (BSI, 2007b), as appropriate. Older non-type-tested buffers should be tested in accordance with the standards to which they were designed.

Testing at full speed may not damage the buffers or the lift but the tests are severe and should not be repeated unnecessarily. Energy dissipation buffers should be inspected before testing to ensure they have the correct quantity and type of oil. After testing check that they have not lost oil and have returned to their fully extended position. BS EN 81-1/2 (BSI, 1998a/b) and BS EN 81-20 (BSI, 2014a) require an electrical switch to be fitted to ensure the car cannot run if the energy dissipation buffer is not fully extended.

Type-tested buffers require inspection and do not normally require further testing other than that required by BS 8466-1 or BS 8466-2, as applicable.

7.12.5 Active buffers

Active buffers are normally used as a means to create artificial free space where only restricted headroom or pit space exists.

This device consists of a buffer, usually an energy dissipation type (hydraulic) located in the pit, normally in a retracted position out of the line of the lift car, see Figure 7.38. They are usually additional to the normal buffers provided under the car or counterweight. When required the device moves by gravity into the path of the lift to block its travel. Such devices will in future become more common with the introduction of new requirements for lifts with reduced lift pits and headroom spaces as these become more widespread.

These devices are required to be type tested, CE-marked and provided with a declaration of conformity as safety components under the Lift Directive 1997 (TSO, 1997).

Testing should be as defined by the manufacturer.

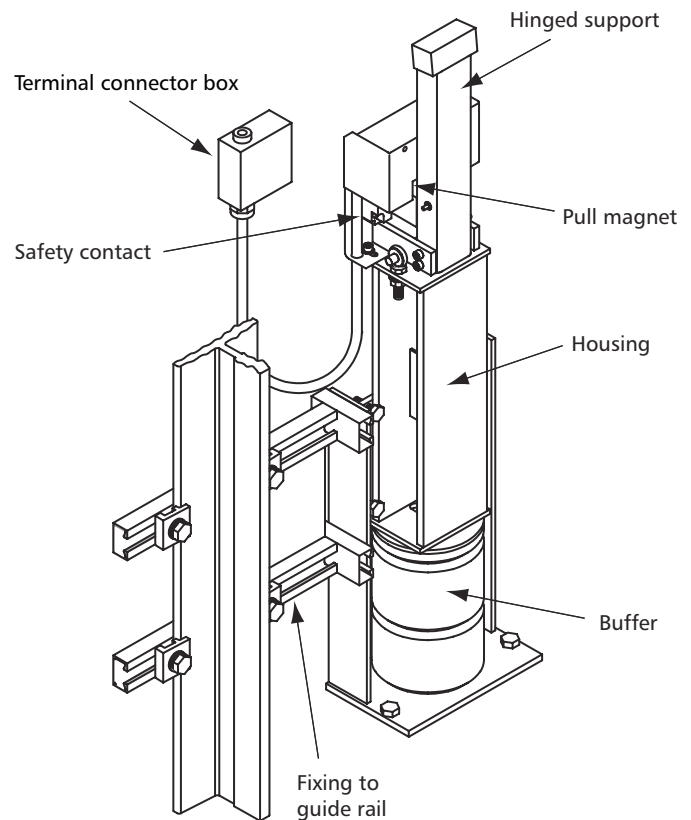


Figure 7.38 Active buffer (courtesy of Wittur K+S GmbH)

7.13 Uncontrolled movement devices

7.13.1 Ascending car overspeed protection (uncontrolled upward movement)

New lifts are required by the Lift Regulations 1997 (TSO, 1997) to apply Essential Health and Safety Requirement 3.2, by providing a means to prevent ascending car overspeeding where such a risk exists. The risk does not exist in all lift designs, but where failure of a component (electrical, mechanical or electronic) could result in the lift travelling up at a speed greater than the designer intended then a device to stop the condition, or at least reduce speed to equal the buffer impact speed, should be provided.

In an electric traction lift a counterweight is normally employed. The lift motor may drive the car and its counterweight via a gearbox with the traction sheave attached to the low speed output shaft (see Figure 7.8). In such a design the main brake is acting on the gearbox high-speed input shaft and a failure in the gearbox would in effect separate the motor and brake from the load (lift car and counterweight). In this condition gravity acting on the counterweight would result in the counterweight weight descending and the car moving upwards. This movement could not be stopped by the brake or lift motor and therefore would be uncontrolled upward movement.

In a conventional hydraulic lift without a counterweight, see Figure 7.14, the upward speed of the lift is controlled by the delivery of the pump unit. Over-speeding in the up direction is not possible and such designs do not therefore

require a device to prevent the condition. This is assuming the up speed is equal to the maximum pump delivery.

Various means can be employed to stop uncontrolled movement but they should act directly on the car, counterweight, main ropes or driving sheave or piston. It is also permissible for the device to act on the same shaft as the traction sheave if it acts in the immediate vicinity of the sheave. A conventional safety gear fitted to the counterweight and activated by an overspeed governor is one simple solution. This can be economical if a counterweight safety gear is already required to address the risk resulting from it running above an accessible space. A car safety gear capable of operating in either the up or down direction ('bi-directional safety gear') is another possibility as is a brake acting directly on the traction sheave. A further possibility is a rope brake. This device can clamp the main ropes under the required conditions to arrest the car.

Whatever device is used it is required to operate at not less than 115% of rated speed and not more than 125% of rated speed. When activated it should bring the car to a stop with a rate of retardation not greater than $1.0 g_n$ (9.81 m/s^2). Once activated it should be possible for a competent person to release the device without having to gain access to the car or counterweight.

Devices used for uncontrolled upward movement are classed as Safety Components under Annex IV of the Lift Directive (OJ, 1995) (enacted in the UK by the Lift Regulations 1997 (TSO, 1997)) and as such should be type tested, CE-marked and issued with a Declaration of Conformity. BS EN 81-1 Annex F (BSI, 1998a) and BS EN 81-50 (BSI, 2014b) define the type test requirements for such devices.

7.13.2 Protection against unintended movement

Amendment A3 to BS EN 81-1/2 (BSI, 1998a/b) required a system that prevents uncontrolled movement of the lift car away from a floor with doors open. This amendment required the lift to be stopped before it had moved more than 1.2 m from the floor, see Figure 7.39.

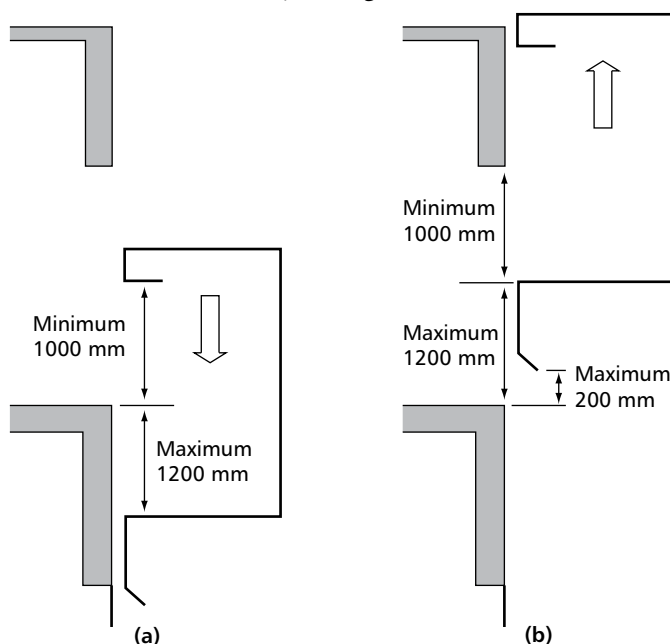


Figure 7.39 Limits to uncontrolled movement



Note: these requirements have been carried over into BS EN 81-20 (BSI, 2014a) with the type-testing requirements defined in BS EN 81-50 (BSI, 2014b).

Uncontrolled movement of the car with doors open can occur for a number of reasons, for example loss of traction, failure of a gearbox shaft or gear, or failure in a drive. The amendment to the standard does not address a traction failure as it is considered that this is an unlikely event when the lift is designed to the current BS EN 81 series of standards. The current traction calculation being sufficiently robust in terms of its safety margin and traction is not something that just fails. It deteriorates over time and therefore is an observable condition, unlike a gearbox failure where the gear can suddenly fail.

In principle any movement of the car at the floor is monitored and in the event that the car moves beyond certain limits with its doors open a device will be used to arrest the car before it has travelled beyond the limits indicated in Figure 7.39.

The monitoring of the car position may be performed by electronics, whilst the arrest of the car can be made by a number of different devices or a combination of devices such as, a bi-directional safety gear, car safety gear in the down direction with a rope brake in the up direction or sheave brake or a main brake if designed and tested for this purpose.

Where a machine brake is used it must be a double brake as required by the current BS EN 81 standards. A double brake means that all elements acting to stop the lift, brake shoes, springs, arms, pole etc. are provided in two sets so that if one set fails the other set is capable of arresting the car.

When a brake is used for this purpose it must also possess a self monitoring system that checks the operation of the brake and in the event of one brake failing the lift should be removed from service until the situation is corrected. A brake used for this purpose should be type tested and CE-marked as a safety component for this purpose. It should also be positioned on the machine in a location to ensure a gearbox failure is covered.

Whatever device is used to arrest the lift it should act on the car, counterweight, traction or compensating ropes or traction sheave if in the immediate vicinity of the sheave. It should also be a device that is not used in the normal safe movement and stopping of the lift unless its proper operation is monitored.

There are usually several elements to the uncontrolled movement system, namely a device to detect the position of car in relation to the floor level, and a device to check if the movement is intentional or unintentional. A device to stop the lift and in some designs a monitoring system. All these elements are subject to type-testing unless incorporated within a single device that is itself type-tested.

If a PESSRAL ('programmable electronic systems in safety related applications for lifts'), see section 8.3, is also incorporated it must be tested in its own right under the rules for PESSRAL.

If the device used to arrest the lift is already a type-tested device, such as safety gear, it must be tested for this particular uncontrolled movement condition.

These devices are not legally classified as safety component but are treated in the same manner by BS EN 81-50 (BSI, 2014b). This means they are required to be laboratory tested but not CE-marked. These devices are not classified as safety components. All items involved in providing a means to control uncontrolled upward movement are subject to laboratory testing.

There are now many devices on the market to cover this condition for both traction and hydraulic lifts.

7.14 Suspension systems

This section discusses traditional suspension systems, but also considers developments in suspension including flat construction and use of non-metallic materials (see section 7.14.3). These suspension systems are lighter and more flexible than traditional ropes, enabling them to be used with smaller sheaves. They produce less noise when passing over the sheaves and, depending on the construction, can have less stretch and a longer life expectancy than conventional ropes.

7.14.1 Steel ropes

7.14.1.1 General

Steel ropes used for hoisting lift cars are of standard construction, each strand consisting of a number of wires. Strength and flexibility are the most important properties. The strength is obtained by the use of steel with a high carbon content while flexibility is provided by the stranded construction.

7.14.1.2 Steel rope construction

Various rope constructions are used, and the size and tensile strength of the wires vary according to the construction. BS EN 81-1/2 (BSI, 1998a/b) states that the strength of wires for single tensile strength ropes should be 1570 N/mm or 1770 N/mm or, where BS EN 81-20 (BSI, 2014a) is being followed, comply with BS 12385-5 (BSI, 2002). The strength of wires for dual tensile strength ropes should be 1370 N/mm for the outer wires and 1770 N/mm for the inner wires. The wires are formed around a fibre or steel core. This core is impregnated with a lubricant to reduce friction of the internal parts when in use and prevent corrosion when not in use.

Rope construction is referred to by numbers such as $6 \times 19(9/9/1)$, see Figure 7.35(a). The first number '6' indicates the number of strands used to form the rope whilst the second number '19' indicates the number of wires used per strand. The way the strand is constructed is indicated by '(9/9/1)'; nine outer wires around nine inner wires around a single central wire. A rope designated as $6 \times 19(12/6+6F1)$, see Figure 7.35(b), indicates six strands each made up of 19 wires. The 19 wires are arranged with 12 on the outside, within which is a ring of six wires, plus

six smaller 'filler' wires (i.e. 'F') around a single central wire.

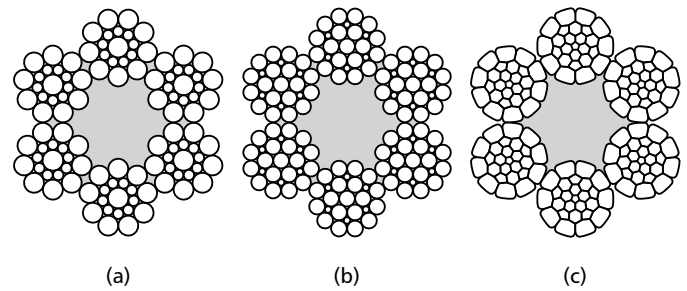


Figure 7.40 Types of rope construction; (a) $6 \times 19(9/9/1)$, (b) $6 \times 19(12/6+6F1)$, (c) 6×26 dyform rope with fibre core

Conventional lift ropes use wires of round sections, see Figure 7.40(a) and (b). In the dyform rope, the outer wires are not of simple circular section but are shaped to provide a larger exposed area, see Figure 7.40(c). This results in an increased breaking load, reduced stretch, and maintains fatigue resistance. Dyform ropes have been developed for high-speed high-rise applications but may also be used for other applications.

7.14.1.3 Rope sizes

The size of a rope is its nominal diameter, which for lifts is usually between 8 and 22 mm, according to the strength required. The most common sizes are 11, 13, 16 and 19 mm. The diameter is that of the circumscribed circle and is measured over each pair of opposite strands. BS EN 12385-5 (BSI, 2002) specifies that the actual diameter when supplied is that measured with the rope under a tension of 10% of the minimum breaking load. The size should be within +3% and -0% of the nominal diameter. Some special ropes may be manufactured to even tighter tolerances.

7.14.1.4 Rope lays

Generally, two types of lay are employed in lift ropes: Lang's lay and the 'ordinary' lay, see Figure 7.41.

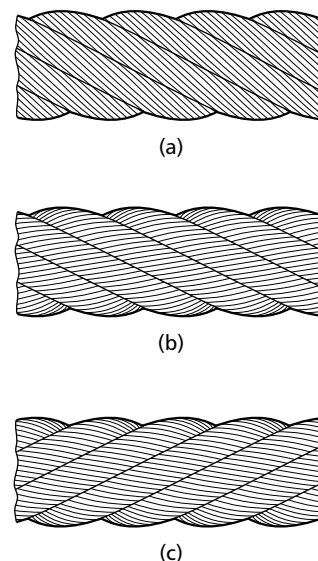


Figure 7.41 Rope lays; (a) Lang's lay, (b) ordinary lay, right hand, (c) ordinary lay, left hand

In the Lang's lay, the direction of the twisting of wires in the strand is the same as the direction of the twisting of the strands that form the rope, see Figure 7.41(a). The advantages of this arrangement over the ordinary lay are that it

offers a greater wearing surface when in use and therefore a longer life. It is also more flexible but the rope is easy to kink if mishandled during installation and any benefits are then lost. A disadvantage with Lang's lay is that it does not exhibit the same surface strand breakage as ordinary lay, thus making their detection more difficult.

In the ordinary lay, see Figure 7.41(b), the wires in the strand are twisted in the opposite direction to the strands in the rope. Ordinary lay ropes are now used more frequently because they are more tolerant of mishandling and, provided the rope and sheave system is properly designed, give adequate life.

For both Lang's and ordinary lays, the length of lay of a rope is the distance, measured parallel to the axis of the rope, in which a strand makes one complete turn about the axis of the rope. The length of lay of a strand, similarly, is the distance in which a wire makes one complete turn about the axis of the strand. The rope strands can rotate either clockwise (right hand) or anti-clockwise (left hand) for both types of lay.

7.14.2 Aramid ropes

7.14.2.1 Aramid rope construction

Aramid (sometimes referred to as Kevlar®) is a high tensile synthetic fibre that can be spun to form rope of round section, which can provide the strength of a conventional steel ropes with a significant reduction in weight and increased flexibility. The increased flexibility allows the rope to be passed over small diameter sheaves whilst the reduction in weight allows for ease of handling during installation and reduced power demand on the machine.

Rope weight is a significant factor in high-rise lifts and conventional steel rope imposes a rise limit of approximately 600 m. The introduction of lightweight suspension systems may allow this rise limit to be extended significantly.

7.14.2.2 Aramid rope condition monitoring

This new material requires new rejection criteria and in some cases monitoring devices have been developed to keep track of the rope condition. Conductive fibres can be spun into ropes that allow a current to be passed through. By monitoring this current passing through the rope deterioration can be monitored.

7.14.3 Flat belts

7.14.3.1 Flat belt construction

For many years lifts have used steel wire rope for the suspension system but today materials other than steel are being used and in new ways. Amongst these are flat belts, see Figure 7.42. These consist of a series of steel cords placed side-by-side and encapsulated within a polyurethane jacket.

Such belts possess the same strength as conventional steel ropes whilst weighing considerably less. Their slender thickness (approximately 3 mm) permits the belt to pass over a small diameter sheave whilst introducing very limited fatigue to the steel cords.

The use of small sheaves permits considerable savings in space whilst the belt has reduced weight with high traction properties from the jacket and protection of cords from containments in the atmosphere.

Such an innovation has many advantages, not least of which can be an increased life, ease of handling, reduced motor power demand etc.

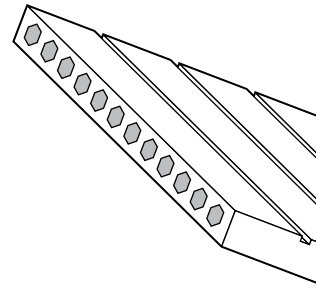


Figure 7.42 Section through a flat construction belt with a non-metallic covering (courtesy of Otis Ltd.)

7.14.3.2 Flat belt condition monitoring

The inspection and rejection criteria for conventional steel ropes have long been established, but the introduction of flat belt technology has resulted in the need to develop new rejection and inspection criteria by the manufacturers.

The condition of a belt can be determined by visual inspection. Detailed inspection is time consuming and it is not surprising to note that remote belt monitoring devices have been developed. These consist of a small box of electronics mounted at one of the belt termination points in the lift well. The electronic systems monitor the internal condition of the belt and can either remove the lift from service if a serious defect is detected or notify a remote monitoring centre of belt deterioration.

7.14.4 Plastic coated ropes and other man-made fibre rope types

The use of various types of material are now being utilised in suspension ropes. The material used offer better protection against corrosion and can assist in noise reduction. Whatever type is used need to comply with the standards defined the standards chosen for design such as BS EN 81-20 (BSI, 2014a) that stipulates ropes to BS EN 12385-5 (BSI, 2002). If ropes used are not to the required standard a Notified Body approval should be available from the manufacturer.

7.14.5 Safety factor for suspension

The rope safety factor is the ratio between the minimum breaking load of rope and the maximum force in the rope when the car is stationary at the lowest landing.

$$S_r = n F K / w \quad (7.3)$$

where S_r is the safety factor for the rope, n is the number of separate suspension ropes, F is the nominal breaking strength (N) of one rope, K is the roping factor (1 for 1:1, 2 for 2:1, etc.) and w is the load suspended on the ropes with the car at rest at the lowest floor (N).

The load suspended includes the weight of the rope, the car and its rated load, a percentage of the suspension ropes plus a percentage of the compensation, if provided. BS EN 81-1 (BSI, 1998a) states that a minimum safety factor of 12 should be used for traction lifts with three or more ropes; 16 in the case of traction drive with two ropes, and 12 for drum drive arrangements. Greater factors of safety may result from use of the calculations in BS EN 81-1 Annex N. BS EN 81-20 (BSI, 2014a) requires the same safety factors and BS EN 81-20 provides a method for evaluation of traction and safety factor.

7.14.6 Terminations

Various methods of terminating the rope are available, the most commonly-used today being the swaged end, other types being bulldog grips and socketed end, see Figure 7.43. Whichever form of termination is used, its strength should equal at least 80% of the minimum breaking load of the rope. With bulldog grips, see Figure 7.43(a), it is important to use the correct number, tightened to the correct torque. Where socket terminations are used, the ends of the rope are bent over and tucked into the socket, see Figure 7.43(c). The socket is then filled with white metal (also known as babbitt) or resin.

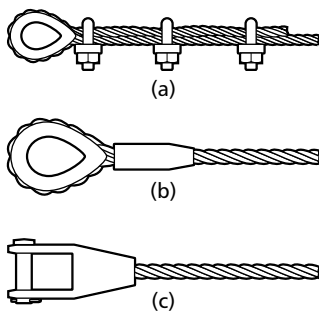


Figure 7.43 Rope terminations; (a) bulldog grip, (b) swaged end, (c) socket end

The introduction of non-metallic ropes has resulted in the development of new types of terminations, however all types of termination must provide at least 80% of the strength of whatever suspension is used.

In the recently published BS EN 81-20 (BSI, 2014a) the types of acceptable termination have been limited to the following:

- swage terminals to BS EN 13411-8 (BSI, 2011b)
- asymmetric wedge sockets to BS EN 13411-3 (BSI, 2008)
- symmetric wedge sockets to BS EN 13411-7 (BSI, 2006b)
- ferrules to BS EN 13411-3 (BSI, 2008).

7.14.7 Rope length and rope stretch

When installed on a traction lift, the rope length should be such that when the car is on its buffers, and the buffers are fully compressed, the counterweight is clear of the underside of top of the lift shaft or any other obstruction. When the counterweight rests on its fully compressed buffers, no part of the car may touch the top of the shaft or any obstruction in it. The actual clearance depends upon car speed. BS EN 81-1 (BSI, 1998a) and BS EN 81-20 (BSI, 2014a) stipulate requirements for these clearances.

When a load enters a car, elongation of the rope occurs. The amount depends on the type of rope, its length and the load applied. On high-rise installations this elongation can cause the car to move down below the floor by a small amount. To compensate for this the lift should be provided with a re-levelling feature to maintain the lift at floor level.

7.15 Roping system

7.15.1 General

There are many different roping systems, some of which are shown in Figure 7.44. The best method to employ depends upon the particular situation, e.g. machine position, available headroom, rated load and speed. However, whatever are the requirements, the simpler the roping system the better.

The lift machine is usually situated either at (or near) the top or bottom of the shaft. All types of electric traction drive are suitable for either top or bottom drive, but the best, and simplest, roping system is with the machine at the top. This usually provides the best rope life, lowest capital cost, least power consumption and minimum structural loads. Bottom drive is generally mechanically more complex in its roping arrangement and hence more expensive than top drive.

Typically, the structural load applied to a building with the machine above is the total weight of the lift machine, control gear, car, car load and counterweight. With the machine below, the structural load is approximately twice the sum of the weight of car, car load and counterweight. If the weight of the machine and control gear is considerably greater than the combined weights of the car, car load and counterweight, the structural load may be less with the machine below, but this is unusual.

For a machine located at the top of the building, the simplest rope arrangement is that of the single wrap 1:1 system in which the ropes pass over the traction sheave once and the rope ends are terminated at the car and counterweight, see Figure 7.44(a). With this system, the car travels 1.0 m for every metre of rope moved over the traction sheave.

Figure 7.44(b) shows a single wrap 1:1 arrangement with the machine located below. This arrangement removes the need for a full height machine room at the top of the building, but space for the overhead sheave may still be required. The saving is generally about 900 mm in height but extra costs may result due to the additional rope and sheaves. Figure 7.44(g) is also a single wrap 1:1 arrangement but with compensation.

With a 2:1 roping system, the car travels 0.5 m for every metre of rope moved over the traction sheave. This means that the speed of the car is half that of the driving machine. Either top- or bottom-located machines may be used with a 2:1 roping system. An advantage of this arrangement is that it enables a small number of machines to cover a wider range of speeds and loads since, by halving the speed, the load may be doubled. In addition, the load imposed on the machine sheave shaft is effectively halved as half the mass of the car and half the mass of the counterweight is

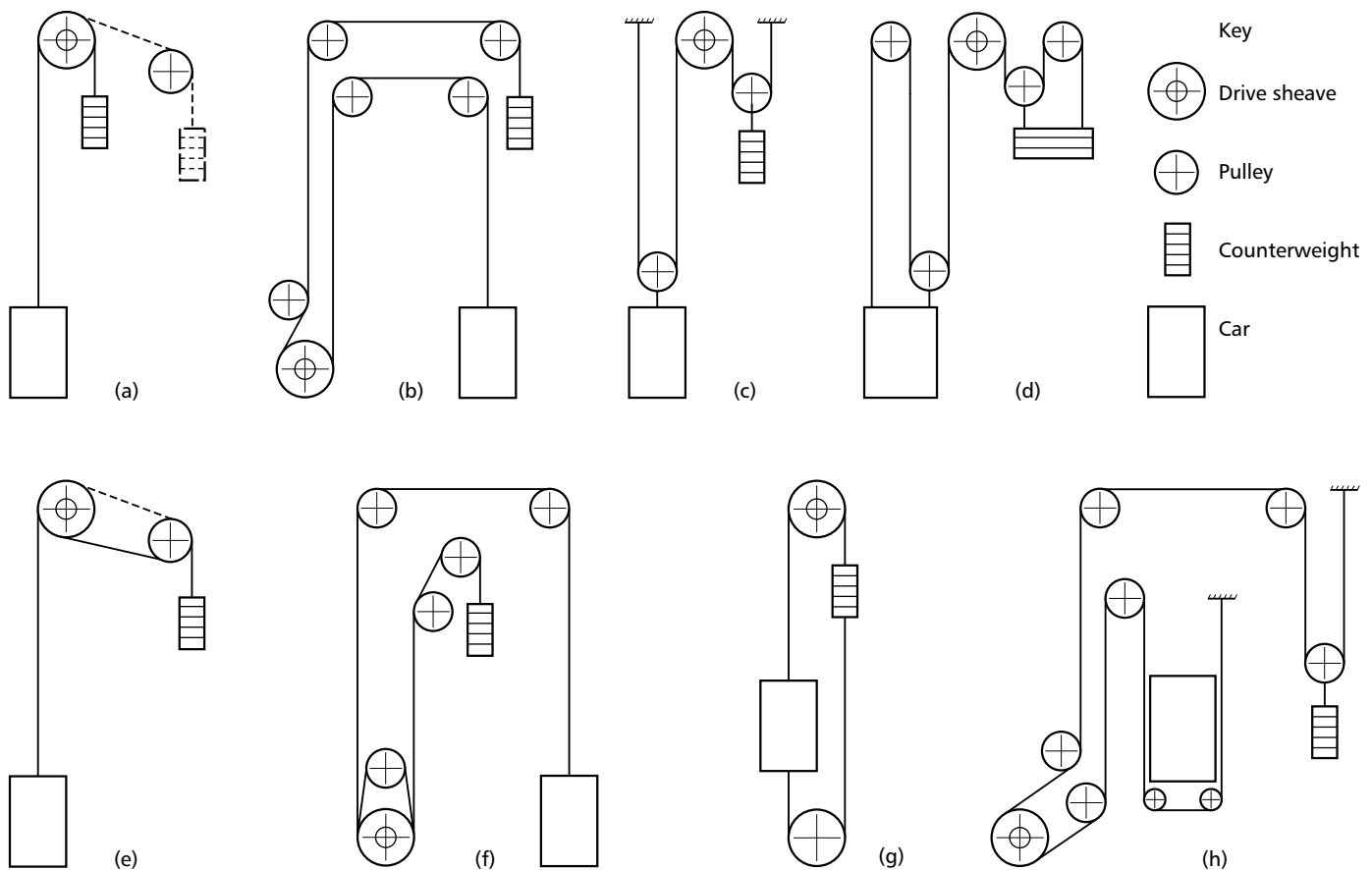


Figure 7.44 Roping systems; (a) 1:1 single wrap, machine above, (b) 1:1 single wrap, machine below, (c) 2:1 single wrap, machine above, (d) 3:1 single wrap, machine above, (e) 1:1 double wrap, machine above, (f) 1:1 double wrap, machine below, (g) 1:1 machine above with compensation, (h) 2:1 single wrap, machine below, underslung car

supported by the building structure, see Figure 7.44(c). The reduction in the load carried by the ropes passing over the traction sheave reduces rope pressure and may enable fewer ropes to be used. The system does, however, require longer ropes and rope life may be reduced by the additional bending stress caused by the number of sheaves that the ropes should pass over. Figure 7.44(h) is also a 2:1 arrangement but with sheaves located below the lift car.

Where bottom drive is employed, a reduction in headroom may be obtained using an underslung arrangement for the lift car. This involves mounting pulleys on the underside of the car and positioning high-level pulleys and rope anchorages (outside the line of the car roof) at the top of the lift shaft, see Figure 7.44(h). No pulley room is required with this arrangement. It should be noted that increased running noise may be apparent with the under slung arrangement, therefore speeds are usually limited to 1.6 m/s.

Many other rope systems have been used, such as 3:1 (see Figure 7.44(d)) but these are not commonly used except for very large goods lifts or other special applications.

Figure 7.44(e) and (f) show double wrap arrangements. The ropes pass twice over the drive sheave and as a result the traction is increased dramatically. This arrangement is usually found on large, high speed gearless drives.

7.15.2 Rope compensation

Ropes may be hung under the car to the counterweight in order to compensate for the weight of main ropes, see

Figure 7.44(g). Compensation is used to ensure that adequate traction is available, wherever the car is in the shaft, and/or to reduce the power requirement for the drive motor. For lifts up to 2.5 m/s, chains or free ropes may be used, tensioned by gravity. For speeds above 2.5 m/s, a tensioning device may be required. This usually takes the form of a weighted sheave fixed between two guides. For speeds above 3.5 m/s, an anti-rebound device is required. This prevents the counterweight from rising through its own inertia if the car should be stopped abruptly, and prevents the car from continuing upwards if the counterweight should be stopped suddenly. This is sometimes referred to as 'tied-down' compensation, see section 7.6.4.

7.15.3 Traction systems

In all traction rope systems, the power developed by the machine is transmitted to the ropes either by a single-wrap or double-wrap traction system. In the single-wrap system the ropes pass once over the sheave, into which specially shaped grooves are cut. These are known as traction grooves. The traction force depends on the specific pressure between the ropes and the sheave, the frictional properties of the rope and sheave materials, the groove angle (shape) and the amount by which the ropes wrap around the sheave.

These factors govern the ratio which can exist between the rope tensions on the two sides of the sheave before slipping occurs. The traction developed should be sufficient to enable the car plus 125% load to be safely supported but should be low enough to ensure that, if the tension in either the car or counterweight side of the rope is reduced to zero,

the traction is insufficient to permit the car or counterweight to be hoisted. Excessive traction can also result in excessive sheave and rope wear. BS EN 81-1 (BSI, 1998a) or BS EN 81-20 (BSI, 2014a) provide formulae for the calculation of traction using conventional steel ropes.

The shape of the groove has a considerable influence on the tractive force. Figure 7.45 shows typical grooves that may be employed. The straight V-shape provides the greatest traction, the least support to the rope and, therefore, the greatest wear. The round-seat type provides the most support and the least traction and wear.

Flat construction belts do not use shaped grooves to develop the required traction. Traction is achieved by means of the large surface area of material in contact with the sheave, the surface of which is also virtually flat. The absence of a groove avoids pinching the rope, which greatly extends the life of the rope.

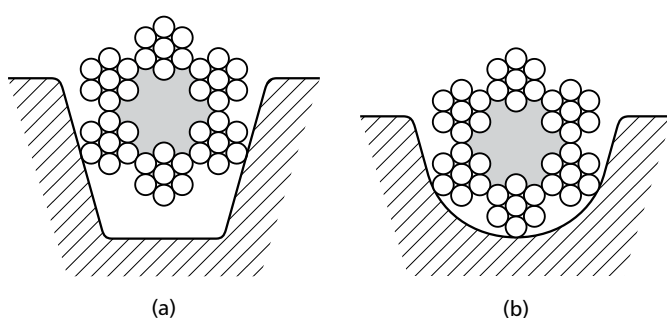
The number of variables involved in the traction and rope life means that it is unreasonable to request a particular groove or material and the manufacturer should be allowed to provide the combination that they feel to be the most appropriate. Ropes may be expected to last seven to ten years for the lifts in a typical office building. However, this may not be achievable in environments such as large hotels, where lifts operate for up to 20 hours per day.

7.16 Car and landing features and inspection controls

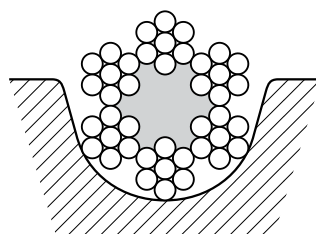
7.16.1 General

The term fixtures embraces car operating panels, indicators, push buttons, hall lanterns and any signs, magnetic card readers or key-pads. If properly designed, they can help to make a lift more 'user friendly' and can improve service. While these items can contribute greatly to the appearance of the lift, their prime function is to inform users of what is happening and/or to enable instructions to be given to the lift control system. Essential fixtures such as buttons, indicators and hall lanterns should be large, conspicuous and easy to see against the surrounding walls.

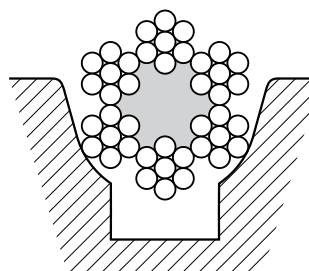
BS EN 81-70 (BSI, 2003c) defines requirements for lift controls and fixtures that enable all users including those with disabilities to use the lift with relative ease.



(a)



(b)



(c)

Figure 7.45 Common types of groove; (a) 'V' groove, (b) round seat ('U' groove), (c) progressive or undercut groove

7.16.2 Pushbuttons

Buttons may be square, round or any other shape but should not be small. Ideally, the area pressed should be at least 400 mm² and no side should be less than 20 mm. Some means of informing users that their call has been registered is good practice and this may be by illumination of the button or a surrounding halo or by a separate indicator. In addition to this visual feedback, audible feedback may also be provided. Illumination is best provided by light emitting diodes (LEDs), which give long trouble-free life. Face plates should be of sufficient size to make the buttons easily noticed. Buttons without face plates are difficult to see and therefore should never be installed without a face plate. The face plate should contrast both with the button and the surrounding wall to ensure that it is easily noticed.

Markings on buttons should be in a clearly, easily read typeface such as Helvetica and by some form of tactile indicator, if possible. Braille markings are sometimes provided, to assist those persons with impaired vision who can read Braille. If used, Braille should preferably be 'Grade 2, English', unless the client requires something different. Simple tactile markings are preferred since these are discernible by all. Any such markings should be on the button itself or adjacent to it. The size of the markings should be of the order of 15 mm in height and located at between 10 and 15 mm from the button.

The height of the buttons above floor level in the car should be between 900 mm and 1200 mm. Where it is intended that the lift should be accessible to wheelchair users, buttons inside cars and on landings should be not less than 400 mm from any wall at right angles to the buttons.

7.16.3 Lift position indicators

Preferably indicators should be provided within the car and on the main landing. On single units, an indicator at all floors is a useful addition which provides users with a visible indication of the progress of the lift. It may be desirable to indicate when lift cars are unavailable for passenger use, although this is not required by BS EN 81-1/2 (BSI, 1998a/b) or BS EN 81-20 (BSI, 2014a). On non-collective lifts, a 'lift busy' indicator is necessary so that users know that the lift cannot accept calls.

Some lift systems deliberately order a car to bypass a landing call in order to optimise overall response times. Passengers observing this operating sequence are likely to interpret it as a fault. Thus, when two or more lifts are operating together, it is better not to provide indicators on every landing but only at the main entrance floor for the building. Figure 7.46 illustrates three types of indicators; multi-light, dial and digital.

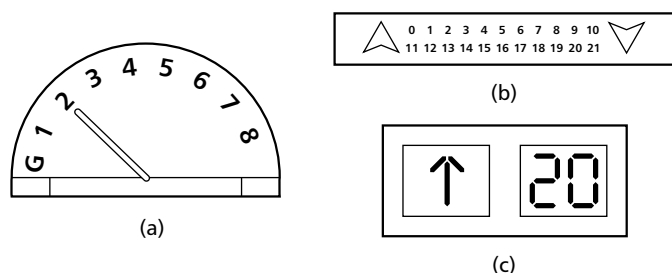


Figure 7.46 Lift position indicators; (a) multilight, (b) dial type, (c) combined hall lantern and digital indicator

Incandescent lamps are not a good choice for position indication since they consume more energy and have a shorter life than other forms of illumination. On large groups of lifts, indicator lamp replacement can become a frequent maintenance task. The power requirements are illustrated by the fact that the car lighting and indication can consume half the total energy required to run the lift.

Digital-type indicators are by far the most popular and many versions exist. Illumination may be by LCD (liquid crystal), TFT (thin film transistor or solid-state indication using LEDs (light emitting diodes)). LED displays provide a compact, energy efficient solution. Dot matrix displays allow great flexibility in floor identification. Large dot matrix displays can be used to display messages which can be read easily from anywhere in the car.

Whichever type is chosen, the display should be clear to all users including the partially sighted. This requires that any symbols should preferably be between 30 and 60 mm in size and located between 1600 and 1800 mm from floor level. It is also good practice to provide audible feedback with any such signals. Voice annunciators are useful. However, the announcements can become a source of irritation to lift users. This can be avoided in part by enabling the volume to be adjusted between 35 and 55 dBA.

Fixtures should be displayed against a dark background to provide a sharp contrast in colour and should be visible from acute angles 140° as stated in BS EN 81-28 (BSI, 2003a). In large cars (i.e. 1600 kg and above), two operating panels, each with an indicator, should be considered.

7.16.4 Lift direction indicators

On any simplex collective lift, passengers should be provided with a means of determining the direction of travel of the car before they enter. This can be achieved by providing a hall lantern or direction indicator at each landing or a single direction indicator within the car, positioned so as to be visible when the doors open. Again illuminations by LEDs or vacuum display are preferable because of their high reliability. The sizes and sound levels should follow the guidelines for lift position indicators given in section 7.16.3.

7.16.5 Hall lanterns

Hall lanterns should always be provided at each landing for groups of two or more cars and may be provided on single lifts, if desired. The lantern should illuminate and chime before the car arrives at the floor to alert waiting passengers. This enables the passengers to start moving toward the arriving lift so that door dwell times can be kept to a

minimum. To assist the partially sighted, the chime should emit notes of different tones and sound once for up and twice for down. Numerous designs are available but again the essential points are reliability and practicality. It should be borne in mind that the principal function of lanterns is to provide the passengers with information. The sizes and sound levels should follow the guidelines for lift position indicators given in section 7.16.3.

7.16.6 Passenger communication and alarm devices

All lifts require an alarm device for use in an emergency. In the past, this has taken the form of a simple bell to summon help. However, the Lift Regulations 1997 (TSO, 1997) required new lifts to be connected to a device that allowed trapped passengers both to summon help and to communicate directly with those who can arrange for their rescue. BS EN 81-28 (BSI, 2003a) is a harmonised standard that defines requirements for such devices. Other designs are still possible but as a harmonised standard it's best to stick with the standard, rather than trying to define something new that will certainly cost more and require approval by a Notified Body for lifts.

The button or other device used to activate the alarm should be provided in the car operating panel should be yellow and marked with a bell shape symbol. When operated it should provide both audible and visual information to the user. A yellow pictogram should indicate that the alarm has been sent. A green illuminated pictogram in addition to any audible signal should indicate when the alarm call has been registered by the rescue organisation.

The design of the system should be such that once the alarm has been raised there should be no need for further action or speech by the trapped passenger. The system should inform the rescue service of the location of the lift. This ensures that in the event of the person being unable to communicate for any reason, their predicament and location is known. A conventional telephone does not therefore satisfy this requirement.



Note: the requirements for the pictogram are not defined in BS EN 81-28, but will be defined in the next revision of ISO 4190-5.

7.16.7 Inspection controls

These have historically been provided on the top of lift cars to permit the lift to be moved at reduced speed in relative safety. It is now recognised that with the introduction of machine-room-less lifts and an increasing drive to reduce accidents to persons working on lifts, the provision of controls in other areas of the lift may be beneficial. This has been taken into BS EN 81-20 (BSI, 2014a). Where multiple inspection controls are provided (e.g. car top, lift pit, inspection platform), for safety reasons special design rules apply.



Note: multiple inspection controls are not just inspection controls connected in parallel but specially interlocked.

BS EN 81-1/2 (BSI, 1998a/b) already recognises the need for more than one inspection control in some situations. Where more than one inspection control is provided it needs to be

electrically interlocked with any other inspection control to ensure that the operation of one device does not override an instruction from another.

7.17 Guarding

It is generally accepted in the UK that all exposed rotating parts of lifts should be guarded. The old practice of painting parts yellow is an ineffective and unacceptable solution, although still apparently acceptable according to the BS EN 81-20 (BSI, 2014a). It is advisable to insist on full guarding by specification. The specification should request that guards have fixings that remain with the guard, or with the item to which the guard is attached, in the event that it is removed.

This guarding requirement stems from the third amendment to the Machinery Directive (OJ, 2006) (on which the Lift Directive (OJ, 1995) rests) and has created a discussion over what constitutes a guard. Is a car operating panel a guard? It clearly protects users from electric shock.

Covers, shields etc. designed to fulfil a protective function that may be required to be removed for maintenance are guards and require captive fixings. Parts fulfilling an operational function are not guards and do not require captive fixings.

As an example a wire mesh cover over a traction sheave may, depending on design need to be removed reasonably frequently (once per year) for maintenance. If this covering is removed the lift still operates as normal so it is a guard. The prime function of a car operating panel is to hold the operating buttons in place and whilst it also guards persons from shock it is not classed as a guard and the fixings do not need to be captive. A trunking cover lid could be considered as a guard but it does not need to be removed for maintenance, whereas a landing lock cover does, therefore the lock cover will require captive fixings.

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8 Lift drives and controls

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8 Lift drives and controls

8.1 Introduction

The objective of this chapter is to provide a guide to lift controls so that users and specifiers may compare manufacturers' products and have confidence that they are indeed specifying the correct control equipment for each lift application. It is intended to assist the reader in identifying good and bad features and to be in a more informed position of asking the correct key questions about manufacturers' products. Documentary proof of performance, reliability and control characteristics should always be requested from the manufacturer in case of any uncertainty.

Historically, buildings and users have often suffered because of the incorrect selection of lift products within a building. Changes in office working practices and the cost of office accommodation have also played a significant part in the overall lift design; both factors can lead to the building population increasing far beyond the capabilities of the original lift control systems. In these cases, installing new computer-based equipment will normally improve the passenger-handling capacity of existing groups of lift cars. The selection of the most suitable control system for optimum performance needs to take into account the building use and also environmental performance objects. Other factors such as energy consumption saving techniques should also be considered.

8.1.1 Performance parameters

The controller influences the efficiency of a given group of lifts to move people. Parameters such as flight times, round trip times and interval (see section 3.3) provide a guide to the relative efficiency and these parameters can be either measured or obtained from the lift supplier. As an example, one second saved on a single floor transit time improves the traffic handling capacity of the lift by approximately 5%.

To maximise the transportation capacity for a given size and speed of lift car, the cycle time must be as short as possible. In practical terms:

- The lift should be capable of driving straight to floor level (known as 'direct-to-floor approach') without the need for a slower levelling speed, to ensure accurate stopping at floor level with as short a single-floor flight time as possible.
- The opening time for the doors must be short; this time may overlap with levelling.
- The door open time must be optimised to the building type, size of the lift car and passenger movement. Non-contact passenger detectors (see section 7.8.6) can be used to shorten the door open time and are necessary for lifts to be used by persons

with disabilities as required by BS EN 81-70 (BSI, 2003a).

- The door closing time should be as short as possible, commensurate with the kinetic energy limitations imposed by BS EN 81-1/2 (BSI, 1998a/b) (see section 7.8.2) and passenger comfort.

These factors have important consequences for the design of lift components and control devices.

8.1.2 Operation monitoring

In the past, lift controllers have provided little or no information on the operational state of the lifts. This information has been typically confined to:

- lift position indication on landings and in the car
- actual and intended travel direction
- 'lift in use' indication for simpler lifts using automatic-push-button control.

The Lifts Regulations 1997 (TSO, 1997) requires that a new lift has a means of generating an alarm and two-way communication system that provides direct communication to an organization capable of releasing the passengers safely. This organization and communication must be permanently available. The organisation is typically the lift maintenance company. However, it may be a 24-hour security organisation on a large industrial complex. BS EN 81-28 (BSI, 2003b) is the harmonized standard that defines the requirements for the alarm equipment and management of the alarm.

Computer-based control systems have resulted in the development of more sophisticated monitoring of the state of the lift and its traffic handling efficiency. Features typically available include:

- add-on or built-in fault detection and diagnosis
- statistics on call handling and lift usage
- a summary of group waiting times and stopping accuracies
- communications capability for transmission of information to a remote point
- the ability to monitor third-party control systems from the same remote monitoring package
- video monitor displays of the real-time operation of the lift group(s)
- voice annunciation of lift position and other messages



Caution: groups of lifts in busy public use, e.g. those in airports and hospitals, should always have some form of lift monitoring, either local to or remote from the building. If monitoring of small

groups or individual lifts is installed for maintenance purposes, the equipment local to the lift should not be over-complex. The monitored information must be checked for accuracy and relevance. False or irrelevant information can be worse than no information at all. Current alarm systems can have integrated remote equipment monitoring capability. This allows reporting of faults and equipment condition to the maintenance organization. Most manufacturers have their own solutions to lift monitoring which, in the main, rely on special computer software and it is essential to consult with the potential suppliers before specifying non-standard monitoring equipment (see chapter 14). It is rarely cost-effective for manufacturers to design one-off software for individual customers. Furthermore, it may prove difficult to locate a maintenance company willing to accept responsibility for such software.

8.2 Lift controllers

8.2.1 General

The primary function of a lift controller is to respond to inputs and produce outputs in order to monitor and control all the operations of an individual lift car. The lift controller coordinates passenger traffic demands (despatching), door control (opening and closing) and lift motion (travel speed and positioning) with other lifts that may be under combined group control within a multi-lift system.

The lift controller should sequence lift drive motion in order to always achieve the optimum speed for any travel distance. Uneven floor heights should not result in long periods of low speed travel when slowing in to some floors. The lift controller may also modify the opening time and speed of the doors in response to signals from the passenger detectors.

In general, the controller inputs are:

- car calls
- landing calls or signals from a despatcher, where applicable
- signals from devices such as fire recall, evacuation lift switch, firefighting lift switch
- door safety device signals
- lift well safety signals
- signals from passenger detection devices on car, doors and landings
- feedback from the lift drive mechanism.

The controller outputs are:

- door control signals
- lift drive control signals
- passenger signalling (call acceptance, lift position, direction of travel indication).



Note: the basic despatching task of moving a lift car in response to calls is relatively straightforward.

However, two factors combine to make the lift controller one of the most complex logic controllers to be found in any control situation. These are:

- control options.
- fail-safe operation should faults occur.

8.2.2 Lift control options

Lift control options are customer-defined modes of operation of the lift. Many options are standard and defined in the operational sequence of the lift, and are offered by many if not all lift manufacturers. In some circumstances, the complexity or combination of options makes the use of computer-based controllers essential. Amongst the most common options are:

- car preference or independent operation of one lift car
- priority passenger service, such as ‘bed service’ for hospital lifts
- destination despatching
- rapid closing of doors when a car call is registered
- reduction in door open time when passengers are detected by the interruption of a light curtain or other passenger detection device
- differential door timing so that doors stay open for longer period of time at the main floor and/or vary according to the lift traffic and use by persons with disabilities
- ‘door close’ button
- recall of all or some lifts to specified floor(s) in the event of a fire
- evacuation lift switch and firefighting lift switch inputs
- emergency power operation (the exact operational sequence is usually defined by the customer, with the crucial need for understanding the required operation to ensure appropriate equipment selection)



Caution: a detailed description of the required operation of particular options should always be provided by the manufacturer when discussing the specification with the customer. This can avoid ambiguity and misunderstandings, leading to either excessive or unexpected costs. Other modes of operation may be specified by the customer. When special operating modes are required, it is important to note that they may require special computer software and/or additional controller hardware in, for example, the case of hall call allocation-based systems. The commissioning and maintenance of such special modes is not always as straightforward as that for conventional lifts. It is important to discuss the details of such custom features between all parties during the project design stages. In many cases, not agreeing upon nor producing a functional design specification meeting all parties’ technical needs is one of the biggest causes for not providing the client with what is expected of the new system.

8.2.3 Fail-safe operation



Note: safety requirements are laid down in BS EN 81-1 (BSI, 1998a) for electric traction lifts, BS EN 81-2 (BSI, 1998b) for hydraulic lifts and in section 5.11.1.2 of BS EN 81-20 (BSI, 2014a), which states that any single fault listed in 5.11.1.2 in the electric equipment of a lift, if it cannot be excluded under conditions described in 5.11.1.3 and/or section 5.15 of BS EN 81-50 (BSI, 2014b) shall not on its own be the cause of a dangerous malfunction of the unit.

8.2.4 Controller cabinet and its location



Design tip: the introduction of machine room-less lifts and the associated amendment A2 to BS EN 81-1/2 (BSI, 1998a/b) has fundamentally changed the design of the lift. Now it is possible for the controller to be split into several decentralised components located somewhere within the lift installation.

The major part of the controller (e.g. hoist motor drive) may be mounted in the top of the well, the pit, within an enclosure on a landing or to the side of the well. Other components may be located on top of the car. Call buttons, indicators and door operator may be intelligent and communication between all parts of the control system may be carried out using serial data transmission or even by radio or laser in some applications, instead of a conventional hard-wired system. Large capacity, high-speed lifts may still use machine rooms due to the size of the hoisting machine and the associated control system and drive components.

The size of controller cabinets varies with complexity of the controls. Most cabinets are between 0.8 m and 2.5 m high. They should be installed plumb, square and securely fixed in place. They should not be located in awkward corners or restricted spaces that may cause servicing or safe-working problems. Control cabinets should be positioned such that they are not subjected to the heat resulting from machine ventilation fans or any other direct source of heat. Lighting with an illumination of 200 lux (BS EN 81-20, section 5.2.1.4.2 (BSI, 2014a)) must be provided where work needs to be carried out on control systems and machinery. The equipment should also be provided with clean, environmentally controlled conditions in accordance with those instructions outlined by the manufacturer.

The main control cabinet should be designed to allow a free flow of cooling air in order to limit the internal temperature rise and not exceed high temperature limitations according to the equipment manufacturer. All power resistors and high temperature components should be mounted in order that they do not cause undue heating of any adjacent components.



Warning: high humidity and rapid changes in temperature may cause condensation. These conditions should be avoided in the machine room or the machinery space. This is not a problem in most applications. However, where the environment is severe and condensation cannot be avoided, the following precautions should be considered:

- all equipment should be 'passivated' or galvanised with corrosion-resistant paint applied
- all components and printed circuit boards should be 'tropicalised' (to avoid mould growth and damage from condensation)
- forced ventilation and temperature/humidity control of the cabinet should be considered and if required, introduced.

8.3 Controller technology

8.3.1 General

The size of the building (i.e. the number of floors) and the complexity of the lift operations required determine the technology used for the controller. Three basic controller technologies have been used:

- electromagnetic relays
- solid-state logic
- computer-based ('intelligent') systems.

Computer-based systems offer the greatest flexibility to accommodate changes in the use of the building and the requirements of the user. For this reason, it is now by far the most commonly-used technology. Electromagnetic relays offer the least flexibility. Electromagnetic relays and contactors are used in computer-based and solid-state logic controllers in order to satisfy the requirements of the relevant British and European safety standards (BSI, 1998a/b, 2012a).



Design tip: additionally, BS EN 81-20 (BSI, 2014a) details those requirements allowing for PESSRAL (see section 8.3.5) to take over tasks traditionally achieved using relay controls; therefore whilst relays are one way to meet some of the requirements of the standards they are not the only way.

8.3.2 Electromechanical switching

Electromechanical switching devices include electromagnetic relays and mechanically driven selectors. Relays are designed for low-power switching operations and contactors for higher powers. Lift selectors, mechanically driven from the motion of the lift by a tape or rope drive, may be used for low-power logic operations in lift control. Some manufacturers use tape drives for lift position indicators, even in computer-based controllers.

To maximise the reliability of the lift controller, the number of electromechanical components should be kept to a minimum. When a relay controller is 8–10 years old, the breakdown rate of the lift rapidly increases as the relays wear out and reach the end of their useful working lives. O'Connor and Kleyner (2012) give intermittent faults as 70% of relay failures during the wear-out phase.



Caution: relay-based controllers have often presented maintenance problems when fitted to larger lifts and group systems (see chapter 9). Often, manufacturers do not include sufficient indication

to show the operational state of the relays. In cases of intermittent faults, this lack of indication can increase repair times unnecessarily. Although the controller drawings are on site, they often do not show the actual circuits because modifications may have been made without the appropriate changes being made to the circuit diagrams. Updated electrical drawings are therefore essential following any subsequent controller modification. Additionally, any associated wiring modification should be to an accepted 'factory standard' such that with an ongoing maintenance regime and the correct drawings on site, lift availability can be maximised (see BS 7255, sections 4.9, 4.19 and Annex D (BSI, 2012b)).

8.3.3 Solid-state logic technology

Solid-state logic technology includes both discrete transistor circuits and integrated circuit boards. With integrated circuits based on complementary metal oxide silicon (CMOS), 12–15 V power supplies may be used that provide high immunity to electrical noise interference.

Call signals and other direct current input signals are usually interfaced via passive filter circuits. Light-emitting diodes (LEDs) may be easily incorporated into the design to aid maintainability. It is still normal practice to use some contactors and relays to satisfy requirements of BS EN 81-1/2 (BSI, 1998a/b) and BS EN 81-20 (BSI, 2014a). Small cased relays may be used to interface between logic circuits and the high voltage parts of the controller and lift. Figure 8.1 illustrates the basic features.

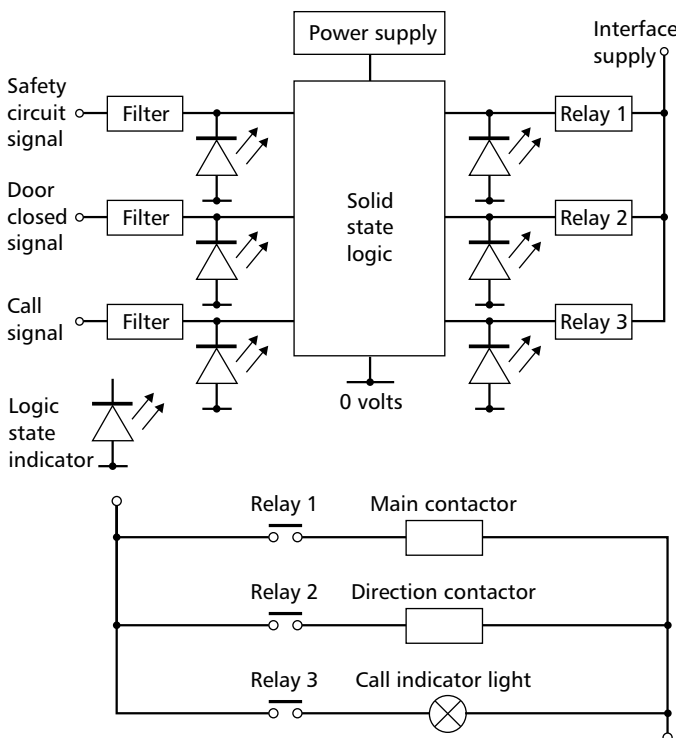


Figure 8.1 Schematic of a typical solid-state logic controller



Caution: the reliability of solid-state logic devices is dependent upon the ambient temperature, the operating point of the device (in relation to its maximum rating) and the complexity of the device. The following points should be considered to ensure maximum life:

- Increasing the ambient temperature by 25 °C increases the failure rate of a device by a factor of ten. Therefore, the lift motor room should be kept as cool as possible.
- Running a solid-state device at 70–80% of its maximum rating doubles its reliability compared with running at maximum rating.

Integrated circuits allow lift controllers to incorporate many lift options and are suitable for single and duplex lifts, where there is a low density of traffic.

8.3.4 Computer-based technology



Note: computer-based technology enables complex and adaptable functions to be performed. However, non-standard features should be avoided because of the expense involved in developing and testing special computer software. It is for this reason that open-protocol systems are generally viewed more favourably by end users, lift consultants and lift contractors alike. Dedicated, lift processor-based controllers offer flexibility in the options provided and permit fine-tuning to match the building requirements. They are at present still the preferred choice for lift groups of any size and for all lift traffic situations. The following features should be provided to ensure adaptability and trouble-free operation:

- isolated floating power supply for the lift processor (i.e. not connected to the electrical safety earth or supply common)
- power supply regulation with a high input/output voltage differential to ensure immunity from fluctuations in the mains supply
- galvanic isolation (also known as opto-isolation) of all inputs and outputs to the processor to reduce the pick-up of electrical noise and possible destruction of low-voltage components
- program written in a high-level language for ease of program maintenance, with in-built multiple-layer password protection to cater for all types of lift user
- real-time operating system to control lift program execution
- diagnostic capability to monitor performance and record controller logger events to aid fault diagnosis
- visual indicators on key input and output signals to aid maintenance
- a means of altering lift parameters (e.g. door times, parking floor) on site without the use of special programming tools or replacement programs.



Caution: the basic reliability of computer-based devices is the same as for solid-state devices. However, considerably improved reliability is achievable if the hardware and software are carefully engineered. The construction of the processor, its programming and the interface to the rest of the lift controller profoundly affects the reliability of the control system as a whole. Software

also affects reliability. The use of a high-level language is essential for all but the simplest programs. It is necessary to thoroughly test new software and software modifications to ensure that any programming errors cannot cause lift malfunctions. Standardised software will ultimately ensure that optimum reliability is achieved. This also ensures that software traceability is more easily maintained than the alternative option of relying upon bespoke software.

Computer-based controllers are suitable for:

- all types of lifts
- all drive speeds (i.e. 0.5 to 15 m/s)
- lift groups of all sizes.

The group control function should have at least one level of backup to ensure continued landing call service if the main group control fails, i.e a ‘bus-stop’ type service.

8.3.5 Programmable electronic systems in safety related applications (PESSRAL)



Design tip: the Lifts Directive 1997 (TSO, 1997) (see chapter 17) allows the function of safety switches to be implemented by solid state devices and software. Potentially this allows a reduction in the use of wiring in the lift.

As an example, a landing lock contact could be replaced by a lock latch position sensor that communicates its state and receives its power supply by electromagnetic induction. Such a lock implementation removes the need to run high voltage power supplies to the locks.

This implementation needs to have the same level of reliability and safety integrity level (SIL) at least as high as the electromechanical device that it replaces. The design, production and maintenance of these devices and systems should be rigorously controlled. Compliance with BS EN 81-1 (BSI, 1998a) or BS EN 81-2 (BSI, 1998b) as appropriate, BS EN 81-20 (section 5.11.2.6) (BSI, 2014a) and IEC 61508 (IEC, 2010) requirements (see chapter 17) is an effective way of providing that control.

Control of design also needs control of the components purchased by the manufacturing company. They must demonstrably meet the specification determined by the designer.



Note: existing installed control systems generally cannot be modified at a reasonable cost to incorporate and use PESSRAL devices.

8.3.6 Building security systems

Computer-based lift control systems using hall call allocation control and other advanced traffic controls (see chapter 9) are ideally suited to be an integral part of the building security system. Access control gates located in the lobby can be linked to enter a person’s destination call into the lift system. It should be noted however that a lift car is not an inherently secure device like a locked door.



Warning: the use of machine room-less lifts as an access direct into apartments should be avoided. It is not possible to provide effective security without the addition of a normal building door providing access to the apartment. However, this is now allowed by BS EN 81-20 (BSI, 2014a) albeit with additional safeguards in place. This is due to the difficulties of providing access to the lift entrance in the apartment for maintenance and rescue.

8.4 Control of lift drives

8.4.1 General

Drives for lifts are separated into two main categories: electric traction (see section 7.2) and hydraulic drives (see section 7.3). Electric traction drives are further divided into geared and gearless drives in both synchronous and asynchronous variants, and in non-regenerative or fully-regenerative configurations.



Design tip: DC motors are almost never used in new lifts nowadays, although by introducing the very latest available DC pulse-width-modulated (DC-PWM) drive technology they still provide a very viable control system solution for modernisation-based projects (see section 8.6.6).

It should be noted that hydraulic lifts also use electric motors for driving the hydraulic pump. The characteristics and applications of each type of drive vary considerably.



Caution: an inappropriate drive selection can cause poor reliability and inefficiency of the lift installation. It may also lead to increased capital and recurrent costs for the building.

Key parameters in choosing between hydraulic or electric traction lifts are as follows:

- height of travel
- projected number of starts per hour
- required ride quality
- nominal lift speed to provide an acceptable transit time between terminal floors of the building (e.g. 20–40 s)
- the number of lifts required in order to move the projected building population.

As a general guide, if hydraulic lift activity is likely to exceed 45 motor starts per hour (or up to 60 motor starts per hour if additional oil cooling is provided) and/or if more than two lifts are necessary to move the population efficiently, hydraulic lifts should not be specified. This is because the temperature of the oil is very important for reliable operation and most of the energy from the motor is dissipated in the oil, causing its temperature to rise. However, it should be noted that for hydraulic lifts that do not use a counterweight, the number of motor starts is not equal to the number of lift starts since, for travel in the down direction, only the fluid control valve is opened. Down travel does still produce some heat into the oil and tank however, as the lift is slowed and the energy it contains is dissipated.

The ride quality of hydraulic lifts at high speeds is generally inferior to that of controlled electric traction drives. For goods and service lifts, however, this is of minor importance provided that levelling accuracy is not compromised.

Guidance on the selection and application of various drive systems is given in BS 5655-6 (BSI, 2011).



Caution: the repeated starting and stopping of lifts imposes heavy stresses on the equipment. Lift motors and their drives should be capable of lift duties of up to 180–240 starts per hour under widely varying load conditions. The overload capacity of a lift motor drive should be greater than that provided by a typical industrial rated drive of equivalent nominal capacity. There is also a need to be able to control and reverse the motor torque linearly and smoothly at any speed without causing an unwanted jerk in the lift car. The net result is that standard industrial DC and variable frequency AC drives are generally unsuitable for lift-related applications because they do not offer sufficient current reserves, nor do they provide adequate lift related control within their software configuration and available parameter adjustment.

The selection of drive and motor type can make a significant difference in the demand for mains operating power. A comparison of the basic electrical characteristics of various electric motor drive types is illustrated in Figure 8.2. Note the major differences in (a) power factor, (b) kVA and (c) mains current demand. The graphs shown are for a nominal 10 kW output motor under acceleration. Consideration of these factors for a particular building may influence the final choice of drive. This process of comparison has been simplified courtesy of a number of lift and drive manufacturers who have provided an ‘energy calculator’ in order that the lift company, consultant and end user is assisted in his or her final choice of control system pertinent to each building project.

The basic lift requirements, characteristics and usage of the lift within the building are initially inputted into a calculator. The mechanical energy consumption is then calculated on a lift-by-lift basis, based upon the number of lift runs per day. Typical energy consumption losses are then factored in within the various combinations of motors and drive systems available, with derivatives such as ‘with and without mains regeneration’, including periods of where the lift(s) is sitting idle. The information is then presented in an easy to understand format, with comparisons being presented for daily and yearly energy consumption.

8.4.2 Motor speed reference

In the case of traction drives, a motor speed command or reference signal is generated by the lift controller to indicate the desired speed and direction of movement of the lift. The motor controller then adjusts power to the motor in the correct direction in order to move the lift in response to instructions received from the lift controller.

The lift controller or motor controller may introduce smoothing functions to control jerk, acceleration, deceleration and maximum running speed. For speeds of up to and including 1.6 m/s, simple ‘go fast/go slow’ logic

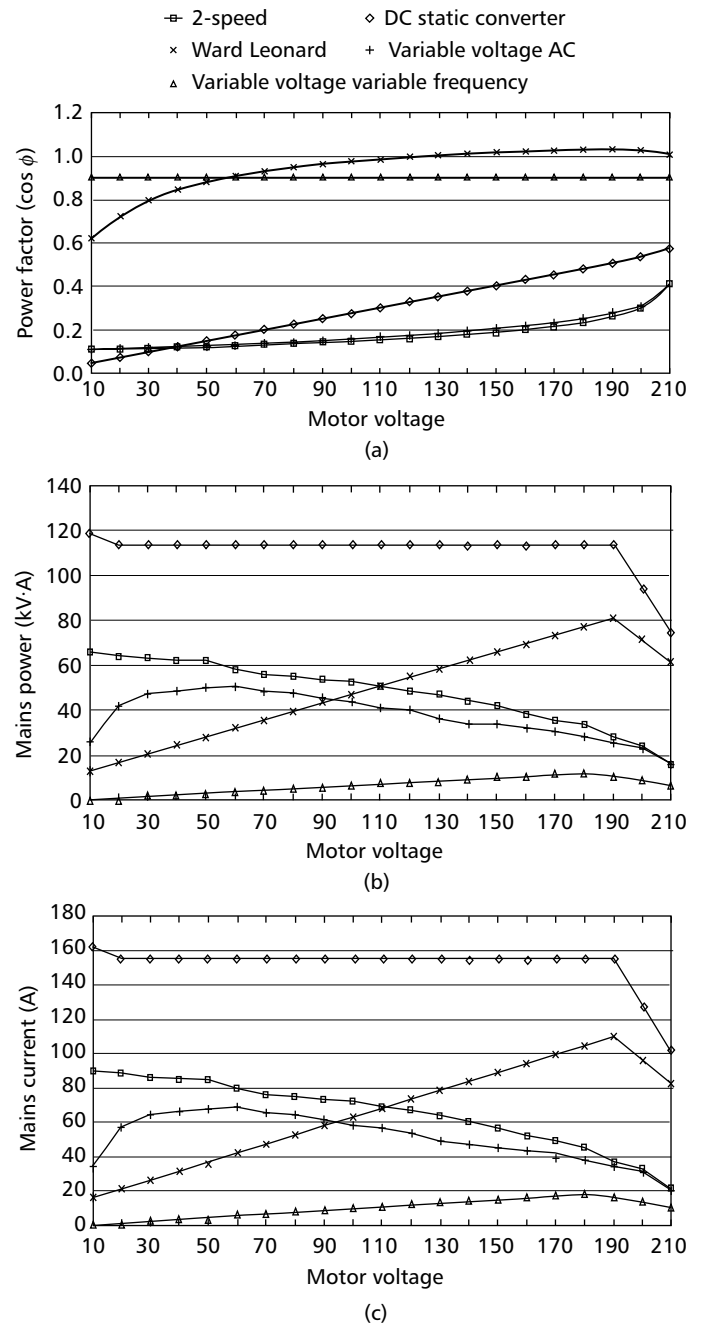


Figure 8.2 Simulation of basic electrical characteristics; (a) power factor, (b) kV·A, (c) line current demand

signals may be requested by the lift controller whilst the motor controller (drive) selects an internal preset speed and controls the rate of acceleration, deceleration and jerk rates via its own internal ramp generators. However, this is not always the case.



Design tip: for many applications the lift controller provides a more intelligent, adjustable speed command profile for the motor controller to follow based upon ‘distance to go’ position control measurements. The distance-based speed reference gives better control, maximum handling capacity and in most cases, superior ride comfort. In addition, the lift user benefits from ‘direct-to-floor’ approach when a position-based speed reference signal is used.

The actual signalling between the lift controller and motor controller may be analogue or rely upon digital serial communication. In combination with either method of

communication stop/start interlocking sequencing commands are also required.

8.4.2.1 Time-based speed reference

Figure 8.3 shows a typical velocity/time graph for time-based speed control. The speed command reference is generated in response to a lift call. It has predetermined speed, acceleration, deceleration and jerk values. At the start of a run between floors the speed reference increases to the maximum speed for multi-floor runs. For single-floor runs the speed is limited to a value determined by the shortest inter-floor distance. For lifts with speeds of greater than 1.6 m/s, two or more intermediate speeds may be used for two- or three-floor runs where the lift does not reach its maximum speed.

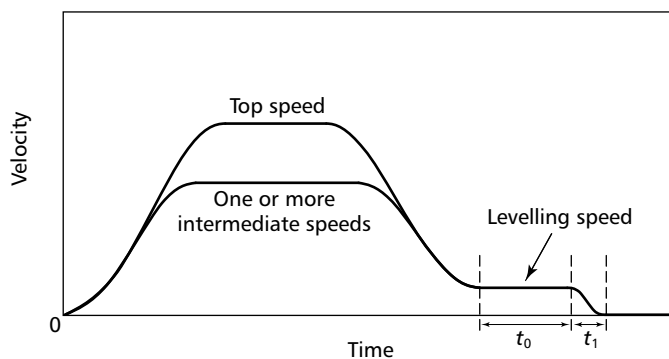


Figure 8.3 Velocity/time graph for time-based speed reference; t_0 = levelling time (typically 2–3 seconds), t_1 = levelling to zero time (typically 150 ms)

For simple time-based speed generators, there is no feedback of lift position to the reference generator except at each landing level. Due to inaccuracies of the system it is not possible for the controller to bring the lift to rest by means of constant deceleration, primarily due to changes in load. This is typically overcome by ensuring that, as the car nears the required floor (as calculated by speed and running time), the commanded speed is then reduced to a levelling speed of 0.05 m/s just before the car reaches floor level. This is generally determined by an electromechanical switch located in the shaft.

Multi-step deceleration is initiated at one or more fixed points in the shaft as the lift approaches the desired landing. As the lift approaches this landing a step change in the speed command causes the lift to decelerate to a levelling speed. The lift is finally brought to a standstill in response to a position sensor at the landing.



Note: lifts using a digital time-based speed reference with a well-tuned velocity control can have an approach levelling time of less than one second. It is not uncommon though for poorly adjusted lifts to run at approach and levelling speeds for four or five seconds. This can have undesirable effects such as excessive floor-to-floor times as well as energy wastage during this levelling speed process.

8.4.2.2 Distance-based speed reference

Figure 8.4 shows a typical velocity/time graph for a distance-based speed reference which yields more optimal performance over a speed-time-based system. This method of

drive control is often referred to as ‘arched travel control’. The maximum acceleration, deceleration and jerk values are fully adjustable and are preset during the commissioning stages of the lift as they will ultimately affect ride comfort and lift traffic handling performance.

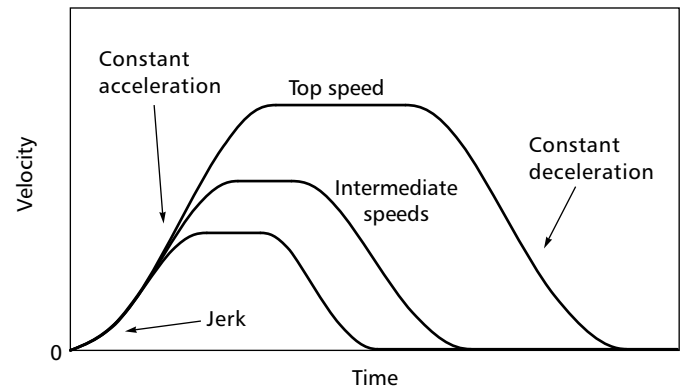


Figure 8.4 Velocity/time graph for distance-based speed reference

There are no intermediate speeds used for short distance travel, whereby the lift cannot attain rated contract speed. The speed reference generator has inputs that are independent on lift position and velocity. These allow the reference generator to calculate the ideal speed profile at the maximum possible speed for the distance to be travelled.

For speeds of up to approximately 2 m/s, signals from devices mounted on the lift car or in the lift well are used to initiate deceleration. Because the speed of the lift is known at the signal point, the deceleration distance can be calculated by the speed reference generator. The start of deceleration can be immediate or delayed, corresponding to the actual lift speed. During deceleration, the distance from floor level is calculated on a continual basis and the braking torque applied to the motor is varied to ensure that the lift tracks its required velocity–distance curve.

For high-speed lifts or buildings with uneven inter-floor distances, it is common to utilise a digital ‘absolute position’ measuring system to measure the lift position in the well to within an accuracy of 3 mm per count or better. This will typically involve the use of an encoder system mounted to the overspeed governor or a separate encoder belt, an ultrasonic encoder wire system, or laser system mounted within the lift well. With any method of shaft encoding, the location of each landing level is calibrated and then stored within the lift processor’s memory. The method of establishing each individual floor position during the commissioning phase is often referred to as a ‘learning travel’ or ‘learning run’.

As the lift departs and approaches the desired landing at a speed calculated by the motor drive or by other means, the speed reference profile is continually recalculated and smoothly adjusted according to the remaining distance to go, without exceeding the preset maximum speed, acceleration, deceleration and jerk rate comfort limits. There may also be automatic error-correction mechanisms at several landings in order to readjust for minor encoding counting errors, traction rope stretch or slip, etc.

If a precision positioning system is not in place or motor speed may not be exactly following the speed command, a compromise of the landing position mechanism is to

calculate an ideal speed profile but to also leave room for possible position errors to accumulate. In this case, the target distance may be calculated as slightly short, causing the lift to smoothly decelerate and approach at slow levelling speed for a short distance before encountering the 'at landing' switch.

With technological advances in lift processor speeds and the accuracy of absolute shaft encoding systems, however, it is becoming the norm for control systems to offer distance-based, 'direct-to-floor' control. The interface between lift processor and drive is typically via serial communications for systems of this type.

8.4.3 Protection against failure of feedback systems



Caution: protection against failure of feedback systems must be built into all closed-loop drive systems. The protection must be fast-acting and stop the lift immediately. This is absolutely critical.

Closed-loop drive systems operate by attempting to reduce the difference between the speed reference signal and the feedback signal to zero. In doing so, if a feedback device fails or becomes disconnected, the output of the drive becomes large and uncontrolled. The most vulnerable of feedback devices is usually the speed sensing device such as an encoder or resolver, which in some control systems is often duplicated for additional security. Monitor circuits built into the drive compare the accuracy of the measured

speed feedback signal with that of the commanded speed reference. Figure 8.5 highlights the supervision logic that is applied to a closed-loop drive such as a static DC-SCR drive. The motor armature current feedback is monitored separately. Figure 8.6 outlines the elements of closed-loop speed control. The speed sensor type will vary depending upon whether the motor is asynchronous or synchronous in nature.

8.4.4 Traction lift: hoisting motor rating

For a given lift capacity and contract speed, the hoisting power requirement is dependent upon:

- whether or not a gearbox is used and, if so, its associated starting and running efficiencies
- the roping arrangement of the lift, e.g. 1:1, 2:1
- the percentage of rated load counterbalanced by the counterweight
- the type of guide shoes: sliding or roller
- the type of motor selected, e.g: DC, AC induction, AC permanent magnet synchronous (AC-PM).
- design values such as acceleration, deceleration and jerk.



Design tip: to minimise the energy used by the hoisting machine, it is preferable to avoid the use of a gearbox; select the highest efficiency motor type (AC-PM) and use roller guide shoes.

However, there is often still the requirement for gearboxes to be used within certain lifting applications. Increased starting and running torque associated with modern gearbox designs will reduce the hoisting power requirement than previously was the case. Other engineering and cost factors will affect the combination of these parameters for a particular lift design.

Modern traction lifts minimise the torque (and current) requirements of the motor to lift the payload by counterbalancing the mass of the moving equipment at mid-range payload. However, a significant amount of energy is still necessary to accelerate the inertia of the moving equipment and load. When stopping the lift, the kinetic energy stored in the moving mass must be removed in order to cause deceleration. This phenomenon occurs during every start-stop cycle of the lift.

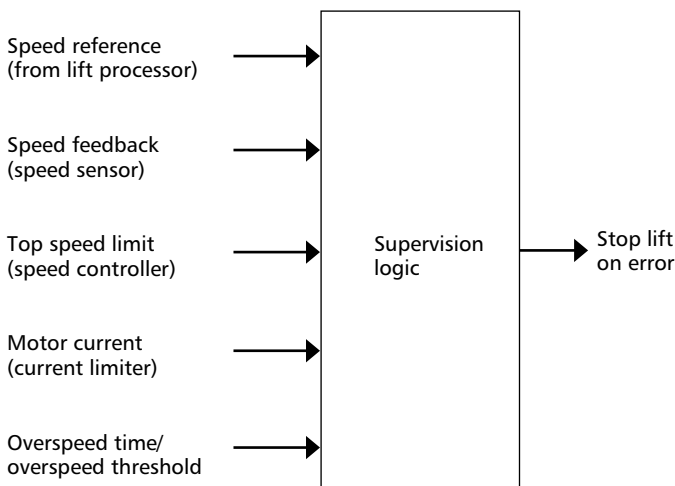


Figure 8.5 Supervision logic for closed-loop drive

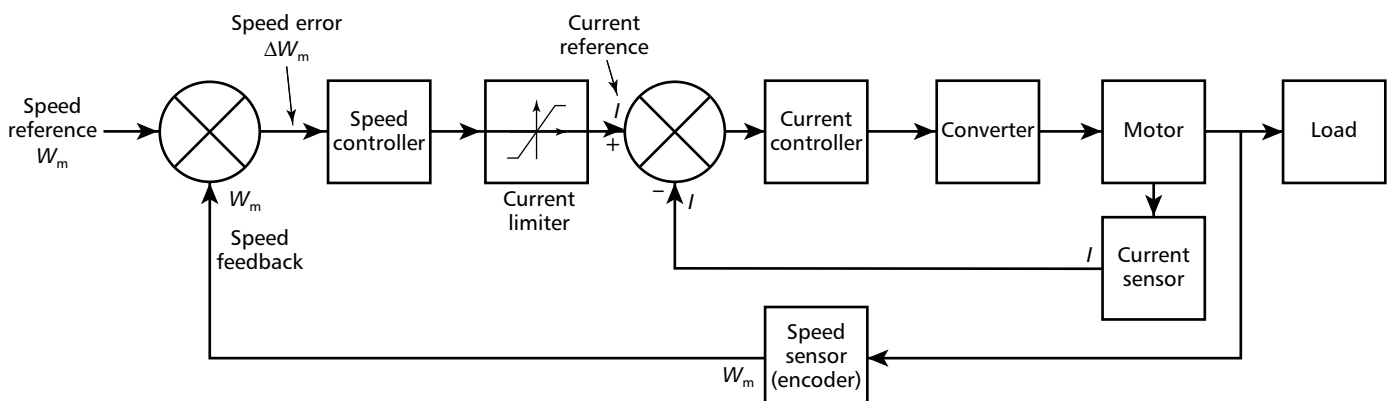


Figure 8.6 Elements of closed-loop control



Note: what happens to the inertial energy (wasted by machine friction or as heat in the motor, electrical resistor bank or reclaimed by regeneration back into the mains supply) is an important factor to determine overall energy consumption (kW·h) over the course of a year and for the entire life-span of the equipment. This becomes increasingly important with higher lift speeds as the inertial energy is proportional to the square of lift speed.

8.5 DC motor control techniques

Geared and gearless DC machines used to be the most commonly used variable-speed solution for lifts but are rarely used nowadays for new-build projects. The smaller sized geared DC units have become excellent candidates for replacement by modern AC-PM gearless machines and drives. However, many DC gearless machines still exist in good working condition in larger buildings where operating lift speeds are 2.5 m/s and above.

The primary mechanism to control speed and torque with a DC machine is to vary the voltage applied to the armature. There are essentially three methods of controlling DC lift motors:

- a Ward Leonard motor-generator (M-G) set
- a DC-SCR drive
- a DC-PWM drive (see section 8.6.6).

8.5.1 Ward Leonard set

A Ward Leonard set (Hindmarsh, 1995) is an AC motor driving a DC generator at relatively constant speed. Output voltage of the generator is adjusted by varying the field current of the generator, which in turn adjusts the speed and torque of the DC lift motor. The M-G set operates on the principle of true-power conversion. Older M-G sets may still be operating from simple relay-based controllers. Many high-speed M-G powered units may have already been modernised with closed-loop tacho-generator feedback systems. Ward Leonard sets emit a significant amount of acoustic noise and carbon brush dust into the lift machine room. They are only marginally efficient as the induction motor continues to draw rotating power when the lift is idle. These losses can be as high as 15% of the rated power when idle. However, favourable operating characteristics of the M-G set are the absence of mains harmonics, high immunity against mains line disturbances and also the fact that the M-G set is inherently regenerative in nature. In spite of the somewhat lower efficiencies, a significant amount of energy is returned to the mains supply on each deceleration phase or with overhauling loads.

8.5.2 Static converter drives

A DC-silicon-controlled-rectifier (DC-SCR) or 'static converter' drive is an electronically controlled unit that converts selective segments of sinusoidal mains supply

voltage into variable DC voltage, which is then applied to the armature of the DC lift motor. The primary adjustment method is 'current-lag phase-displacement' control, which has the benefit of high power conversion efficiency. However, unfavourable characteristics include widely varying power factor during lift operation and the generation of unwanted mains current harmonics.

Dual-way DC-SCR drives have been a reliable workhorse for the lift industry, having now replaced M-G sets for several decades. They are regenerative in nature, by smoothly controlling motor current in either direction of motion. The majority of drives designed for industrial use cannot reverse motor torque with the smoothness required for lifts. Hence, purpose-designed drives are preferred. Later designs of electronic speed feedback (encoder feedback) also allow the drive motor to precisely follow speed and position commands from the lift controller.

8.6 AC motor control techniques

Historically, many smaller capacity, low-speed lifts in residential or low-rise buildings have been operated from low-speed, geared, single-speed or two-speed lifts. For these applications, an AC motor-starter type control with an electromechanical brake was often used.

Where levelling accuracy is important in order to allow wheelchair or hospital bed access, for example, a drive with re-levelling capability is almost always specified. These applications, as well as those requiring lift speeds of greater than 1 m/s, should employ variable speed drives in order to obtain better positioning control at each landing. Although many older technologies still exist, modern day efficiency requirements practically dictate the use of variable voltage, variable frequency (VVVF/3VF) drives.

In general, VVVF drives provide better all-round performance for lift speeds from 0.5–10 m/s and above. Either asynchronous and synchronous machine types may be used. What is key however is the correct selection of drive.



Caution: although mains supply currents may be at a relatively high power factor, most VVVF drives can and do create significant mains harmonics. In some applications there may be the need to provide additional filtering in order to meet site specifications. Add-on regeneration products and fully regenerative unity power factor AC drives also exist for this reason (see sections 8.6.5 and 8.6.6).

8.6.1 Variable voltage drive with single-speed motor

There are several variations using the variable voltage technique, depending on whether or not the speed of the motor is controlled during all phases of the lift movement.

For low-speed, low-grade lifts (e.g. car park lifts and goods lifts) it is possible to obtain accurate and consistent stopping at floor level by controlling only the deceleration of the lift. This technique is suitable for lift speeds up to 1 m/s. Some drives of this type do not allow re-levelling.

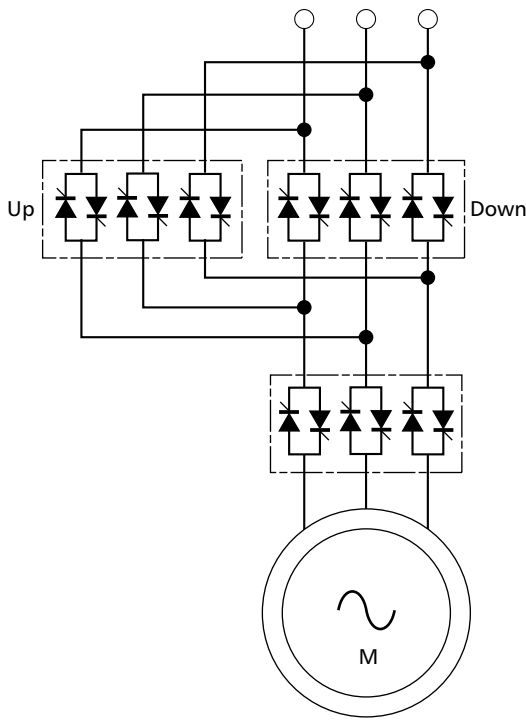


Figure 8.7 Variable-voltage drive with a single-speed motor

Thyristors can be used to control the acceleration of the lift. They also reduce the voltage on the motor during deceleration and can be controlled to produce DC to obtain more braking torque if necessary. This technique is also suitable for lift speeds up to 1 m/s.

Both the acceleration and deceleration of the lift can be controlled using thyristors by reversing the phase rotation of the supply (see Figure 8.7). Due to the lower efficiency of AC phase rotation reversal for braking, the design of the control for the thyristors is critical to obtain good jerk-free torque reversal of the motor. This technique also increases motor and machine room heating compared with DC braking. This technique is suitable for lift speeds up to 1.6 m/s.



Caution: using variable voltage to control the torque and speed of an AC motor causes a great deal of internal motor heating. In all but low traffic situations a special motor design must be employed for successful operation.



Design tip: wherever possible, lift controls of this type should be modernised by using a new asynchronous or synchronous AC motor and correctly dimensioned VVVF drive.

8.6.2 Variable voltage drive with two-speed motor

In general, the low-speed windings of the motor are used as braking torque windings. The AC supply voltage to the high-speed windings is controlled using phase control by means of thyristors (see Figure 8.8). The speed of the motor is under control at all times during movement of the lift. With variable voltage control, the starting current of the motor is reduced to approximately 50% of the current drawn by the same motor running as an uncontrolled two-speed motor. During deceleration, the AC voltage is reduced and a variable DC voltage is applied to the low-speed winding to produce additional braking torque if required.

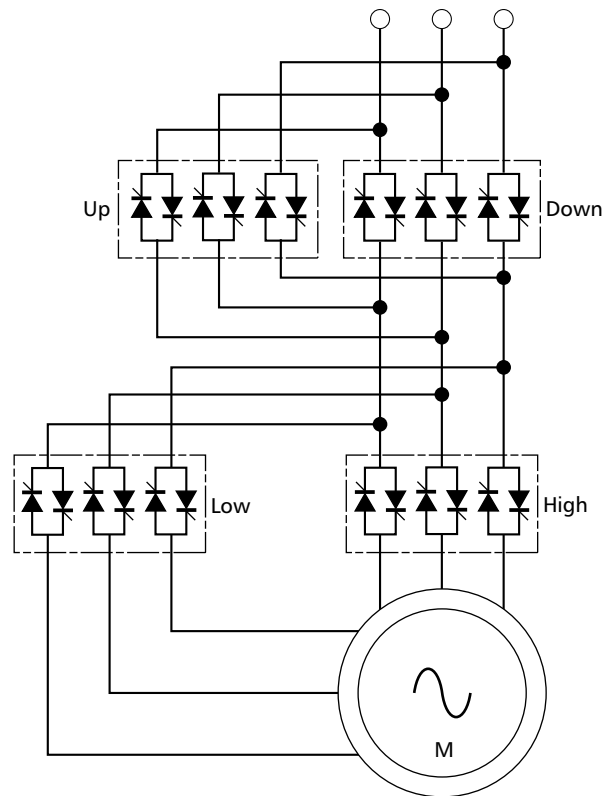


Figure 8.8 Variable-voltage drive with a two-speed motor



Design tip: whilst better levelling accuracy is achieved with the addition of DC braking, performance problems associated with the temperature-related drift of those variables set by analogue adjustment ultimately impact on overall levelling accuracy.

The same recommendations therefore apply. Lift controls of this type should be modernised by using a new asynchronous or synchronous AC motor and correctly dimensioned VVVF drive.

8.6.3 Variable voltage, variable frequency (VVVF/V3F) drives

Variable voltage, variable frequency drives use the fundamental characteristics of the AC induction motor in that the synchronous speed and voltage necessary for operation is proportional to the supply frequency. By varying the voltage and frequency the motor can be made to function at its most efficient operating point over a wide speed range. However, the conversion of power from the mains supply frequency to variable voltage power at a frequency suitable for motor speed control is a complex process (see Figure 8.9).

Common VVVF drives utilise a three-phase input rectifier fed from the mains supply. This provides a high mains supply power factor (i.e. >0.9) at all lift speeds, with low electricity consumption and machine room cooling costs. There are however often significant mains supply current harmonics.

For geared lift speed applications of up to 2 m/s the energy regenerated by the lift is relatively small and can normally be dissipated by a braking resistor network. For higher speeds or heavy-duty, large capacity lifts the amount released by braking resistors may be objectionable and the

use of a regenerative power converter may be warranted (see section 8.6.5). This will significantly improve the overall operating efficiency.

Lifts capable of up to 10 m/s or even higher speeds are normally installed using AC permanent magnet (AC-PM) gearless machines. In this instance 'active' fully regenerative front ends are nearly always selected such that the regenerative energy is fed back into the mains supply as opposed to the energy being dissipated within braking resistors.



Design tip: AC-PM VVVF-controlled motors are more efficient than induction motors and are physically more compact. This reduces the required space and floor loading in machine rooms.

Variable voltage, variable frequency drives require only a single-speed three-phase induction or AC-PM motor to provide variable speed control. Where existing lifts are being modernised, the drive may be fitted to an existing single or 2-speed motor. In such cases, the suitability of retaining the existing motor for use with a variable voltage, variable frequency drives must be verified.



Caution: it is often the case that VVVF drives are fitted to existing motors previously controlled on an AC-VV (variable-voltage) basis. The application of VVVF drives as part of any modernisation project should also include a check of the motor's nameplate to establish the suitability of the motor's existing installation class rating. The high speed switching of VVVF drives produces high-frequency dV/dt voltage peaks which may fatigue the motor's winding insulation. It is for this reason that motors are often replaced with 'inverter-specific' types of suitable insulation class rating. An alternative approach would be to have the existing motor checked by a reputable motor rewind company and if necessary, have the motor windings replaced with a higher insulation class rating. This is most certainly a sensible and pragmatic approach to take as motors previously having been applied with variable voltage control are more prone to failure when subjected to the dV/dt voltage levels associated with VVVF control.

To control an induction motor one must be able to predict, calculate or actually measure rotor slip with a shaft encoder or let the motor establish it. An electronic inverter is used to vary the frequency. A multitude of 'volts per hertz',

'closed-loop' or 'open-loop' (encoder-less) vector control schemes exist to control motor current and torque.

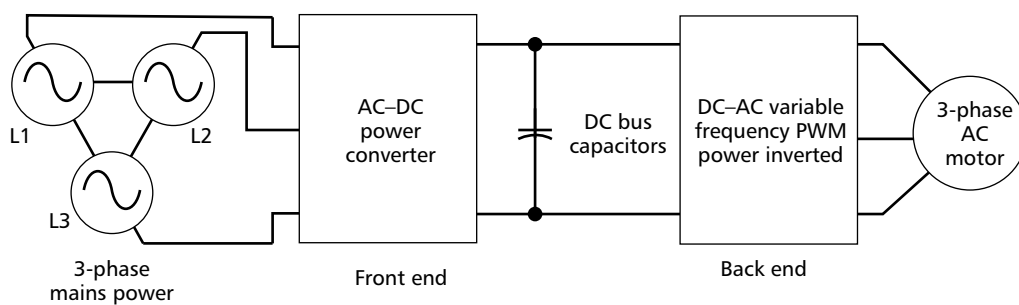
The most fundamental approach of induction motor speed control is to simply adjust the frequency and voltage in proportion to the desired speed, with a slight voltage boost near zero speed in order to overcome the resistance of the motor windings. This technique is known as volts per hertz (V/Hz) or 'V by F' (V/F) control. Speed control at near zero for levelling may be difficult and is often assisted by DC current injection. This mode of operation may be the only way to successfully control older induction motors originally designed for variable voltage control. With some drives, speed control can be marginally improved upon in V/F mode by the use of adding encoder speed feedback.

'Flux vector control' provides enhanced performance over V/F control. Internal algorithms compare the commanded reference speed with encoder speed feedback to measure actual slip, and then continuously calculate what voltage, frequency and current should be supplied to the motor to produce the required torque and speed, thereby adjusting the output to achieve this. The internal calculations are centred upon 3-phase vector control-based mathematical analysis. Extremely smooth torque and speed control is possible over a wide operating speed range which includes zero speed with this particular technique. The drawback of this approach is that slip/torque and impedance characteristics of the motor must be known and be relatively linear in order for the predictive algorithms to be correct.



Note: the on-site adjustment of critical VVVF drive parameters (such as no-load current, stator resistance and other associated motor map values), in addition, inertial 'feed-forward' settings and speed loop proportional gain settings will yield the best control performance and hence optimum ride quality of both existing and VVVF-specific motor types. It may well be the case that older 'non-standard' motors are not suitable for providing improved performance. In such cases, replacement with an inverter-specific motor might be necessary.

A further variation on the above control types is 'sensor-less vector' control. Determination of the applied voltage, frequency and resulting current is used to calculate motor torque and magnetisation current from motor model algorithms. Internal operation of the motor is continuously re-calculated to estimate actual speed and torque. This enables the motor speed sensor (encoder) to be eliminated on low-speed lift systems.



Constant voltage
and frequency

Variable voltage, variable
frequency AC motor control

Variable voltage and frequency
= variable speed and torque

Figure 8.9 Schematic of a variable voltage, variable frequency drive

However, sensor-less vector drives have no way of actually measuring motor speed or slip, or a change in position for precise landing or levelling speed control. For medium and high-speed systems encoder feedback is still required and is generally considered the norm.

8.6.4 Variable voltage, variable frequency drives with permanent magnet synchronous motors

Variable voltage, variable frequency drives are also used to control permanent magnet synchronous motors (PMSMs) (also known as 'AC-PM'). However, the operation of these motor types is significantly different to that of an asynchronous induction motor. Even though the voltage application pattern appears to be similar to that of V/F control, the angular location of current in the motor windings of the stator in relation to the actual location of the moving permanent magnets on the rotor is what is important to produce torque. Permanent magnets create the magnetic field whereas, in an induction motor, a component of the stator current does this.

Typically, an electronic position encoder or resolver attached to the motor shaft is calibrated with the inverter drive to determine the alignment or physical location of the magnets in relation to the resolver signals. This procedure is often referred to as an 'alignment' process.

During operation, the microprocessor within the inverter calculates what torque is necessary to satisfy the speed regulator and adjusts the 3-phase voltage output to ensure that stator motor current maintains the correct angular position ahead of or behind the permanent magnets as the shaft rotates at the desired speed.



Design tip: AC-PM motors are more efficient than induction motors in that they produce less heat and are physically more compact. As previously outlined, this reduces the required space and floor loading in machine rooms. AC-PM motors can also be provided in numerous cylindrical and 'pancake' designs for conventional machine room or machine-room-less (MRL) applications. The improved efficiency also means that there will be increased regenerative braking energy returned when compared to the more conventional geared induction motor types. This translates to increased heat dissipation within dynamic braking resistors. Adding a regenerative module or using a fully regenerative drive is a significant overall energy efficiency improvement for lifts using AC-PM motors (see section 8.6.5).



Note: one application consideration with AC-PM motors is that most 3-phase inverter drives are designed with some minimum operating output frequency in mind. The operating frequency of a AC-PM motor when stopped at a landing, where it may still be required to produce more than rated torque for re-levelling is zero, i.e. DC. It is therefore important that the selected inverter drive is capable of providing these levels of current for the prescribed duty, otherwise premature output device failure can and probably will occur. It is for this reason that drive manufacturers apply the necessary

'derate factor' within their drive selection when running at the lower frequencies associated with AC-PM motor control.

8.6.5 Non-regenerative and fully regenerative drives

Regeneration (recuperation) is an electronic means of recovering the kinetic energy of the moving mass of lift equipment during deceleration and the potential gravitational energy of passengers and goods as they are returned to a lower floor.

Every motor type (DC or AC induction or AC-PM) can act like a generator when the mechanical forces of the lift push on the motor to go faster than the controlling electronic controls permit. DC motor drives (Ward Leonard M-G set, SCR-DC, PWM-DC) are all inherently regenerative. A common misconception is that only AC-VVVF drives are associated with regeneration. This is simply not the case.

However, basic VVVF drives controlling AC motors utilise a one-way rectifier interface to the mains supply and these are termed 'non-regenerative'. As a result, these AC motor control drives typically divert energy from the lift motor to a dynamic braking resistor network, where it becomes wasted as heat. This is of not much consequence for lifts of low duty operation or of low operating speed.



Design tip: for lift speeds of 2 m/s and above, regeneration should be employed wherever possible. Add-on regenerative units can be fitted to most VVVF drives, alternatively, new lift control systems may be purchased with fully regenerative units included as standard.

The benefits of fitting a fully regenerative drive are that during overhauling conditions (for example, 'empty car going up' or 'full car going down') kV·A will be higher for this period of time, albeit as negative power and energy flow. In real terms, a critically balanced car ride with a high-efficiency motor and drive will consume almost no energy.

A regenerative drive must always remain in synchronisation with the mains supply during the entire run and not just synchronise with the mains before the start of each run. If this were the case, the drive would not be ready to start decelerating the car or prevent gravity-fed overspeeding of the car.



Caution: one consideration regarding regenerative drives is that they always rely upon well-behaved mains power for repeatable, trouble-free operation. If mains supply conditions are poor one will potentially have a difficulty with regeneration. In this case, a VVVF drive with a conventional rectifier front end featuring dynamic resistance braking should be used, given that for this particular drive configuration voltage distortion is not a critical factor.

It is also important to recognise that by improving the efficiency of lift motors and drives by the addition of regenerative units, increased instantaneous power will be returned to the mains supply. This can cause issues for marginally sized standby generator systems or where

attached loads are insufficient to absorb the peak magnitude of power returned during the lift regeneration phase. Under generator back-up conditions it is typical for the drive to be reconfigured such that the regenerative unit becomes temporarily disabled in order to revert to dynamic resistive braking. This is due to the fact that when the electricity supply to the lift is coming from an emergency generator driven by a diesel engine, the engine can only absorb a very small amount of regenerated energy before it shuts down due to over-speeding of the generator.

Despite the above considerations when applying fully regenerative drives, the application of these drives will return the energy, which would otherwise have been wasted as heat within braking resistors, back into the mains supply. Implementing fully regenerative drives will therefore make a significant contribution in energy reduction, particularly with low friction, high-efficiency AC-PM machines.

8.6.6 DC pulse-width-modulated drives (DC-PWM)

Geared and gearless DC machines used to be the most commonly used variable-speed solution for lifts but are rarely used nowadays within 'new build' projects. The smaller sized geared DC units have generally become replaced by modern AC-PM gearless machines and drives. There are still many DC gearless machines in good working condition in larger buildings where operating lift speeds are 2.5 m/s and above.

Figure 8.10 shows the active rectifier input section of a PWM drive, additionally, a DC-PWM output diagram and schematic layout for AC-PWM motor control.



Design tip: DC-PWM is the latest technology available for controlling DC machines, offering the following technological benefits when compared with using the more traditional DC-SCR drives:

- Increased energy savings: despite the fact that DC-SCR drives are fully regenerative in nature, DC-PWM technology offers conservatively a further 25–30% saving in energy consumption. This translates to the type of savings associated with a combined AC/PM fully regenerative drive solution.
- Reduced heating: there is no longer the need for incorporating isolation transformers or ripple filters.
- A boosted and regulated DC bus voltage, which compensates for sagging mains voltage levels or increased motor voltage required during acceleration.
- A greatly improved power factor of typically >0.95, when compared with DC-SCR technology (the power factor of which is highly variable, at times tending towards zero). As a side benefit, this eliminates the need to increase 3-phase mains supply wiring, which would typically have been the case if the control system upgrade had been based upon changing from an M-G set to a DC-SCR drive.
- Typically less than 8% total harmonic current distortion (THD). The ultimate goal with any drive system is high operating efficiency,

sinusoidal waveform current demand, unity power factor with no electromagnetic interference (emissions and susceptibility). DC-PWM technology is certainly moving towards these goals in that respect.

Since DC-PWM technology is essentially derived from an AC-PWM hardware platform, should the DC shunt machine be replaced in the future if so required, the drive can later be modified within its hardware and software such that it is suitable for the control of new AC-PM machines.



Caution: there are also considerations to make however when applying DC-PWM drives to existing DC machines. PWM-DC can potentially cause insulation damage to older DC machines. It is therefore recommended that prior to using this drive type with any DC machine, the insulation integrity and operation of both armature and field windings are first verified and any necessary repair work undertaken before connecting to this new technology.

Additionally, for geared DC machines in which DC-PWM drives are being considered, given that DC-PWM drives will induce motor shaft currents that can potentially cause unwanted electrical discharge machining (EDM) of the bearings and bearing races (causing pitting and eventually failure), it is recommended that earthing bushes are fitted such that any current circulation is diverted away from these bearings. This will guard against failures of this type.

8.6.7 Linear induction drives

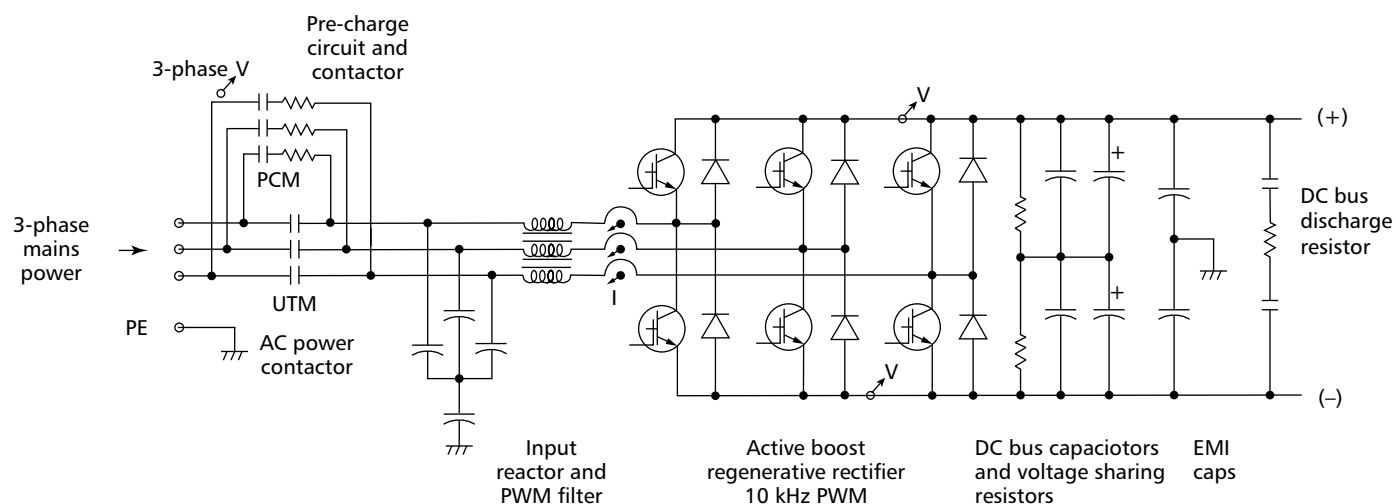
A linear motor may be regarded as a conventional AC motor that has had its stator and rotor 'unrolled' to lie flat (see section 7.2.9) so that instead of producing rotational torque it produces a linear force along its length.

Many lift-specific designs have been put forward with excellent results, but the limiting factor associated with this technology up to this point has been cost. Two linear motor categories exist: low acceleration and high acceleration types. The former is suited to lift systems as an alternative to the more common traction lift systems using conventional DC, AC induction or AC-PMSM motor types. Control is typically achieved by AC-VVVF inverter types as described in sections 8.6.3 and 8.6.4 above.

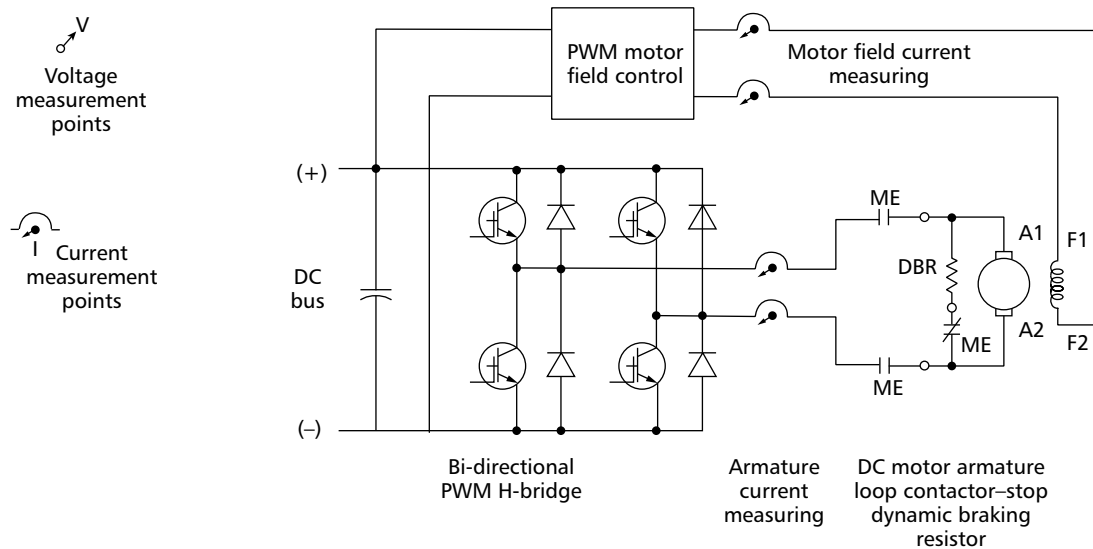
8.7 Harmonic-related issues

Most regenerative-based products (see section 8.6.5) impose unwanted harmonic currents in a similar fashion to the power input rectifier of a basic VVVF inverter unit.

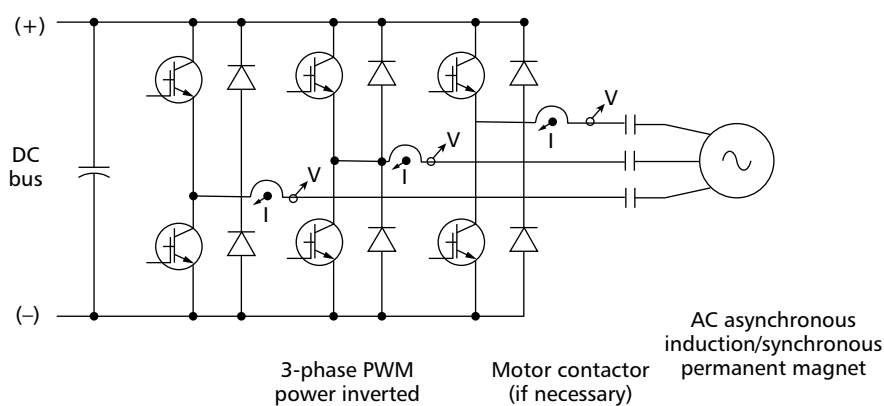
Some types of regenerative motor drive system utilise inverter-like power controls in synchronisation with the mains supply voltage in order to reduce mains current harmonics and operate with near-unity power factor. These products are capable of complying with the mains harmonic requirements of IEC 61000-2-2 (IEC, 2002), IEC TS 61000-3-4 (IEC, 1998), BS EN 12015 (emissions) (BSI, 2014c), BS EN 12016 (immunity) (BSI, 2013), Energy Networks



(a) PWM active input section



(b) PWM DC output schematic



(c) DC-PWM rectifier input section with DC/AC motor control

Figure 8.10 DC-PWM rectifier input section with DC/AC motor control

Association Engineering Recommendation G5/4 (ENA, 2001) and IEEE-519-1992 (IEEE, 1993) at the point of common coupling (PCC).

Figure 8.11 (ABB, 2013) highlights those factors within a VVVF drive that have some influence on harmonics.

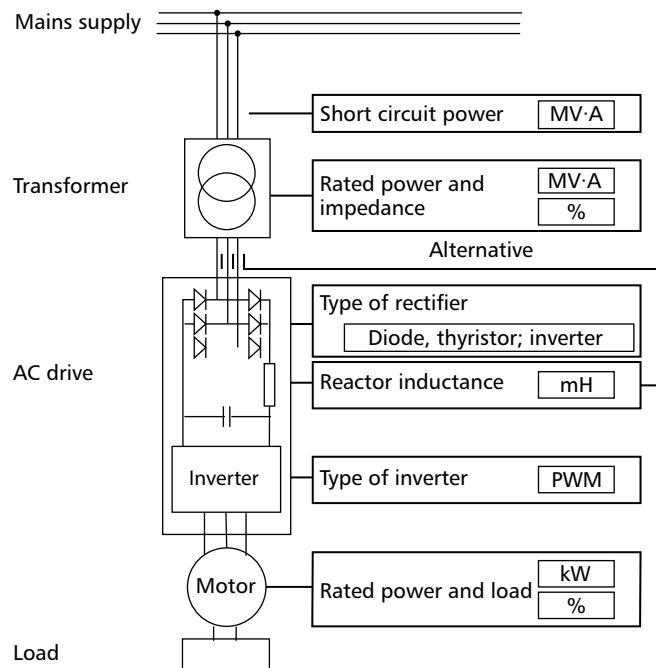


Figure 8.11 Factors influencing harmonics within a VVVF drive

Voltage distortion is caused by distorted current flowing through the impedance of the mains supply. Practically all drive types cause distorted current to flow; DC-SCR drives are the worst, with Ward Leonard M-G sets being the best in this respect.

Current harmonics are therefore dependent upon the drive type, with voltage distortion equating to these current harmonics multiplied by supply line impedance.

The resulting voltage distortion is also proportional to the percentage of current distortion of the drive multiplied by the lift's current demand, divided by the mains supply current capability.

Adding upstream inductance on the mains may reduce voltage distortion at the point of common coupling, however this will cause it to become worse at the drive or regenerator converter terminals.

There is also a practical limit for total line impedance ($< 8\%$) as it reduces the voltage available to operate the drive equipment at full voltage and power. An impedance of greater than 8% means that the short-circuit current magnitude at the drive should be greater than $1/0.08$, or at least $12.5 \times$ rated current.

In real terms, the majority of lift drives and regenerative units are fairly resistant to voltage distortion caused by their own operation.



Note: the effects of current and voltage harmonics can be overheating of transformers, cables, motor,

generators and capacitors connected to the same power supply with those devices generating the harmonics. Electronic displays and lighting may flicker, circuit breakers can trip, computers may fail and metering may give false readings.

8.8 Energy saving considerations



Note: many factors should be considered when designing a lift control system from an energy saving perspective. The lift's handling capacity requirements, equipment design, its operational requirements and on-going maintenance regime all factor into and influence the overall energy efficiency of a lift.

The type of drive system has a direct impact on the running and standby losses of the overall lift system. As previously outlined, energy calculators exist for determining the comparative energy consumption for differing control system and drive types based upon the specific applications demands of each lift, i.e., its required payload, contract speed, number of floors served and population demand.

The following are key areas for energy-saving consideration:

- 'eco' shutdown modes to provide:
 - running power reduction
 - standby power reduction
- drive and motor types and their idle/running power losses
- intelligent control systems
- cross-call cancellation or 'overlay' systems.

Eco shutdown modes

The majority of control system manufacturers now provide several stages of 'eco-shutdown' control to cater for both running and standby lift states. Several techniques exist and these are as follows:

- Running power reduction:
 - The ability to provide 'direct-to-floor' profiling. The absence of a crawl path when approaching each landing will have a dramatic impact on running power reduction. Alongside optimising floor to floor runs, drive running power can be reduced by as much as 10% .
 - The inclusion of AC-VVVF drives, whose power factors approaching unity overcome the issues of load dependant power factor associated with non-VVVF-controlled machines; the latter type of which have a very poor power factor at light loads.
 - The use of closed-loop control as opposed to open-loop control, whereby speed regulation is enhanced, thereby reducing peak current demand.
 - The implementation of regenerative drive systems, allowing power to be diverted back

into the mains as opposed to being dissipated in braking resistor networks during periods of overhauling loads (deceleration / empty car up / full car down).

- The selection of AC-PM gearless machines that do not suffer the running and starting inefficiencies associated with geared machines. This will equate to physically smaller machines by virtue of their 'high torque-per amp' characteristics, with reduced running losses when compared to previously-used DC and AC geared units. The added benefit of this later technology are smaller inverter drive units, lower ratings on ancillary components, smaller control system cabinets and reduced machine room losses.
- The use of brake switches in order that the drive can accelerate as soon as the motor brake is lifted, as opposed to holding zero speed for excessive periods.
- The appropriate setting of acceleration, deceleration and jerk rates. If values are set too high during the commissioning stages this will have a direct impact on acceleration torque demand (increased motor current), in addition, an increase in heat dissipation within the braking resistors during the lift's deceleration phase.
- Assessing then adjusting the car-to-counterweight balancing, such that for the majority of lift operation, an average reduced payload of typically less than the nominal payload thereby reduces the motor's acceleration and running current demand.



Caution: The maintenance of safe traction must be maintained under all car load conditions if the balancing is adjusted in the above manner.

Idle power reduction

- Shutdown techniques typically include the shutting down of car lights and car fans during idle lift periods. These features are typically implemented in modern lift control systems. The turning off of car indicators, car operating panel (COP) and landing signalisation, in addition the dual-illumination of the landing pushes is now also considered common practice.
- Additional shutdown techniques include switching the AC-VVVF drive off during extended periods of lift inactivity. This shutdown procedure normally features within the 'phase-2' stage of most eco-equipped control system types. Care should be exercised however, as shutting the drive down does have limitations in re-establishing normal lift service as all VVVF drives require a period of time in which to discharge then 'reboot' (recharge) the DC bus circuit. Failure to provide this period of time can and will inevitably result in a lock-up situation where the drive cannot restart. This explains the reason why all control system manufacturers require an extended 'reboot' time once the lift is required to transition back to normal service

operation. The majority of AC-VVVF drives also have an imposed limitation on the number of mains power-downs/power-ups per hour. Caution should be exercised to ensure that this duty is not exceeded or the long term reliability of the AC-VVVF drive can otherwise become compromised.

- Ensuring that for DC-SCR static drives, the field current is switched into a 'standby' level ensuing that unavoidable DC motor field losses are minimised.
- DC-SCR drives can also be equipped with the capability to disconnect the power isolation transformer during periods of non-use, further minimising idle power consumption.
- Turning off drive fans, such that drive standby losses are reduced. As an example of the typical achievable savings, standby power reduction with drive fans disabled can save up to 50% of a drive's overall idle losses compared with those drives that do not feature this facility.
- The ability to introduce 'swing control' for multiple group systems whereby one or several lifts in the group are switched off during periods of low traffic demand. Sequential introduction of each lift back into the group based upon increased lift demand is the norm, with each lift being switched into different levels (stages 1 or 2) of hibernation mode in order to quickly cater for subsequent changes in traffic demand.
- Ensuring that the machine brake is not energised when the lift is stationary.
- Turning off lift processor backlight displays during periods of lift inactivity.
- The selection of and subsequent shutting down of the door operator, which is typically undertaken in conjunction with drive shutdown operations. For this to be possible, the door operator system must not be of the 'stall-closed' type.

Drive and motor types and their idle/running power losses

DC-SCR static drives require a constant current field regulator circuit in order to separately excite the field coils of a DC machine. Despite the fact that the field current is switched to a lower standby value during periods of lift inactivity, this still translates to unwanted machine/control system losses.

Motor-generator sets, whose power conversion process is based upon 'real power to real power' suffer with losses related to power conversion inefficiency and motor generator idle losses. By taking into consideration motor armature losses and motor field losses associated with this technology it is clear that this technology has been superseded by more advanced, energy-efficient systems.

When compared with the above technologies, AC-PM gearless machines require no separate field excitation, since the rare earth magnets integrated within the motor rotor provide the permanent field excitation (see section 8.6.4). The high efficiency of these machines will also mean that smaller motor types can be selected, which equates to smaller physical motor footprints, reduced machine room

loadings, less motor losses and a smaller rating of drive unit.

In the case of AC-VVVF drives, the ultimate benefit is that of near-unity power factor and high motor efficiency when VVVF-controlled, compared to pole-changer and AC variable voltage motor types, the power factor of which is affected by load and speed changes.

Intelligent control systems



Design tip: with the advent of high-speed, intelligent control systems having the ability to 'self-learn' the building in response to changing traffic demands, energy optimisation can be further enhanced.

An example is the ability within the control system to intelligently distribute parked cars in those zones seeing the highest levels of traffic demand, such that the number of floor travels required in order to serve each call are subsequently reduced.

Other techniques used are intelligent group control algorithms to automatically detect up peak, down peak, balanced heavy traffic and main up peak traffic demands, strategically and automatically adapting the group algorithm to best cater for the traffic demand at that specific time, then continuing to do so on an on-going basis.

Another example of intelligent group control is that of an adaptive, hybrid-based hall call allocation control system having the ability to automatically transition to full-collective control as traffic changes dictate, whereby under certain specific conditions full-collective control is then better suited.

Whilst this facility is advantageous in some cases, it cannot replace the basic requirement of always ensuring that the best control strategy is selected during the initial design stages.

Cross-call-cancellation or 'overlay' systems

During the modernisation phase of any lift group, it is beneficial to provide a means of ensuring that the 'old' and 'new' group systems do not chase calls during the gradual modernisation process. The use of cross-call-cancellation or overlay schemes are therefore used to eradicate these issues, further removing the risk of energy wastage associated with unwanted journeys.

8.8.1 BREEAM credits for lifts

BREEAM (Building Research Establishment Environmental Assessment Method) (BRE, online) provides a set of advanced tools and procedures designed to measure and evaluate the levels of sustainability of a building, from the design stage through to construction and installation of the particular characteristics of each principle building type.

If a lift (or number of lifts) is installed in a building, the number of credits to be achieved increases by two. Thus for a lift to contribute to a building's classification it must achieve two BREEAM credits.

Refer to sections 13.4.4.1 and 13.4.4.2, which detail the criteria for BREEAM Credit 1 and Credit 2 application.

8.9 Passenger evacuation following mains power failure

There are five main application-related reasons and associated methods for supplying emergency power for lifts in the case of mains power failure:

- (1) To allow passengers to be evacuated from a lift that has gone out of service with the car position being outside the door zone. This method of evacuation typically allows the lift car to be run for one journey, in order to recover the car to the next available landing. During this process, the lift car may move up or down primarily according to the suitability of the direction of travel and also upon the car-to-counterweight balance at the time.
- (2) Running the lift car on a one-time-only basis to the main floor, to allow trapped passengers to exit. The worst case scenario would be a full shaft travel (i.e. empty car down from the top landing level). Whilst this would require a larger battery (UPS) rating, the required rating can easily be determined based upon the travel, speed and load demands. This procedure is often carried out at reduced speed which will reduce the required battery (UPS) size.
- (3) The requirement for performing a limited number of runs in either direction in order to evacuate staff from a building. Battery and/or UPS kV·A capacity would be significantly greater than 1 and 2 above.
- (4) The operation of the lift at full speed without load restrictions for an indefinite period of time. This evacuation requirement normally involves a robust diesel generator or other suitable secondary supply. This system must also be able to account for regenerative power if applicable (see section 8.6.5).
- (5) To be used solely to energise the mechanical brake to allow the cabin to travel unpowered in the lightest loaded direction to the nearest floor. However, this method is dependent on the car load being unbalanced and able to overcome any static friction in the system.



Note: methods 1, 2 and 3 above cannot usually deal with regenerative power demand, so the chosen drive technology must have the capability to divert regenerated power to a braking resistor network when operating on UPS power.

If full speed running of the lifts is required under diesel engine powered electricity generation (method 4 above) then sufficient substantially resistive loads need to be within the building to absorb the regenerated energy from the lifts. Additionally, the generator needs to be sized so that it can recover quickly under a full load start. Typically, recovery to supply to full voltage is required within 40 ms in order to avoid tripping of the phase failure device.

In order for successful passenger release operation, all other associated equipment such as the lift processor, power relays and door operator must also function. Therefore the

UPS or battery system must be of sufficient kV·A/A-h rating to cater for the load demand of these items. Whilst the full operating voltage provided by the UPS unit would allow for contract speed to be maintained during the evacuation process, reduced evacuation speeds are chosen for the reasons described above.

It is also considered best practice to ensure that monitoring of the UPS battery condition is undertaken and in the event of potential battery/UPS failure, a signal into the control system will notify the control system that the lift should be removed from service after its next controlled stop, following operation of the doors.



Warning: there may be a reason to prevent the lift from travelling in the lightest load condition (e.g. fire etc.), so under these conditions it is paramount that the car controller determines the direction of travel regardless of car loading and, under these conditions, the UPS should be sized accordingly.

8.10 Unintended car movement (UCM)



Note: clause 5.6.7.1 of BS EN 81-20 (BSI, 2014a) stipulates that lifts shall be provided with a means to prevent or stop unintended car movement away from the landing with the landing door not in the locked position and the car door not in the closed position, as a result of any single failure of the lift machine or drive control upon which the safe movement of the lift car depends (except failure of the suspension ropes or chains and the traction sheave or drum or sprockets of the machine, flexible hoses, steel piping or cylinder).

Clauses 5.6.7.2 and 5.6.7.3 of BS EN 81-20 stipulate that the means shall detect unintended movement of the car, shall cause the car to stop, and keep it stopped. Any means used that is part of the normal operation for controlling speed or retardation, stops the car or keeps it stopped, must have built-in redundancy and for correct operation must be self-monitored.

Machine brakes in accordance with clause 5.9.2.2.2 of BS EN 81-20 are considered to have built-in redundancy, but are regarded as a safety component and must be verified to the requirements of clause 5.6 of BS EN 81-50 (BSI, 2014b).

According to clause 5.6.7.4 of BS EN 81-20, the stopping element of the means shall act on:

- the car, or
- the counterweight, or
- the rope system, or
- traction sheave, or
- the same shaft as the traction sheave provided the shaft is statically supported in two points, or
- the hydraulic system (including the motor / pump in the up direction by isolation of electrical supply).

The stopping element of the means, or the means keeping the car stopped may be common but not restricted to those used for:

- preventing overspeed in the down direction
- preventing ascending car overspeed (BS EN 81-20, clause 5.6.6).



Note: in lift control terms, the adopted solutions for preventing unintended car movement are similar but not necessarily the same as preventing ascending car overspeed and should be treated separately.

Prevention of UCM

Unintended car movement is prevented by the following:

- Brake switch monitoring of typically a gearless machine, whereby two or more brakes are present and each brake has a contact which is monitored by the control system, with type-tested certification in accordance with Lifts Directive 2014/33/EU Annex III (List of Safety Components for Lifts) (OJ, 2014), BS EN 81-20 (5.9.2.2.2) and BS EN 81-50 (5.8 and 5.6).
- The implementation of an overspeed governor for monitoring/restricting movement away from the landing with the landing door not in the locked position and the car door not in the closed position in accordance with Lifts Directive 2014/33/EU Annex I (1.4 and 3.2) and Annex III (List of Safety Components for Lifts) (OJ, 2014), BS EN 81-20 (5.6.2.2.1) and BS EN 81-50 (5.4).
- The implementation of a bi-directional rope brake device for monitoring/restricting movement away from the landing with the landing door not in the locked position and the car door not in the closed position in accordance with Lifts Directive 2014/33/EU Annex I (3.2) and Annex III (List of Safety Components for Lifts) (OJ, 2014), BS EN 81-20 (5.7) and BS EN 81-50 (5.8).

Ascending car overspeed

The means, comprising speed monitoring and speed reducing elements, must detect overspeed of the ascending car in accordance with BS EN 81-20 (5.6.6.10), and cause the car to stop, or at least reduce its speed to that for which the counterweight buffer is designed. The means must be active in normal operation.

The means must operate an electric safety device in conformity with BS EN 81-20 (5.11.2) if it is engaged.

Speed monitoring

Speed monitoring is achieved by the following:

- The implementation of an overspeed governor, in accordance with Lifts Directive 2014/33/EU Annex I (1.4 and 3.2) and Annex III (List of Safety Components for Lifts) (OJ, 2014), BS EN 81-20 (5.6.2.2.1) and BS EN 81-50 (5.4 and 5.7)
- The implementation of a device conforming to BS EN 81-20 (5.6.2.2.1.1)

Speed reducing

Speed reduction is achieved by the following:

- Brake switch monitoring of typically a gearless machine, whereby two or more brakes are present and each brake has a contact which is monitored by the control system, with type-tested certification in accordance with Lifts Directive 2014/33/EU Annex III (List of Safety Components for Lifts) (OJ, 2014), BS EN 81-20 (5.9.2.2.2) and BS EN 81-50 (5.8 and 5.6).
- The implementation of a bi-directional safety gear in accordance with Lifts Directive 2014/33/EU Annex I (1.4 and 3.2) and Annex III (List of Safety Components for Lifts) (OJ, 2014), BS EN 81-20 (5.6.2.1) and BS EN 81-50 (5.3 and 5.7)
- The implementation of a single-directional rope break device in accordance with Lifts Directive 2014/33/EU Annex I (3.2) and Annex III (List of Safety Components for Lifts) (OJ, 2014), BS EN 81-20 (5.6.6) and BS EN 81-50 (5.7).



Note: It is imperative that lift control systems feature the necessary monitoring and shutdown functions when interfaced to one of the above methods of UCM detection and prevention, at the same time catering for prevention of overspeeding in either the up or down direction.

In order for this functionality and associated compliance to be met it is also a requirement that the door zone detection device used within the control system meets Lifts Directive 2014/33/EU (OJ, 2014), BS EN 81-20 (5.3) and BS EN 81-50 (4: List of significant hazards).

This compliance is required as some control systems allow for overbridging of the door safety circuit. After detecting any UCM event, one of the control system's primary functions is to keep the lift out of service until the fault is rectified.

8.11 Control of hydraulic drives

8.11.1 General

Hydraulic lift control systems manufactured in the 1970's were generally of a simple operation whereby a motor pumped (forced) the hydraulic oil through the pipework into a hydraulic ram, therefore propelling the lift in an upward direction. A valve or valves then allowed the oil to return to the reservoir thereby controlling the speed of the lift. There was little if any consideration given to load compensation for variations in oil viscosity due to oil temperature changes. As a result, ride quality was compromised.

Advances in modern valve and motor control technologies, combined with research into hydraulic oil performance, mean that hydraulic valve control can offer significantly improved ride quality.

Oil flow, oil pressure and oil viscosity can now be monitored to give greater stability and control over hydraulic lift performance, allowing for enhanced speed control and improved levelling accuracy with shorter levelling times. This also allows for hydraulic lifts to travel faster than previously was the case; 1 m/s is now achievable.

On modern hydraulic control valves, the oil flow is controlled by an internal hydraulic feedback valve (or pilot valve), or via an electronic oil flow sensor. Electronic oil flow sensors are generally more efficient as they have the ability to react to oil temperature changes and extremes.

8.11.2 Speed control

Traditionally, the pump motor runs only in the up (forcing) direction and raises the complete load for the entire travel of the lift. The required motor power is potentially up to 400% of the required power of an equivalent traction lift if no balance weight option is employed. The speed in the up direction is restricted by the oil flow rate that the pump can deliver (litres per minute) and the diameter of the pipework.

On smaller capacity lifts the motor may be of direct-on-line starting operation. However, these demand high starting torque (current), which equates to reduced ride quality. Lift speed, acceleration and deceleration profiles are controlled by restriction of the oil flow by the valve block.

Figure 8.12 shows direct-on-line control of a hydraulic pump motor.

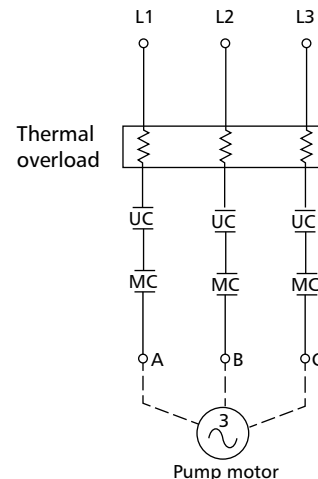


Figure 8.12 Direct-on-line control of a hydraulic pump motor

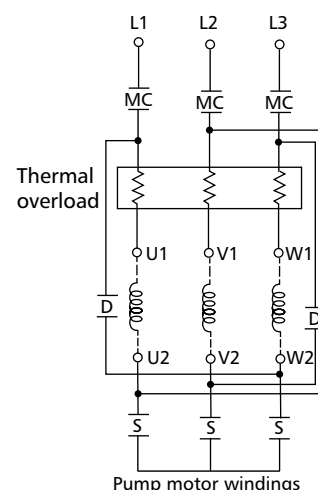


Figure 8.13 Star-delta control of a hydraulic pump motor

Star-delta pump motors are used for small to mid-range hydraulic lifts, with reduced starting torque and current when compared to direct-on-line starting. As with the direct-on-line pump, lift speed, acceleration and deceleration are controlled by oil flow restriction of the valve block. Figure 8.13 shows star-delta control of a hydraulic pump motor.

Soft-starter units are now more prevalent on larger hydraulic lifts. Although initial costs may be higher, reduced starting current demand offsets these costs throughout the life time of the lift. By controlling the current and voltage to the pump motor a controlled start can be achieved. Figure 8.14 shows soft-starter control of a hydraulic pump motor.

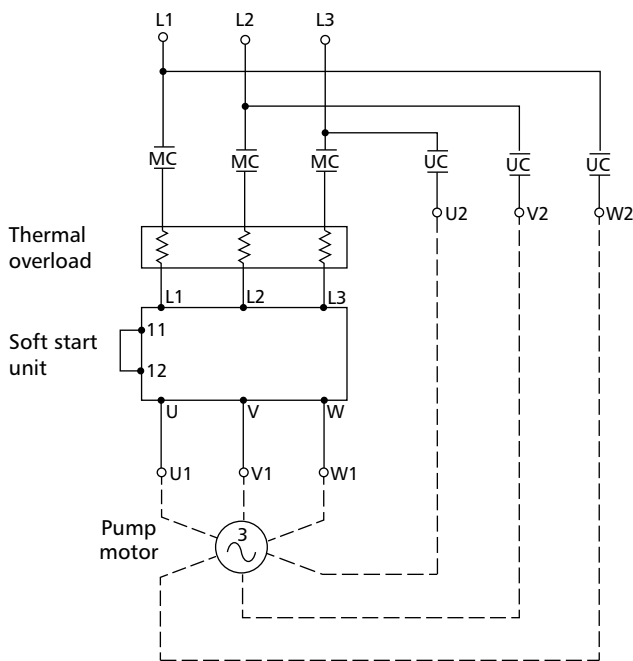


Figure 8.14 Soft-starter control of a hydraulic pump motor

When the lift is commanded to travel down, the down direction valve(s) are opened and the lift descent is controlled via these valve(s) under gravitational force. The down speed can be higher than the up speed therefore reducing the round trip time and increasing traffic handling capacity.

The valve system operation is rated by oil flow rate (litres per minute) and the required rated top speed. For higher speed hydraulic lifts, an electronically controlled valve system would be used. The hydraulic feedback valve system is more suited to lower speed lifts where cost is a higher consideration than hydraulic performance.

8.11.3 Anti-creep devices



Note: BS EN 81-20 (BSI, 2014a) specifies the use of some form of anti-creep device on all hydraulic lifts. This is a safety measure to prevent the lift sinking down from floor level due to oil leakage. The anti-creep action may be 'active', whereby the lift is driven up if the lift sinks below floor level due to leakage or oil compression when a heavy load is placed in the car. Larger lifts may also have a re-

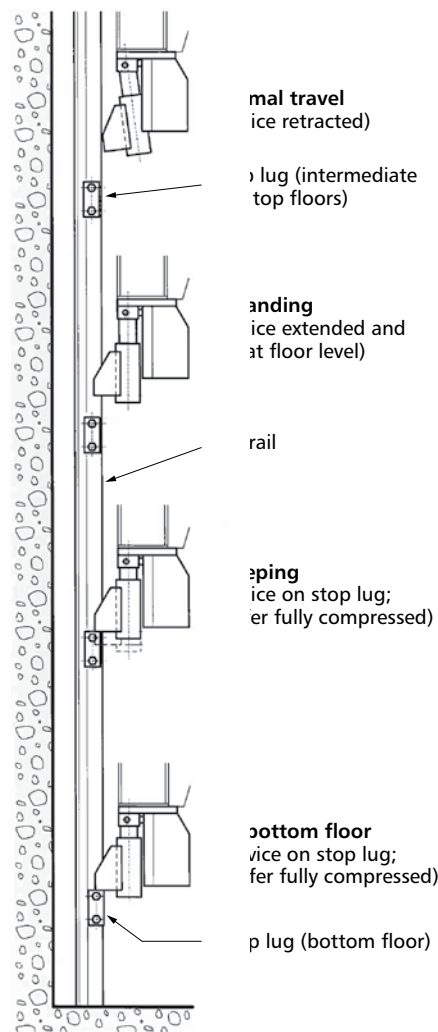


Figure 8.15 Typical down-prevention (pawl) device (courtesy of Focus Lifts Ltd.)

levelling motor to reduce motor starting current demand.

On lifts such as freight or vehicle lifts where large loads are transported, a physical mechanical down-prevention device or 'pawl' device can be fitted. Figure 8.15 shows a typical pawl device.

When the lift stops at the floor, the mechanical stops are deployed by electrical solenoids such that if the lift sinks with load being placed in the cabin, the downward movement is prevented by the stops, which engage with brackets normally fixed to the guide rails. When the lift is under normal operation these mechanical stops are not utilised. The operation of these electrical solenoids is monitored by the lift controller; if they are deployed the lift will not move until the error is rectified.

Another option, albeit more complex, is for 'active stops' to be used. These are deployed when the lift is at floor level and the lift 'sinks' onto the stops, therefore ensuring that load displacement movement is eliminated. Once the lift is instructed to travel again, the lift must move slowly upwards (even for a downward travel) and the operational status of the pawl devices is then monitored. Further travel is prevented if the pawl devices are not in the correct operational state. This system requires complex mechanical and electrical operation, but it is a suitable alternative for larger capacity lifts otherwise relying upon hydraulic re-levelling.

8.11.4 Hydraulic drives with energy accumulators

Systems are now available that use gas-filled energy accumulator reservoirs to harness the potential energy of the lift moving in the down direction. During downwards travel, the potential energy of the lift car and hydraulic ram are used to pressurise gas in the accumulator. When the lift is instructed to travel upwards, the accumulator is released to reduce the starting current demand.

It should be noted that these systems are subject to the Pressure Equipment Directive 97/23/EC (OJ, 1997) and the additional examinations required under the Directive.

8.11.5 Variable frequency pump motor drive



Design tip: systems are now available that utilise a variable voltage variable frequency (VVVF) inverter unit to control the hydraulic oil pump. In conjunction with electronic oil flow sensor control, the system can better control lift speed, allowing for differing load and temperature conditions.

The inverter unit also reduces starting current demand and provides excellent ride quality performance. These VVVF units may also be used in conjunction with accumulator systems (see section 8.11.4).

8.12 Control of door operators

8.12.1 General



Note: it is recommended and preferred that the door operator and its control system should meet the following requirements:

- The opening and closing high and low speeds and slowing profiles should preferably be independently adjustable
- Safety edges must be fast-acting and tolerant of mechanical impact. Remote sensing edges (i.e. electronic) are inherently better than mechanical edges in this respect and reduce the possibility of the doors striking passengers, causing injury. Optical (i.e. photocells) or other passenger/object detection devices may also be used to modify door control. In addition, they can be used in conjunction with a load sensor to prevent nuisance car calls.

Advanced opening is a time-saving feature widely used in office buildings to improve performance. This allows the doors to commence opening once the car speed is below 0.3 m/s and the lift is within the door zone (typically ± 100 mm, maximum ± 200 mm). However, the advance opening door opening action can be disturbing to elderly users and may not be suitable in some buildings.

8.12.2 Control of DC door operators

Two methods have been in use for many years:

- resistance control of motor field and armature
- saturable reactor control.

These are no longer prevalent with the advances in motor control technology and are costly, additionally, requiring regular maintenance adjustments.

DC motors are now either controlled by a PWM controller or an electronic speed control device. The motors typically used for modern door operators are low voltage types (i.e. 24 V DC) using electronic control of speed, torque and door position. This provides higher levels of performance than previously was the case with the advantages of a physically compact door operator design.

Figure 8.16 shows a typical DC door operator.

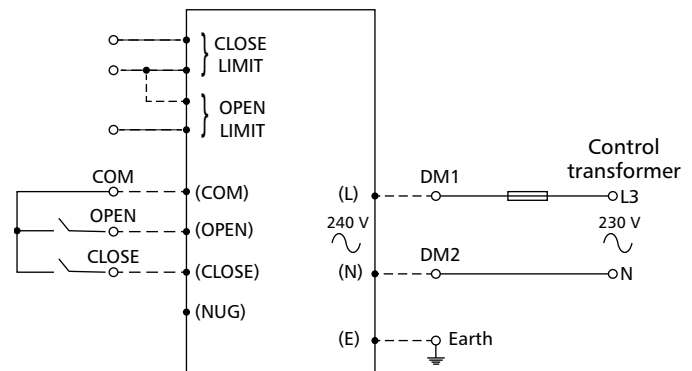


Figure 8.16 Typical DC door operator

8.12.3 Control of AC door operators

Simple AC door operators do not have speed control, whereby the motor runs at a constant speed in both the opening and closing directions. The door motor may be designed to run safely when stalled with the full supply voltage applied in order to prevent the doors 'relaxing open' during lift travel. Constant speed door operation is suitable for narrow doors and where traffic is low so that the limited speed does not restrict lift performance.

Figure 8.17 shows typical 3-phase door motor control.

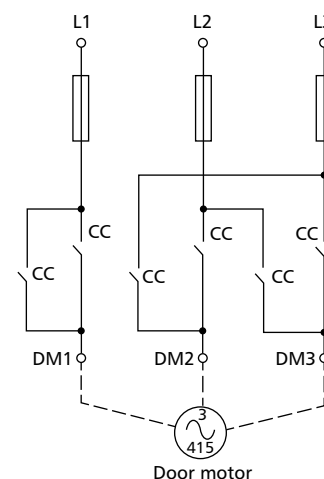


Figure 8.17 Typical 3-phase AC door motor control

8.12.4 Electronic control of AC door operators

AC variable voltage door operators typically use a single speed motor. Braking torque and direction is controlled by reversing the phase rotation of the supply. This technique is satisfactory with low-power motors. The speed, position of the doors and motor torque can be controlled using closed-loop feedback. The feedback signals are monitored and compared with reference signals. If there is loss of, or large errors in the feedback signal, the door drive is stopped.



Design tip: variable voltage variable frequency drives are also now being used for door operators. These provide a higher electrical efficiency than variable voltage drives and also potentially lower noise operation.

Logic circuits built into the door operator control the speed reference so that the doors always follow a distance-based velocity curve. This safely minimises opening and closing times and prevents high acceleration forces on the doors. Logic circuits can also control the reopening of the door in response to safety signals. For example, on a 1200 mm entrance, the doors open only to 800 mm in response to the first re-open signal. This minimises the door operation time to maintain the maximum possible traffic handling capability. Additionally, the lift controller can, as an option, modify the door speeds and open times in response to changes in the level of traffic.

The more advanced electronic controlled operators using velocity and position closed-loop control are suitable for both general use and for demanding applications.

Figure 8.18 shows a typical VVVF door operator.

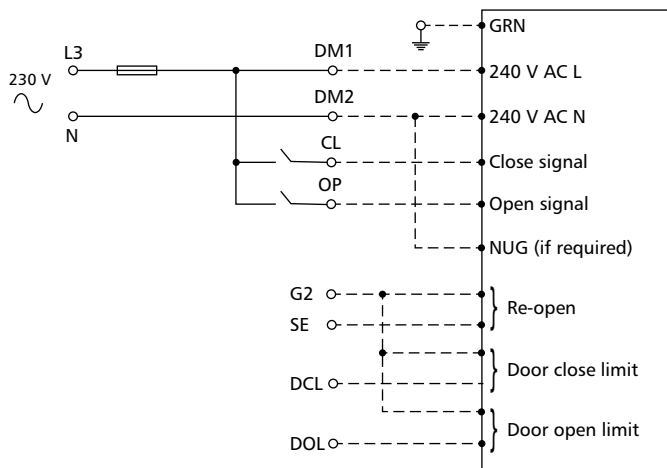


Figure 8.18 A typical VVVF door operator

8.13 Electromagnetic compatibility (EMC), environment and reliability

The use of solid state drives and microprocessor technology employed within lifts requires more attention with regards to EMC-related issues than was previously the case. By way of summary, the Electromagnetic Compatibility Directive

(OJ, 2014) requires that equipment shall not generate interference that can damage or cause malfunctions in other equipment and shall be immune from and not susceptible to interference which is considered in any way hazardous.

The harmonised product standards for lifts and escalators are BS EN 12015 (BSI, 2014c) (emissions) and BS EN 12016 (BSI, 2013) (immunity), see chapter 12.

All (new) equipment should be compliant with these standards. Note that due to the distributed layout of the lift and escalator equipment situated within a building (i.e. parts of a lift are on each floor) it is not meaningful to make compliance tests on site.



Note: of particular importance in the construction of the equipment is the design and installation of the electrical earthing; both internal to control cabinets and external, including the termination of screened signal and power cables.



Warning: the environment must be controlled to ensure that the storage and operating temperature and humidity limits are not exceeded. The performance and reliability of the equipment is adversely affected by operation outside of its design parameters. Such operation may cause breakdowns and adversely affect manufacturers' product warranties.

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9 Lift traffic control

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9 Lift traffic control

9.1 The need for lift traffic control

Individual lift control is a basic necessity and, as such, was present from the very beginnings of lift usage. Early systems used ‘car switch’ controls, in the car operated by an attendant, to move and stop the lift at the various landings. The introduction of automatic motion control eliminated the car switch, but the attendant remained to collect and transport intending passengers. The early group traffic control systems were human dispatchers, sometimes called ‘starters’, who stood in the main lobby during morning uppeak and using various signalling techniques, informed the in-car attendants where to stop their lifts. When multiple lifts were installed to serve the same set of floors, it was quickly realized that efficiency could be enhanced by coordinating the behaviour of lifts in a group, resulting in the concept of group traffic control.

After the Second World War automatic systems utilising relay logic were designed which dispatched individual lift cars in a group from terminal landings separated by a time headway. They picked up any landing calls encountered in their path. These relay based systems were eventually developed to operate ‘on-demand’ and only react to the registration of landing calls by passengers. As time passed these relay based systems gave way to hybrid relay/electronic controllers and eventually to programmable logic controllers (PLCs) and microprocessor-based systems.

The development of fully automatic pushbutton (FAPB) controls has almost completely eliminated the use of an attendant in the car and a dispatcher on the main landing, and thus allowed passengers to ‘drive’ the lifts themselves. The attendant is only retained in exceptional cases, e.g. where there is a security issue, customers or builders beneficial use prior to handover, or to provide a special service to VIPs.

The overall control of lift systems presents two different engineering challenges:

- first, some means of commanding a lift car to move in both up and down directions and to stop at a specified landing should be provided, i.e. motion control
- secondly, to serve passenger demands (landing and car calls) and for a group of lifts to work together in order to make efficient use of the individual lifts in the group, i.e. traffic control.

The first challenge is concerned with drive systems and drive control, which was discussed in chapter 8 of this Guide. The second challenge is concerned with (passenger) traffic control and is the subject of the present chapter.

Both control systems are often found in the same cabinet and thus have become known collectively as the ‘controller’. Another term sometimes used today to describe the traffic controller is ‘dispatcher’ — an echo from history. BSI Code of Practice BS 5655-6 (BSI, 2011) describes different types of traffic controllers.

Appropriate automatic traffic control systems can enable a single lift, or a group of lifts to operate at high efficiency, provided the equipment is well designed, properly installed and adequately maintained. Often the individual controller is referred to as the ‘lift’ (or car) controller and the traffic controller is referred to as the group controller. This chapter provides guidance on the traffic control of single lifts, and for lift groups through legacy systems, based on relay logic, to modern day systems, utilising microcomputers.

In the discussions, the various types of passenger demand (uppeak, down peak, midday and interfloor traffic) are mentioned. These terms are fully discussed in chapter 3.

9.2 Single lift traffic control

There are many lifts installed as single units in buildings such as hotels, small offices, car parks, museums, railway stations, schools, etc. They should respond to the registration of landing calls and the resulting registration of car calls. Where a single lift is proposed, purchasers should consider which control system would suit their purpose from those described below.

9.2.1 Single call automatic control

The simplest form of automatic lift control is single call automatic control. Single pushbuttons are provided on the landings and a button for each floor in the car. This form of control is also termed non-collective or automatic pushbutton (APB) control.

The passengers operate the lift by pressing landing and car buttons. Car calls are given absolute preference over landing calls. Once a passenger in the car presses a car call pushbutton corresponding to the required destination floor, the lift moves directly to this floor, bypassing any intermediate floors. When a landing call pushbutton is pressed and the lift is free, the call is immediately answered. If the lift is in use, a landing signal indicates a ‘lift busy’ and a new landing call cannot be registered until the lift is no longer in use.

This type of control is only suitable for short-travel passenger lifts serving up to four floors, for example, in small residential buildings with a light traffic demand. It provides a very low carrying capability, as most of the time the lift carries a single passenger. It can also produce long passenger waiting times, owing to the many trips that

bypass passengers on the intermediate landings. This type of automatic pushbutton control is, however, suitable for goods lifts, particularly when a single item of goods can fit in the lift at one time.

9.2.2 Collective control

The most common form of automatic control used today for a single lift is collective control. This is a generic designation for those types of control where all landing and car calls made by pressing pushbuttons are registered and answered in strict floor sequence. The lift automatically stops at landings for which calls have been registered, following the floor order rather than the order in which the pushbuttons were pressed. Collective control can either be of single button or two-pushbutton types.

9.2.2.1 Non-directional collective

Non-directive collective control provides a single pushbutton at each landing. This pushbutton is pressed by passengers to register a landing call irrespective of the desired direction of travel. Thus, a lift travelling upwards, for example, and detecting a landing call in its path stops to answer the call, although it may happen that the person waiting at the landing wishes to go down. The person is then left with the options of either stepping into the car and traveling upwards before going down to the required floor, or letting the lift depart and re-register the landing call. Owing to this inconvenience, this type of control is only acceptable for short travel lifts.

9.2.2.2 Down collective (up-distributive, down-collective)

Despite the disadvantages expressed in 9.2.2.1, single pushbutton call registration systems may be adequate in buildings where there is traffic between the ground floor and the upper floors only and no interfloor traffic is expected, e.g. car parks, public high rise housing, flats. Retaining the single pushbutton on the landing, a suitable control system is the down collective control (sometimes called up-distributive, down-collective) where all landing calls above the ground are understood to be down calls. A lift moving upwards only stops in response to car calls. When no further car calls are registered, the lift travels to the highest landing call registered and travels downwards, answering both car and landing calls in floor sequence.

Where levels exist below the main boarding floor a down collective system may not be suitable as the system will assume that a call at the main boarding floor is to initiate travel downwards. Travel in the up direction is more likely.

9.2.2.3 Full collective (directional collective)

The two pushbutton full collective control (also designated directional collective control) provides each landing (except terminal landings) with one UP and one DOWN pushbutton and passengers are requested to press only the pushbutton for the intended direction of travel. The lift stops to answer both landing calls and car calls in the direction of travel, and in floor sequence. When no more calls are registered in the direction ahead of the lift, the lift moves to the furthest landing call in the opposite direction, if any, and answers the calls in the new direction. This control system is

suitable for single lifts or duplexes (two lifts) serving a few floors with some interfloor traffic. Typical examples are small office buildings, small hotels and blocks of flats.

Directional collective control applied to a single lift car is also known as simplex control.

The system can be applied to two or three interconnected lifts to work as a team, where a fully configured group control is not appropriate. Two lifts are termed a duplex and three lifts a triplex. Full collective control is the simplest form of group control.

9.3 Purpose of group traffic control

A single lift may not always be able to cope with all the passenger traffic in a building. Where a number of lifts are installed together, the individual lift control mechanisms should be interconnected and also there should be some form of automatic supervisory control provided. In such a system the landing call pushbuttons are common to all the lifts which are interconnected, and the traffic supervisory controller decides which landing calls are to be answered by each of the individual lifts in the group.

The function of efficiently distributing landing calls to individual lift cars in a group is basically the same for both large and small groups. Thus, a 2-car lift group can benefit from the use of group control as much as an 8-car group. This is called group traffic control, which can be defined (see Glossary of terms) as:

‘a number of lifts placed physically together, using a common signalling system and under the command of a group traffic control system’

The purpose of group control is to allocate (or assign) the landing calls in an optimum way to the various individual lifts in the group. The term ‘optimum’ is difficult to define. Equally difficult is ‘what to optimise’. Some group control algorithms seek to optimise a specific metric while others seek to balance multiple metrics within acceptable ranges. A number of possibilities have been suggested, for example:

- minimise passenger waiting time
- minimise system response time (i.e. the time between the registration of the call until it is answered; this is equal to the waiting time of the first passenger who registered the call)
- minimise passenger journey time (also called time to destination)
- minimise the variance (in statistical terms) in passenger waiting time (or system response time)
- maximise the handling capacity
- minimise the energy consumption
- reduce ‘bunching’ see Appendix A1: Glossary of terms.

Various traffic control algorithms have been developed to achieve some of the above goals and if there is a specific requirement for one of these this should be written into any

specification and discussed with the potential suppliers at the design stage.

The definition of a traffic control algorithm is:

‘a set of rules defining the traffic control policy, which is to be obeyed by the lift system, when a particular traffic condition applies’

Most group traffic control systems provide more than one traffic algorithm to allocate lifts to calls. The control system adopts the appropriate algorithm according to the intensity of passenger demand, and the mix of the traffic (incoming, outgoing and interfloor, see chapter 4. The most advanced traffic algorithms learn repeating traffic patterns for themselves, and adapt their strategies dynamically without the need for time clocks or manual settings.

A simple controller would not be suitable for a busy office building. The most advanced systems may not represent value if installed in a building with minimal demand. Thus at an early stage the expected or predicted type of traffic demand should be established in order to match a suitable traffic controller to the demand. A supplier may be able to indicate the category in which their equipment falls.

For any traffic algorithm to be effective it requires certain information about the building and lift system to be input to the controller see Figure 9.1. The more data that are available, the greater opportunity the algorithm has to optimise performance. The basic data are:

- number and position of served floors
- all the landing calls
- all the car calls registered in the lifts
- number of cars, and their current position
- status of each lift car (i.e. moving up/down, door status, car load, in/out of service, etc.).

Further improvement to the performance of the system may be achieved if the following variables are also input and learnt by the group controller:

- a means of determining if a travelling car can slow down in time to stop for a floor it is travelling towards
- type of prevailing traffic or the time and date if traffic pattern is being learnt

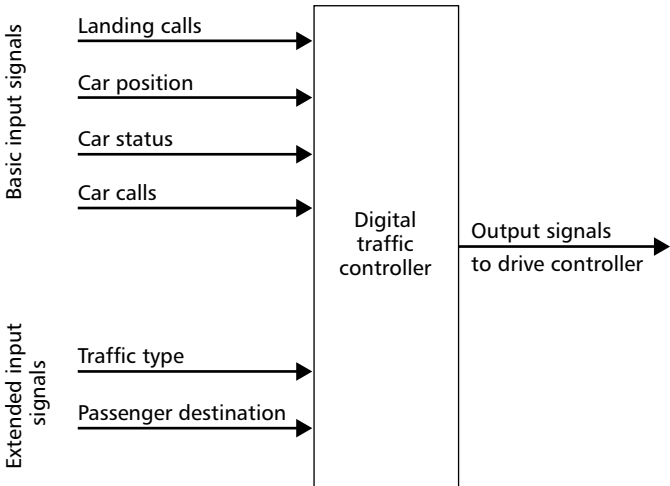


Figure 9.1 Basic schematic of signal flow in a lift group traffic controller

- the destination of each passenger prior to boarding the lift (as in hall call allocation systems (see section 9.4.2.3).

As a general rule, the more information about the lift system that the group controller has access to, the better the performance of the group controller in allocating calls and optimising the relevant parameter or combination of parameters (e.g. passenger waiting time).

9.4 Types of traffic control algorithms

The traffic control system complexity depends not only on the number of available control programs, but also on the complexity of the algorithms themselves. A lift system with a large variety of control algorithms is not necessarily the best system, as some problems may arise in the transfer of control from one algorithm to another, as an effective redistribution of lifts takes some time, making response to transient changes in traffic requirements very difficult to achieve consistently.

Lift group control systems respond to the necessity of providing efficient control of a group of automatic lifts servicing a common set of landing calls. The main goals are to provide the maximum handling capacity and the minimum waiting and travelling time of passengers, whilst using the most economical installation. The criteria are to determine the best allocation of landing calls and to select the best lift car to serve the particular landing call. Various algorithms have been developed throughout the decades.

9.4.1 Legacy traffic control systems

When modernising a lift installation the existing traffic controller may be considered for replacement, often due to reliability or maintainability issues. It is important that the replacement traffic controller, which will almost certainly be microcomputer based, can perform as well, or better, than the system it replaces. Systems developed and installed before the 1980s were typically based on relay logic or primitive programmable logic controllers (PLCs). This does not mean the control algorithms provided were in any way significantly inferior to those available today. In general these legacy traffic controllers concentrated on dealing with the most significant traffic pattern of the day, namely uppeak. The exception to this philosophy was the dynamic sectoring system (see section 9.4.1.4). It is important to understand these legacy controllers when choosing a replacement.

There were four basic (generic) types of traffic controller developed by the proprietary and independent manufacturers. These are briefly described below. A fuller description can be found in Barney and Al-Sharif (2015) and Barney and Dos Santos (1985).

9.4.1.1 Nearest car

The simplest type of group control is the directional collective control described in section 9.2.2.3. It is suitable for a group of two, or three lifts, each operating on the directional collective principles and serving seven or so

floor levels. The assignment of lifts to landing calls is achieved by the ‘nearest car’ control policy.

A single landing call system with one UP and one DOWN pushbutton at each landing, except for the terminal landings is required. The nearest car traffic control system is expected to space the lifts effectively around the building, in order to provide even service, and also to park one or more lifts at a specified parking floor, usually the entrance lobby floor (main terminal). Other features, which might be included, are the bypassing of landing calls when a lift is fully loaded.

The lift answers its car and landing calls in floor sequence from its current position, in the direction of travel to which it is committed. The lift then continues in the same direction to the furthest landing call in the opposite direction before reversing; if there is none, it reverses immediately.

The only group traffic control feature contained in this simple algorithm is the allocation of each landing call to the lift that is considered to be the best placed to answer this particular call. The search for the nearest car is continuously performed until the call is cancelled after being serviced.

9.4.1.2 Fixed sectoring: common sector system

A fixed sectoring common sector control system can be devised for dealing with off-peak traffic and can be complemented with special features to cater for heavy unbalanced traffic. The system divides a building zone into a number of static demand sectors (see Figure 9.2) equal to the number of lifts. Note that a building zone is a number of floors served by a group of lifts. Zones can be adjacent to the main terminal (low zone) or above the low zone (high zones). A sector includes both the up and down landing calls at the floors within its limits. A lift is allocated to a sector if it is present in that sector and the sector is not committed to another lift. Fully loaded lifts are not considered for assignment.

An assigned lift operates on the directional collective principle within the limits of its range of activity. The de-assignment of a lift from its sector takes place when the lift

leaves the sector. A lift picks up calls ahead when travelling in either direction, even if it is not assigned to the sector.

The system, by distributing the lifts equally around the building, presents a good performance under balanced interfloor traffic. It also performs well for uppeak and unbalanced interfloor traffic conditions. It lacks a proper procedure to cater for sudden heavy demands at a particular floor. Under heavy down peak traffic conditions, poor service may be provided to the lower floors of the building owing to problems in recycling the lifts to unoccupied sectors.

9.4.1.3 Fixed sectoring: priority timed system

A fixed sectoring systems can also allocate the lifts to landing calls in a sector on a priority timed basis. The landings in the building zone served by the group of lifts are grouped into up and down sectors. Each sector is timed as soon as a landing call is registered within its limits. The timing is measured in predefined periods of time, designated the priority levels. The system is unique among the classical traffic control systems as it considers time when making an assignment. The other algorithms only consider position.

The assignment of lifts to the sectors takes into account the number and positions of the available lifts and the sector priority levels. A lift is available for allocation when it has completed its previous assignment and has dealt with all the car calls that have been registered. The sector with the highest priority is the first to be allocated a lift.

The control system provides a good uppeak performance. Its down peak performance is very good, especially under very heavy traffic conditions. The interfloor traffic performance is fair, but not as good as can be obtained from dynamic sectoring.

9.4.1.4 Dynamic sectoring system

The dynamic sectoring group supervisory control system provides a basic algorithm and is suitable to deal with light to heavy balanced interfloor traffic. It is complemented by a number of other control algorithms to cater for unbalanced traffic conditions.

The basic dynamic sectoring algorithm groups landing calls into dynamic sectors. The position and direction of each lift defines the dynamic sector, see example definitions of sector boundaries shown in Figure 9.3. Each lift answers the landing calls in the sector ‘ahead’ of it. In parallel with the basic traffic algorithm, another dynamic sectoring algorithm is provided to insert free lifts ahead of lifts serving a large number of floors (e.g. sector DS3 in Figure 9.3) or a large number of calls registered in their dynamic sector.

The dynamic sectoring system provides a very good performance for uppeak and interfloor traffic conditions, but a poor performance for down peak.

9.4.2 Modern traffic control systems

The concept of centralised supervisory control systems for buildings, known as building management systems (BMS) using digital computers, is already well established. As part

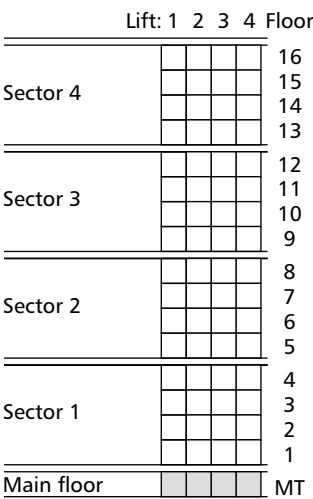


Figure 9.2 Illustration of the fixed sectoring of a building zone

Floor				
	3↓	←3		16
	3↓	3↑		15
	3↓	3↑		14
	3↓	3↑		13
	3↓	3↑		12
	3↓	▲		11
1↑	3↓			10
1↑	3↓			9
1↑	3↓			8
1↑	▼			7
1↑	2↓			6
1↑	2↓			5
1↑	2↓			4
▲			▼	3
4↑			4↓	2
4↑			4↓	1
4↑	←4	←4	←4	MT

Dynamic sector allocation shown is:

- DS1: floors 4–10
- DS2: floors 6–4
- DS3: floors 12–16–8
- DS4: floors 2–MT–2

Figure 9.3 Illustration of the dynamic sectoring of a building zone

of the comprehensive information system for a whole building it includes facilities such as employee identification, security control, fire control, environmental control, water treatment, data logging, etc. It is not sensible to include the task of lift traffic control in any centralised building control system. Thus, a lift should normally have all aspects of its traffic and drive control managed independently of other building systems. In some installations, security systems are used as part of the mechanism to call lifts; in these cases great care should be made to ensure systems fast and reliable integration.

The opportunity exists with a computer to program complex tasks to assist the call allocation process, which are impossible to achieve with fixed program systems. This might be considered to lead to truly optimal traffic control. However, humans (passengers) are involved and they expect certain rules to be obeyed. In summary these are:

- *Rule 1:* car calls must always be served.
- *Rule 2:* a lift should not reverse its direction of travel until all calls in that direction have been served.
- *Rule 3:* a lift should stop at a passenger destination floor (it should not pass it).
- *Rule 4:* passengers wishing to travel in one direction should not enter a lift committed to travel in the opposite direction.
- *Rule 5:* a lift with passengers in the car should not stop at a floor where no passengers wish to enter or leave the car.

Absent-minded passengers could infringe rule 4, but its likely violation can be reduced by effective signalling (indicators, lanterns and gongs). Rule 5 could be violated by the passengers, either in the car or, on the landing, accidentally, or deliberately, registering incorrect calls.

There are three basic (generic) types of traffic controller developed by the proprietary and independent manufacturers. These are described below. Selection of an inappropriate system can have significant negative consequences. Independent advice may be needed for complex projects.

9.4.2.1 Estimated time of arrival (ETA)

An estimated time of arrival (ETA) digital computer-based traffic control system allocates lifts to landing calls, based upon computed car journey times, i.e. how long a lift takes to arrive. Early systems of this type, developed in the 1970s, substituted relay or solid state fixed logic by a truly programmable computer. This technique was an obvious one to use once programming facilities were available. The ETA technique remains the underlying basis of many computer based systems on the market. The quality of the estimation can be improved by use of artificial intelligence (AI) techniques (see section 9.5.1).

The ETA control system can be expected to provide a good uppeak performance. By declaring the main terminal floor as a parking and priority floor, cars can be sent down to deal with the incoming traffic. The system is not, however, particularly suitable for down peak traffic. Under light to medium balanced interfloor traffic conditions, the system behaviour is very similar to a dynamic sectoring system, and good performance is to be expected.

A variation of ETA is estimated time to destination (ETD) (Smith and Peters, 2004). This system not only estimates the time to arrive and pick up the intending passenger(s), but also the time to take them to their destination. The system takes into account the commitments an arriving car has in terms of landing calls already allocated and the current car calls it should honour. AI techniques can be used to improve the estimations.

9.4.2.2 Quality of service equalisation

The stochastic control algorithm (Halpern, 1993) aims to provide an even service to all floors, where every landing call is given a fair consideration. This means that the landing call that has been waiting the longest should be given higher priority. The effect is to give a more even and more consistent service to passengers by trading the instant response calls to reduce long wait calls.

Enhancements to the ETD algorithm (Smith and Peters, 2004) are suggested that apply a similar strategy to stochastic control, recognising that passenger satisfaction is not simply a function of providing the lowest overall average waiting time or time to destination. Optimisation algorithms can be adjusted to target any required goal, including a greater consistency in waiting time.

Prioritising long-wait calls is a valid strategy, but should be applied with caution during busy periods as it reduces handling capacity. If passenger demand exceeds the reduced handling capacity, the system may overload, leading to unacceptable waiting times for all passengers.

9.4.2.3 Hall call allocation (HCA) control

It would be much more useful if the traffic controller knew the intended destination of each landing call. This information can be obtained, for example, by replacing the conventional up/down buttons (Figure 9.4(a)) by a panel of passenger destination buttons at each landing similar to the keypad on telephones (Figure 9.4(b)) or even by touch screens. Hall call allocation (Port, 1961) (also known as destination control) gives the opportunity to track every

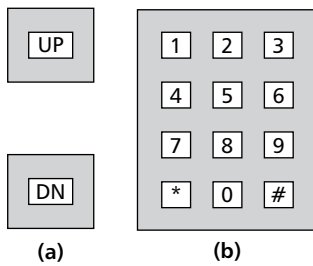


Figure 9.4 Illustration of hall call allocation landing registration panel

passenger from landing call registration through to his/her destination.

The basic system (Barney and Al Sharif, 2015; Schroeder, 1990) works by the algorithm allocating each new passenger call, as it is registered, to each car in turn and evaluating the cost of each allocation. The allocation giving the lowest cost is then adopted and communicated immediately to the passenger by means of an alphanumeric display or graphic. Suitable cost functions are, for example, passenger average waiting time, passenger average journey time or a combination of both. For periods when a boost in handling capacity is not required, a significant reduction in time to destination can be achieved with minimal impact on passenger average waiting time (Smith and Peters, 2004). Other enhancements to cost functions are poorly understood by some manufactures, limiting the effectiveness of their algorithms (Barney, 2014).

During uppeak, passengers can be grouped to common destinations, as there are large numbers of them. The individual waiting time may increase, the travel time may decrease, and there would be an overall reduction in journey time. During down peak there is little advantage as the destination floor is known. During reasonable levels of balanced interfloor traffic there is little advantage as most landing calls and car calls are not coincident. However, during an uppeak with some down travelling traffic, or a down peak with some up travelling traffic, or during midday traffic, there are benefits.

The advantages of the system are:

- Passengers do not need to translate their intention to travel to a specific floor into a request for an up or down command.
- Passengers do not need to rush to the lift whose hall lantern is on as they stand by the pre-assigned lift.
- The supervisory system receives full information regarding the destinations of all passengers and thus it can make more intelligent decisions.
- Handling capacity is increased when there is an opportunity to group passengers travelling to the same floors, e.g. during uppeak.
- Reductions in the passenger time to destination are possible.

The disadvantages of the system are:

- The passenger waiting time may increase.
- Each passenger should register a call.
- Passengers cannot register destination calls in the car.
- Increased cost of call station fixtures.
- Possible passenger misunderstanding of the system.

- Possible abuses by passengers registering more than one call each.
- Allocations have to be made immediately and are fixed.

The 'positive' concept of using a cost function as a performance index can be transposed into a 'negative' concept of penalty functions in order to promote higher efficiency. An example of a penalty function is the rejection of an allocation which introduces an additional stop.

The HCA system is often used to boost an 'under-lifted' building during the uppeak period (Russett, 2002). Unfortunately it does not significantly change the performance during other traffic conditions.

If the boosted handling capacity is temporarily insufficient, some HCA systems may refuse to make an allocation requiring the passenger to 'try again later'. These refusals are very frustrating for passengers and should be avoided if possible. If refusals are disallowed, there are some instances where transporting passengers in the wrong direction (section 9.4.2, Rule 4) cannot be avoided (Gerstenmeyer and Peters, 2014). These reverse journeys (or longer waiting time resulting from not accepting reverse journeys), are particularly prevalent (a) with mixed traffic, (b) at peak times, (c) with multiple entrance floors, (d) where not all lifts serve all floor, (e) with restaurants and other busy floors, (f) in under-lifted buildings. Reverse journeys are not desirable, but sometimes represent the best compromise. Allowing reverse journeys reduces average waiting time and time to destination, but may confuse passengers. Improved indication may mitigate this problem.

If not addressed within the algorithm, HCA can perform worse than a conventional system with landing buttons when it is itself overloaded (Peters, 2013). This is because systems that operate a booking system to map the load of the car can end up in a situation where they have no choice but to allocate a passenger to the only car with a space.

Some suppliers offer a mixed system with a full call registration station at the lobby and other principal floors, and two button stations at all other floors. This approach can yield cost savings, particularly for modernisations if the existing two button stations can be interfaced with the new control system. Mixed landing and destination call systems provide the same uppeak boost as HCA. However they require a car call station in the car, which is susceptible to abuse if passengers at the ground floor join the next car to depart rather than the car allocated by the traffic controller. This abuse can be discouraged by temporarily disabling the car call buttons until a landing call above the main terminal is answered.

9.5 Advanced group traffic controller features

9.5.1 Use of artificial intelligence (AI) in group traffic control

The engineering goal of artificial intelligence is to solve real-world problems using ideas representing knowledge, using knowledge, and assembling knowledge based

systems. Generally, the application of AI techniques to lift systems has not been shown to bring significant increases in handling capacity. However, where the traffic demand is less than the capacity of the lift installation AI techniques do improve overall performance.

A number of AI techniques have been applied to lift traffic control and some manufacturers claim they are advantageous. The most common systems are summarised as follows:

- *Expert system control*: the philosophy of supervisory control based on traffic sensing and rule-based expert systems was developed in the 1990s. The system was implemented using standard packages, built on a spreadsheet in the first instance. Simulated input traffic was generated and dynamically linked to the simulator, showing car movements. An expert system linked to the traffic sensing system continuously calculated optimal car movements.
- *Fuzzy control*: the application of fuzzy logic (Powell and Sirag, 1993; Siikonen and Leppälä, 1991) on elevator systems was first achieved in Japan where the appropriate rule was selected immediately after any hall call button was pressed. A fuzzy logic dispatching system reduces waiting time by operating in an active mode. The dispatcher uses fuzzy rules based on past experience to predict how many people may be waiting for elevators at various times of the day, rather than simply reacting to calls. When several fuzzy features are included in the dispatching decision process, the result is a more effective approach to elevator dispatching than systems based on conventional digital logic.
- *Artificial neural network control*: artificial neural networks (Kubo et al., 1995) have been used to select the appropriate traffic patterns so that the traffic control module could choose the best hall call assignment algorithm. A destination-oriented car allocation service has also been developed to improve services during rush hours.
- *Optimal variance method*: a statistical approach involving variance analysis has been adopted where the variance of hall call response time could be decreased by computerised elevator dispatch systems utilising cost function minimisation. The idea is to improve the variance performance by sacrificing the mean response time to a small extent.
- *Genetic algorithms*: emulating animal genetics and based on the concept that the fittest individuals survive, genetic algorithms (Xiaoliang et al., 2004) can be used to search for a global optimisation of lift service times.

Barney (2014) cautions that many of the advanced control techniques employ complex mathematics and involved programming, which makes the practical implementation of the traffic controllers difficult. Also the proper understanding and correct adjustment on site by installation and service persons is doubtful and there is also an increased risk of system unreliability. Powell and Sirag (1993) state that the added complexity involved in creating neural networks and putting them into production could not be justified given the slight gains in dispatching performance over less complicated techniques.

9.5.2 Methods of detecting traffic patterns and the incidence of peak traffic

Until the 1980s, office working hours were relatively stable. Incoming and outgoing traffic peaks could be predicted and simple time clocks used to switch the mode of operation of the group control. The installation of analogue computer circuits to measure the number and direction of landing and car calls provided additional discrimination. Changes in working practices to more flexible and staggered office hours defeat these simple strategies for handling peak traffic. Also building population densities have often increased beyond the original designed capacity of the lifts using non-computer-based systems. For these reasons, it has become necessary to enable the controller to detect the type of traffic prevailing. The following techniques should be discussed with any prospective supplier:

- *Load weighing devices*: in most cases these devices give the estimated weight in discrete steps of full load, and give a rough estimate of the number of passengers. The conversion process from measured weights to passenger numbers assumes a fixed weight figure per passenger, which could vary widely owing to the differing weights of passenger groups (adults, children etc.) and other disturbances (e.g. passengers carrying objects, or pushing trolleys etc.).
- *Photocell signals*: this method is used to identify the number of passengers leaving or entering the car. In cases where the lift responds to both a landing call and a car call, it is difficult to distinguish between in-going and out-going passengers.
- *Pressure sensitive device*: this can be a platform switch or pressure sensitive pad on the floor of the car, which determines the number of passengers.
- *Imaging systems*: these use artificial intelligence techniques to identify the number of passengers.

9.5.3 Data logging

Before any action of the traffic control algorithm is performed, information reflecting the current status of every car within the system should also be retrieved. This relies on an advanced digital monitoring system.

All modern controllers provide various degrees of data logging. The owner should have access to all operational data in a form which allows its analysis and presentation. At the very least all data concerned with failures and faults should be available. Additionally, dependent on the size of the installation, data should be accessible to the owner regarding performance. These data should comprise performance data such as door times, dwell times, system response times, out of service times, etc. A prospective supplier should be asked exactly what can be made available to the owner.

In addition to remote status monitoring, a diagnostic system should be provided on intensive traffic installations to allow proactive preventive maintenance procedures to be put in place by the installation maintainer. The system should detect failure symptoms, which would not be noticed by even a skilled maintenance technician. It has been found that small abnormalities in some equipment

can cause serious problems when amplified by factors such as wear and deterioration.

9.5.4 Centralised and distributed control and back-up

There is a vast amount of data to collect and process with the modern lift installation. As there are a number of lifts in the group, there are a number of methods by which the data, including landing calls, are collected and processed.

A dedicated group controller can be employed, which collects the data and allocates landing calls to a lift according to a certain algorithm (see Figure 9.5). The disadvantage of this method is that the group controller (typically an industrial computer) may need extra space, and if it fails, it jeopardises the whole system. For this reason, installations utilizing a group controller should include a back-up system in buildings where failure would be catastrophic, e.g. in a high rise group.

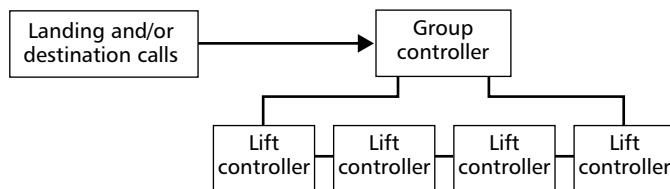


Figure 9.5 Dedicated group controller

An alternative is the master-slave configuration, in which there is no separate group controller hardware (see Figure 9.6). In this configuration every lift controller is also capable of acting as the group control. Each lift controller receives all information about new landing (or destination) calls over a network. The lift controller performs its own calculations, providing a bid for the call according to the traffic control algorithm. The master lift control compares the bids and awards the call. If the master lift fails, one of the other lifts automatically takes over the group control functions.

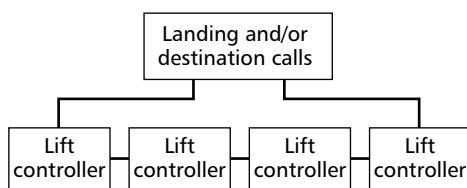


Figure 9.6 Master-slave configuration

Some suppliers opt for a hybrid system combining those of Figures 9.5 and 9.6, with a dedicated group controller, and a back-up on the lift controller boards in case the group controller fails.

With computer-based systems it is relatively simple to provide back-up to normal operation to accommodate failures in the controller which would otherwise cause complete loss of lift service. The first level of group control back-up, however, should never be a 'bus service', where landing calls are ignored and the lifts move continuously between floors, stopping at each floor to pick up any waiting passengers. Back-up service of this kind is inefficient and gives very poor lift service to the building.

It is advisable for a prospective purchaser to determine with their supplier the type of data and control configuration to be supplied.

9.6 Other features of group traffic control systems

There are a number of other features that lift group control systems might provide such as, uppeak service, down peak service, load bypass, heavy demand floors, lobby floor preference service, parking policy, car preference, fire service, etc.

These features are not always necessary or appropriate in many cases. They should be decided at the time of specifying the system to be installed and then discussed with prospective suppliers. Additional costs may be incurred for some of the advanced features.

9.6.1 Load bypass

When a lift fills to its capacity it should not stop in response to further landing calls, as such stops would be useless and particularly annoying to the passengers already in the lift. A load-weighing system is usually available to prevent this. As indicated in chapter 3, larger lifts cannot accommodate the rated capacity as indicated in the standards. For example, if the load detection for a 2500 kg lift were to be set to 60% this would equate to 1500 kg. However, from Table 3.1, a 2500 kg can only accommodate 23.8 passengers. The real 60% value would be equivalent to 60% of 23.8 persons, i.e. 1071 kg. It is important that the load bypass detection is set correctly. (For an example see section 9.9.)

9.6.2 Uppeak service

Most lift group control systems detect and take special action for uppeak traffic conditions. Whilst the uppeak condition applies, as soon as a lift discharges its last passenger on its way upward, as long as there are no down or interfloor calls assigned to the lift, it returns to the main terminal floor.

There are several uppeak detection mechanisms. A common method is based on weighing devices installed in the car floor or by measuring the motor load current as an indicator of loading. When heavily or fully loaded lifts leaving the main terminal floor are detected, the uppeak control algorithm is either selected for a specific time period or until the detected condition has changed. A variation of this method, which is able to cater for slight uppeak situations, detects a lift car load at the main terminal in excess of a predefined level, say 50% or 60%. (Warning: see section 9.6.1 above.) For a certain period of time a parking call is set up at the main terminal to ensure that a lift is available there as soon as possible. Another method counts the car calls registered and initiates the uppeak algorithm when a predetermined number have been registered.

A more sophisticated approach employs an up/down logic counter which increments when loads are above a predefined level, and decrements for loads below this level. Additionally, the counter decrements on a timed basis, say

every 60 s or so, to ensure that the uppeak algorithm is switched off quickly as the uppeak traffic diminishes.

Some systems limit the service to up and down landing calls above the main terminal during uppeak. During uppeak any passenger wishing to travel up from floors other than the main terminal floor should have little difficulty, as the lifts are frequently stopping at the floors, whilst travelling upwards, to discharge passengers. However, passengers wishing to travel down may find a restricted service or no service at all during the 10–15 minutes of heavy uppeak demand. This strategy should be applied with caution. It may increase the handling capacity of the system, but at the expense of very poor performance for outgoing and (down) interfloor traffic, which in modern buildings is significant part of the traffic demand during the uppeak period, see Figure 4.10.

9.6.3 Down peak service

Group control systems frequently include a means of detecting down peak traffic situations, employing similar methods as those used for uppeak detection, but considering heavy loaded lift arrivals at the main terminal floor. Whilst the down peak condition applies, these systems may restrict the service provided to any up traffic and cancel the allocation of lifts to the main terminal, whilst the traffic condition lasts.

Unlike uppeak, where the lifts start and finish their round trips at the main terminal, during down peak lifts can start their journey anywhere in the building before travelling to the main terminal. If the lifts are commanded to travel to a high call reversal floor the lower floors may be starved of service as cars can arrive (or pass by) fully loaded. One system which avoids this groups the down landing calls into sectors and assigns lifts to serve call groups in the sectors in a ‘round robin’ fashion.

9.6.4 Heavy demand floors

Heavy floor demands can occur, for example, at the closing of a meeting or lecture. It is then justifiable to bring extra lifts to the floor to deal with such peaks of demand.

Assuming conventional control, a simple method is to detect at individual floors that a fully loaded lift has left that floor and a new landing call has been registered within 2.0 s (say) for the same direction of travel. The traffic controller can then send free lifts to this floor.

Where controllers use sector-based algorithms the number of landing calls in each sector can be evaluated and compared with the average number of landing calls per sector. A particular sector exceeding the average value by more than a predefined quantity can be set up as a heavy traffic sector. Extra lifts can then be brought to this sector, bypassing the landing calls at other sectors.

9.6.5 Lobby and preferential floor service

The lobby or main terminal floor in a building is normally of great importance, owing to the steady flow of incoming passengers and/or outgoing passengers during some periods of the day. Preferential service is usually provided for these

passengers by parking a lift at the main terminal prior to any other sector. The lobby floor preferential service implies that a slightly poorer service is provided to the remaining floors in the building. The feature is highly undesirable under certain traffic conditions, such as down peak.

A feature called ‘director’ or ‘VIP’ service gives special service to floors where senior executives or directors are located. The lift system can be made to recognise landing calls at such floors and to deal with them with higher priority. Alternatively, key operated switches may be available at these preferred landings or destination entry devices may accept VIP codes, which cause a lift to travel direct to the executive floor bypassing all other landing calls, or a lift may be completely segregated out of the bank of lifts for the directors’ service. It is obvious that this sort of preferential treatment can seriously affect the efficiency of the service as a whole, and it should be avoided whenever possible.

9.6.6 Parking policy

Under light to medium traffic conditions, a lift frequently has no calls to answer. The lift is then free to accept further assignments and, if no further demand exists, it might be parked at its current position, or at a convenient floor, or in a sector in the building zone. The parking procedure is mainly intended to distribute the lifts evenly around the building. A proper parking policy is essential for good lift system performance, particularly in tall buildings. At the design stage a suitable number of floors, in addition to the main terminal floor, should be identified where the lifts may be parked. These could include, for example, basement areas, leisure, restaurant and facility floors.

9.6.7 Car preference

When a lift is taken out of normal passenger control to be exclusively operated from the inside of the lift, it is said to be in ‘car preference’, also referred to as independent service, emergency service or hospital service.

One method is to make the transfer by a key operated switch in the lift, which causes the doors to remain open until a car call is registered for floor destination. All landing calls are bypassed and car position indicators on the landings for the lift are not illuminated. The removal of the key, when the special operation is complete, returns the lift to normal control.

Another method is for the authorised user to enter a code and/or other security device into a destination entry device which can then prompt the user for which car is to be put into independent service.

Car preference may be useful to give a special personal service, or for an attendant to have complete control of the lift, whenever it is required. A typical example is in hospital buildings, where lifts for carrying beds and stretchers require the provision of a car preference switch.

9.6.8 Fire and evacuation service

Some lifts may be designed as firefighters lifts (to BS EN 81-72 (BSI, 2015)) or the older (now obsolete) ‘firemans’

lifts and special recall features are provided. Some lifts may be designated as evacuation lifts provided to allow the safe egress of persons with mobility problems. These are complex areas (see chapter 6) and expert assistance should be sought. BS EN 81-73 (BSI, 2005) defines the behaviour of a lift in the event of fire.

9.6.9 Other facilities

Some lifts may be designated to provide service to persons with disabilities to BS EN 81-70 (BSI, 2003), see chapters 6 and 11. This is also a complex area and expert assistance should be sought.

The provision of suitable indicators, lanterns and gongs to indicate lift arrivals and direction at landings, their direction and floor indication in the car and other landing and in-car announcements are important to ensure improved passenger communication. These can require special interfacing to the group control system.

Another useful feature is the provision of anti-nuisance devices to ensure that a lift does not answer car calls if it is empty. This avoids unnecessary car trips and stops due to a practical joker who registers car calls sometimes pressing or touching all the car pushbuttons and then leaving the lift.

Other features which improve the efficiency of people movement which should be considered are:

- adjustable car and landing call door dwell times
- differential door timing
- limiting the number of door re-opening sequences on the re-registering of a landing call at a floor where a lift is about to depart
- adjustable sound levels on gongs at all floors and in-car voice announcements
- easily seen and brightly illuminated position indicators on landings and in the back and the front of the car
- advanced door opening at landings
- multiple car operating panels (COPs) in large lifts
- combining security checks and lift service requests in hall call allocation systems.

Early call announcement (eca) is a feature popular in some Asian countries. With eca, the assignment of a lift to a landing call is immediate and fixed. This allows the gong and directional indicator of the assigned car to be announced immediately. The traffic control system cannot change its assignment when other passengers introduce new calls; this degrades service. However, early announcement of the call helps efficient loading as passengers have more time to reach and stand in front of the assigned car.

9.7 The effect of the traffic control algorithm on traffic design

9.7.1 Introduction to uppeak boosters

Chapters 3 and 4 indicate traffic design methods to size an installation to meet the expected passenger demand. Chapter 3 dealt with methods, which were independent of the traffic control system used. The simulation methods outlined in chapter 4, however, allow an actual traffic control system to be simulated against a defined passenger demand.

Owing to the fact that the uppeak traffic has, in the past, usually been the most demanding type of traffic for lift systems, most traditional algorithms are built around that type of traffic. Moreover, much of the terminology and the methodology used in lift design still rely on the concept of meeting a heavy uppeak influx over a period of five minutes by circulating lifts at the main terminal, delivering the passengers and returning the lift to the main terminal. Nowadays the lunchtime period is often the most severe traffic condition.

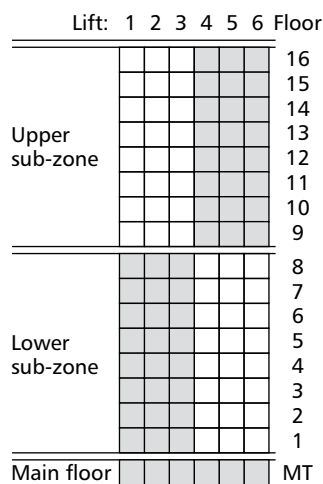
Sometimes the traffic designer specifies too few lifts, or the architect is unable to provide sufficient space for the number of lifts required, or the building population increases and the installed lift system cannot handle the uppeak traffic demand. Several techniques (Barney, 1992) are available to improve the uppeak handling capacity of an installation, which are sometimes called uppeak 'boosters'. The main techniques available are uppeak subzoning, uppeak sectoring and hall call allocation (destination control) and these are available from many manufacturers. Discussions should be carried out with the manufacturers at the design stage in order to determine the most suitable type for a particular installation.

9.7.2 Uppeak boosting by subzoning

In subzoning systems, the building zone is divided into two subzones and the lift group is divided into two subgroups for the duration of the uppeak period. The cars are permanently allocated to a subzone and passengers are directed to the subgroup which serves their floor by illuminated signs. The subzones may not contain equal numbers of floors, nor may equal numbers of lifts serve each subzone, see Figure 9.7. The technique works well with at least six lifts in the group and is available from a number of lift manufacturers.

9.7.3 Uppeak boosting by sectoring

Uppeak subzoning can be extended by dividing the building into more than two sectors to provide an uppeak sectoring traffic control system (Powell, 1992). The number of sectors can be made equal to (or slightly less than) the number of lifts. Each sector generally contains the same number of floors, except the highest may have less floors and the lowest may have more floors. The number of floors in each sector is small, e.g. 3/4/5, and consequently the round trip time is reduced and the handling capacity



Shaded areas indicate the floors served

Figure 9.7 Illustration of uppeak subzoning

increased. An illustration of the uppeak sectoring system is shown in Figure 9.8.

Lifts controlled under an uppeak sectoring traffic algorithm are not permanently assigned to a specific sector. As lifts arrive at the main terminal floor they serve the sectors in a strict 'round robin' fashion. Passengers normally have to wait longer for service, but the group interval is smaller. Passengers are directed to lifts serving their floors by destination signs above the lifts. These have to be continually scanned by the passengers until they find a lift serving their desired destination. Where there are more lifts than sectors, it allows some lifts to be travelling back to the main terminal as the others travel up the building. One lift manufacturer formerly proposed this system with mixed results.

9.7.4 Uppeak boosting by hall call allocation

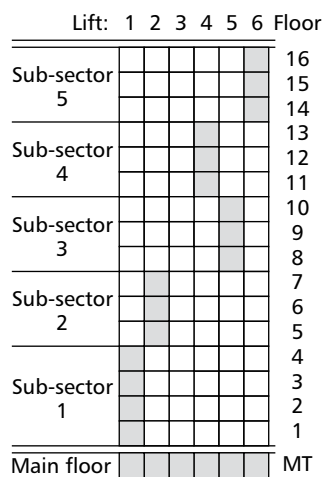
Boosting uppeak performance by basic hall call allocation traffic control (destination control), available from a number of manufacturers (Russett, 2002) has been discussed in section 9.4.2.3.

A further technique with hall call allocation is to use dynamic subzoning. Here the building is divided into two subzones similar to subzoning described above. The boundary of the subzones can change according to the demand to each of the subzones, determined by the individual car loadings. The intending passengers may be unaware of the changing boundary, as they are always told at call registration which lift they are to travel in.

9.7.5 Boosting summary

Uppeak boosters can increase (Barney, 1992) the uppeak handling capacity by approximately:

- 15% using uppeak subzoning
- 40% using uppeak sectoring
- 15% using basic hall call allocation
- 50% using hall call allocation with dynamic subzoning.



Shaded areas indicate the floors served

Figure 9.8 Illustration of uppeak sectoring

However, it is not possible to obtain something for nothing and the increase in handling capacity is usually exchanged by longer passenger waiting times, but not necessarily longer times to destination.

Boosters improve the overall performance of an installation for uppeak, either by increasing the handling capacity with longer passenger waiting times, or by improving the passenger waiting times for the same number of passenger arrivals. However, such techniques do not generally improve the performance of the other major traffic conditions. Their performance may stay the same. Uppeak 'boosters' need to be used carefully and independent expert advice should be sought if such a system is considered.

Calculation methods are available (Barney, 2003) to analyse the four uppeak booster techniques described above and the other traffic conditions (Barney and Dos Santos, 1985). These are, however, only indicative and a better evaluation of the performance of an installation can only be obtained by the use of simulation techniques (see chapter 4). Many manufacturers claim the application of the AI techniques described in section 9.5.1 enhance installation performance for the other traffic conditions. These claims should always be checked by simulation at the design stage. This is a complex area and independent advice may need to be sought.

9.8 Design case study

This case study illustrates how the handling capacity of a lift installation can be increased to meet the changed specification of the occupier.

9.8.1 Background

A developer speculatively built an office block on the assumption that a cellular office layout would be fitted. The building comprised 16 floors above the ground floor with a total net internal area of 14 000 m².

The original lift system was to be designed to the following criteria

- 15% uppeak handling capacity

- a 30-second average interval
- an occupational density of 14 m² net internal area per person.

Thus the design population was 1000 persons ($14000 \div 14$) and the 5-minute peak passenger demand was 150 persons (1000×0.15). The lift system specified comprised six lifts, with 1275 kg rated load, 2.5 m/s rated speed and provided a handling capacity of 147 persons/5-minutes at an interval of 22 seconds. Although the handling capacity is just short of that required the interval is considerably better. The building was to be constructed to accommodate this lift installation.

During construction a tenant became interested in the building, but only if an open plan office arrangement could be accommodated. The tenant measured the net usable area (NUA), i.e. the rentable space as 12000 m² and intended an occupation density of 9 m² NUA per person. This implied a design population of 1333 persons ($12000 \div 9$). However, a more likely peak passenger demand of 13% was proposed. This requires a lift system handling capacity of 173 persons/5-minutes (1333×0.13). Would the lifts cope with the increased demand? The answer is no, as the new demand is approximately 16% larger than the core was designed to handle.

9.8.2 Boosting the lift capacity

It was not possible to add an extra lift and so another solution had to be sought. The extra handling capacity during the morning peak can only be obtained if an uppeak booster is applied. Section 9.7 suggested that uppeak boosters can increase the uppeak handling capacity by between approximately 15% and 50%.

Any of the uppeak boosters can provide a 15% increase and of these the uppeak subzoning system is probably the simplest to adopt. The next decision is should the subzones contain equal numbers of floors, or equal numbers of lifts. The six lifts are arranged as three opposite three leading to the consideration that during subzoning operation they can be easily presented to intending passengers by indicators placed over each sub group of three lifts. In any case a two lift group would provide a very poor interval and in the event of the failure of one would only leave one lift to serve that subzone. Changing the number of floors per subzone also provides a finer adjustment. The next decision is how many floors should be contained in each subzone.

Table 9.1 Comparison of three subzone schemes with underlying installation

Number of floors served	Floor number	Number of lifts	Population served (person)	Handling capacity (person/5-min)	Population served	Interval (s)
16	1–16	3	1000	147	14.7%	22
8	1–8	3	667	101	15.1%	32
8	9–16	3	667	72	10.7%	46
Scheme 1: 8/8 split				Total: 173		
9	1–9	3	750	95	12.7%	35
7	10–16	3	583	72	12.3%	46
Scheme 2: 9/7 split				Total: 167		
10	1–10	3	833	91	10.9%	36
6	11–16	3	500	72	8.6%	46
Scheme 3: 10/6 split				Total: 163		

The logical split would be 8 floors by 8 floors, but it should be remembered that the upper subzone lifts have further to travel before reaching their first served floor than the lower subzone lifts, thus increasing their round trip time and reducing their handling capacity. Table 9.1 below summarises three subzone schemes and compares them to the original design (row 1).

The 8/8 split provides the required handling capacity (173) precisely, but there is a considerable mismatch of percentage population served (15.1%/10.7%). The split 9/7 nearly provides the 13% handling capacity value and only just misses the handling capacity target (167). The final 10/6 split shows deterioration in all criteria. The 9/7 split is preferred even if the intervals (35 s/46 s), as would be expected with only three lifts, are poor. The subzoning solution with a 9/7 split is not ideal, but does provide nearly the handling capacity required.

To implement this solution the traffic controller should detect the onset of the uppeak condition and then split the control system into two groups of three lifts serving the designated floors. Passenger information displays would need to be illuminated to inform passengers the side of the lift lobby to stand, in order to travel to their destination. The service may not be ideal, but the tenant's requirements are almost achieved. Note, however, that the ability to serve mid-day and down peak traffic has not been enhanced to serve the increased population.

9.9 Installation case study

This case study illustrates how a traffic controller can be designed correctly but so badly set up that the installation performs badly.

9.9.1 Background

The building was occupied by a single tenant with a daily population of 1800–1900 persons attending on a flexitime regime. There were 17 floors designated Basement, Ground, Floors 1 to 15, with a restaurant at Floor 1 and office services in the basement.

The lift installation was provided by a reputable, major manufacturer with extensive experience of traffic control algorithms. The lift installation comprised eight, 1250 kg

(16-person) lifts with a rated speed of 2.5 m/s and good dynamic performance.

The building tenant complained that the lift installation was performing badly in the building they occupied. Complaints presented included:

- During the morning arrivals:
 - (a) the lobby 'backed-up' with waiting passengers
 - (b) some cars could only load 10 persons before the overload operated
 - (c) loaded cars did not immediately leave the lobby but continually opened and shut their doors
 - (d) some lifts stopped on the way up for landing calls despite being full
 - (e) when lifts stopped at a floor and no one entered, or left, the lift did not close its doors for eight seconds
 - (f) when lifts stopped at a floor and a person entered, or left, the lift did not close its doors for eight seconds.
 - (g) up travelling passengers entered cars that did not travel up, but down to the basement.
- During the evening departures:
 - (h) lifts arrived at the ground floor with only 5–6 persons exiting
 - (i) long waits were reported at lower floors (Floor 4 reported 10 minute waits)
- During midday period:
 - (j) lifts rarely called at Floor 1
- Generally:
 - (k) passengers hesitated when entering and leaving a car delaying the journey.

9.9.2 Complaint resolution

On investigation it was found that many of the traffic controller features were incorrectly set. The installation maintainer was asked to attend to the following items:

- (1) The load-weighing system for each lift should be calibrated. The lifts are 1250 kg so the overload setting would be 1375 kg. This would deal with complaint (b).
- (2) The load bypass should be set to 750 kg (60%). This means that when more than 10 (average) weight persons are in the car then the lift does not stop for any further landing calls. This would deal with complaint (d). Complaint (h) is resolved by the combination of a well calibrated load weighing (item 1) and correctly set load bypass (item 2).
- (3) The current door dwell times should be reduced and all lifts should present the same times. Car call dwell times should be set to 2.0 s and the landing call dwell times to 5.0 s. This would deal with complaint (e).
- (4) The differential door times should be set to 0.5 s. This would deal with complaint (f).

- (5) The lift doors should re-cycle only once, in order to allow additional passengers to enter, after the first closure of the doors prior to departure. This deals with complaint (c).
- (6) The lifts should be parked whenever they become idle in an even distribution around the building. Two lifts should always be directed to be present at Ground. One lift should be parked at Floor 1. The remaining lifts should be parked at Floors 3, 6, 9, 12 and 15. This would improve the situation with complaints (i) and (j) out of peak times.

Further actions to deal with complaints (a), (i) and (j), i.e. to increase the handling capacity and overall efficiency, would be:

- (7) Each door operator should be individually adjusted to the contract values of door operating times.
- (8) Each drive system should be individually 'tuned' to achieve the contract flight times.
- (9) The uppeak and down peak thresholds (complaint (i)) should be set at three cars leaving/arriving at the Ground floor 60% full.
- (10) The traffic controller should not accept any calls registered on the car operating panel 'behind the car' (car calls for floors already passed). Alternatively at the reversal floor any outstanding car calls remaining should be cancelled.

Complaint (g) can be dealt with by providing large, high illumination direction lanterns and loud gongs on the landing and direction arrows in the back of the car visible from the landing.

Complaint (k) can be dealt with by providing large floor indicators in the cars, audible floor announcements and large visible floor identification signs on the landings visible for the cars.

9.10 Improvement verification case study

A lift installation has been modernised. There have been a number of enhancements, including the application of HCA (destination control) utilising an ETD optimisation algorithm (Smith and Peters, 2008). The client requires the improvements to be quantified so that a report can be presented to the tenants.

The installation includes a data logger that tracks the full life cycle of every destination call starting when it is registered, recording the passenger waiting time when the allocated car arrives, and the time to destination when the journey is complete.

The passenger demand reported by the data logger, see Figure 9.9 can be used as an input to a simulation program.

The simulation program can be used to demonstrate consistency between the simulation and the installed system. If the simulation program also included a model of the old control algorithm, it could be used to demonstrate the performance of the old system with the current demand. Results are plotted in Figure 9.10.

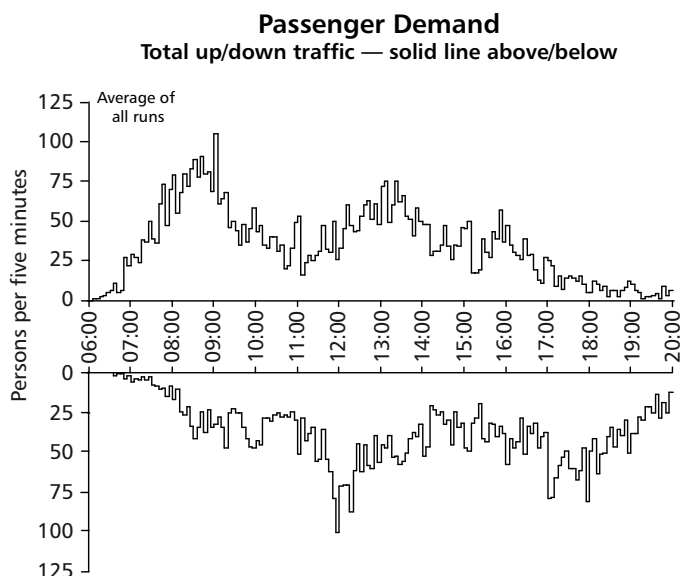


Figure 9.9 Estimated passenger demand for one working day based on data logger

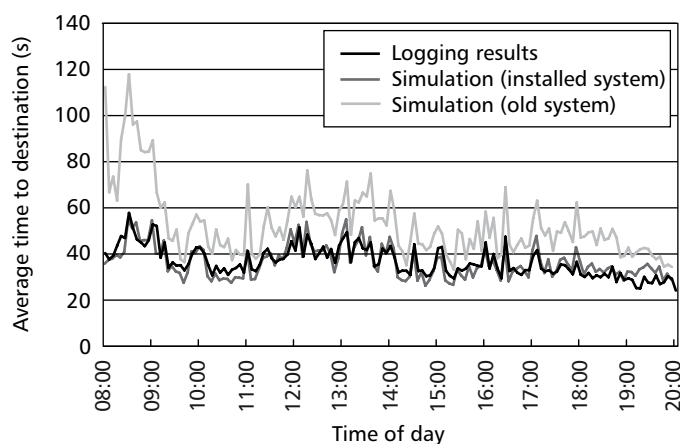


Figure 9.10 Comparison of performance using both data logging and simulation

Daily reporting of passenger demand and lift performance is generated automatically allowing the lift company and building owner to monitor the installation closely. This allows them to act immediately if quality of service deteriorates for any reason other than an increase in passenger demand.

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10 Escalators and moving walks

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10 Escalators and moving walks

10.1 Introduction

Escalators have been in public use since the turn of the 20th century and their derivative the pallet based moving walk since the 1950s. Escalator applications range from low rise installations to accommodate a small change in level within a storey of a building to high rise installations found in locations such as deep underground railways. Inclined moving walks are found in retail premises and transportation facilities, where trolleys need to be accommodated. These two pieces of equipment are installed into a structural opening provided in the building. Horizontal moving walks are typically found in transportation facilities such as

airports and/or retail environments. Horizontal moving walks are installed along wide corridors generally with a fixed walkway alongside. A general arrangement of a typical escalator is shown in Figure 10.1.

With few exceptions, escalators and moving walks are installed for use by the general public of all ages. Therefore, great care must be taken to ensure compliance with all the safety and operating requirements. These are covered in BS EN 115-1 (BSI, 2008a) and BS 7801 (BSI, 2011). Escalators and moving walks are unsuitable for the conveyance of wheelchairs, prams, pushchairs etc., as the risks are considered to be too high. The transportation of shopping/

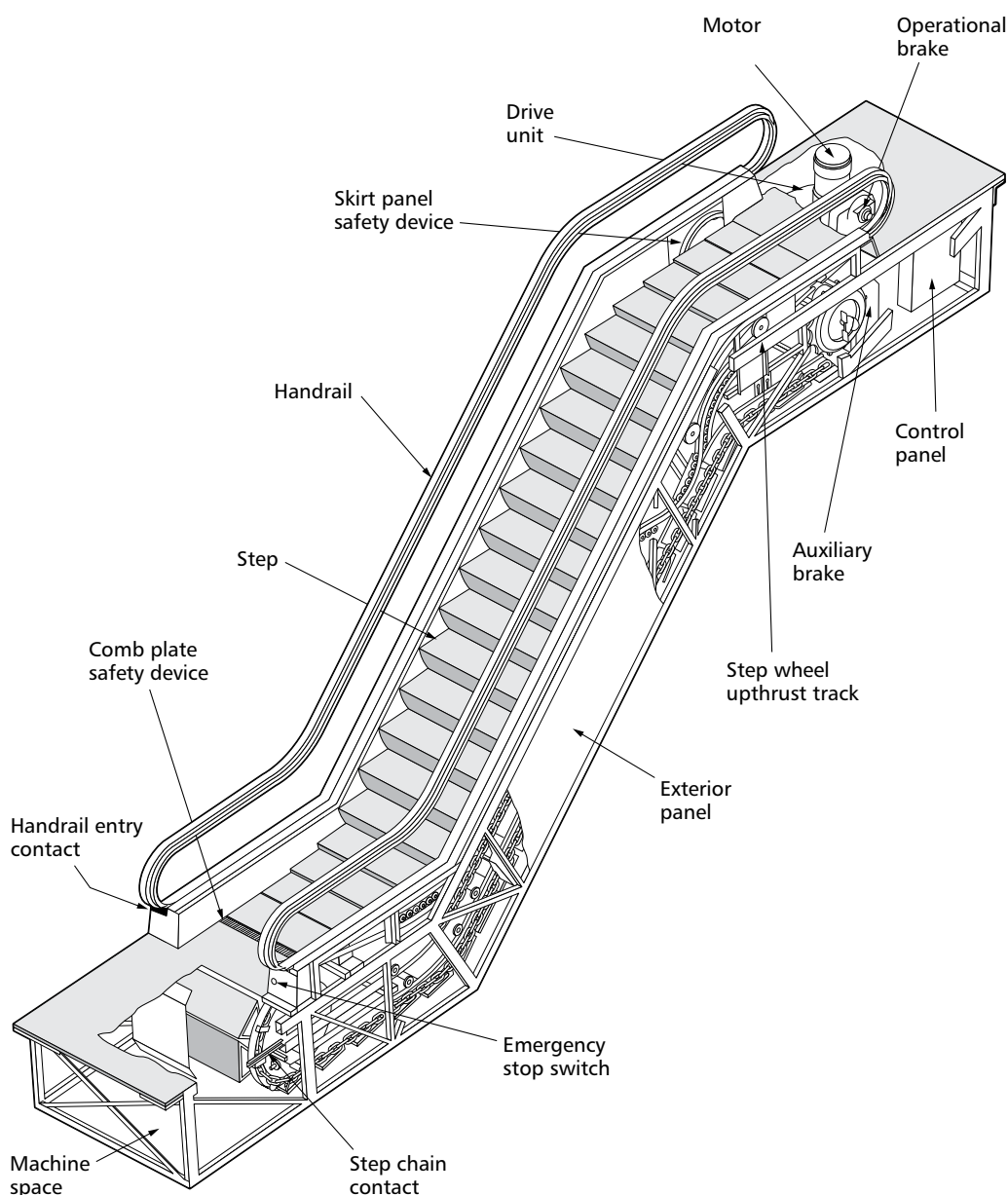


Figure 10.1 General arrangement of a typical escalator

baggage trolleys is not recommended by BS EN 115-1 (BSI, 2008a).

Where escalators are provided, lifts (vertical or inclined) and signage should also be provided, in close proximity to the escalators, for use by individuals who might be at risk to themselves or others when using escalators.

10.2 Definitions, commonly available equipment and duty

10.2.1 Definitions

BS EN 115-1: *Safety rules for the construction and installation of escalators and moving walks* (BSI, 2008a) defines these devices as follows:

- *escalator*: power driven, inclined, continuous moving stairway used for raising or lowering persons in which the user carrying surface (e.g. steps) remains horizontal
- *moving walk*: power driven installation for the conveyance of persons in which the user carrying surface remains parallel to the direction of motion and is uninterrupted (e.g. pallets, belt)

Note the term ‘passenger conveyor’ has been discontinued in favour of the term ‘moving walk’ although some older standards still use the redundant term.

Escalator and moving walks are machines under the Machinery Directive enacted as the Supply of Machinery Regulations 2008 (TSO, 2008) and as such the CE marking is carried out by the supplier by compliance to a harmonised standard or to an EC type examination certificate obtained for a model equipment from a notified body. However, before first use an escalator or moving walk should be tested using BS 5656-1: *Examination and test of new escalators before putting into service. Specification for means of determining compliance with BS EN 115-1 (2008) + A1 (2010)* (BSI, 2013a) or BS 5656-3: *Examination and test of new moving walks before putting into service. Specification for means of determining compliance with BS EN 115-1 (2008) + A1 (2010)* (BSI, 2014a).

10.2.2 Commonly available equipment

There are two types of escalator equipment available. The compact escalator is the most common, where all the drive machinery is located within the truss (structural framework) either in the top machinery space or between the step band. The remote drive escalator is less common and is typical of underground railway systems. Here the drive machinery is located external to the truss in a separate machine room.

Escalators and moving walks are factory built equipment and their characteristics can be closely defined. The most commonly available equipment is as follows:

- (a) Escalator:
 - *Speeds*: 0.5 m/s (also 0.65 m/s, 0.75 m/s)
 - *Inclination*: 30° (an inclination of 35° is permitted for rises ≤ 6 m and rated speeds ≤ 0.5 m/s; however 35° is not permitted in America or Australia)
 - *Step width*: 600/800/1000 mm
- (b) Moving walks:
 - *Speeds*: 0.5 m/s, 0.65 m/s, 0.75 m/s
 - *Inclination*: 0°, 6°, 10°, 12°
 - *Pallet width*: 800/1000/1400 mm for inclination ≤ 6°; 800/1000 mm for inclination > 6°.



Note 1: the maximum inclination of 12° for inclined moving walks was established as the largest safe inclination that most persons could stand on and walk on without overbalancing.

Note 2: moving walks may be adapted to permit the safe transportation of suitable shopping and baggage trolleys, as detailed in annex 1.2 of BS EN 115-1 (BSI, 2008a).

10.2.3 Duty

According to BS 5656-2: *Selection, installation and location of escalators and moving walks* (BSI, 2004), the design of escalators and moving walks falls into four distinct duty categories, as shown in Table 10.1.

Table 10.1 Duty categories of escalators and moving walks

Duty category	Typical usage	Typical locations (passengers per day)
1 Light	Up to 3000	Shops, museums, libraries and leisure facilities
2 Medium	Up to 10 000	Department stores, shopping centres, regional airports and regional railway stations
3 Heavy	Up to 20 000	Major railway and metro stations, major international airports and critical locations such as underground railway systems
4 Intensive	Over 20 000	Ditto



Design tip: when deciding upon the number of escalators in a facility consideration should be given to the impact of failure of an asset and the impact of refurbishment or replacement in future years, i.e. the degraded traffic handling ability during this time.



Design tip: select an escalator or moving walk appropriate for the intended duty. If in doubt specify a more robust machine.

The differences in cost between the categories are significant and care must be taken in assessing the demand, in order to make an appropriate selection to meet the needs of a specific

location. When deciding the duty category, account should be taken of:

- the peak demands that might be made on the equipment
- the number of passengers using the escalator or moving walks per day.

BS EN 115-1 (BSI, 2008a) defines a public service escalator/moving walk. The definition is based on up to 140 hours per week service hours with a load reaching 100% brake loading for a total duration of at least 0.5 hours during any time interval of 3 hours. This type of equipment would fall into duty categories 3 or 4 in Table 10.1.



Design tip: when designing how many escalators are required and their performance criteria, i.e. angle of inclination, speed and width consider the peak loading and consider risks such as overloading, crushing and so on. This can be achieved by undertaking a risk assessment as recommended in BS 5656-2 (BSI, 2004).

10.3 Principal components

Figure 10.1 shows a cutaway view of a typical escalator, showing the passenger and machine sides of the equipment. The machine side is completely enclosed within a steel structure commonly known as the truss.

On the passenger side the machine covers are fitted over the machine spaces at the top and bottom of the escalator. The upper machine space, called the drive station, contains the drive machinery and the lower machine space is the return station. As a boarding passenger passes over the machine covers onto the first escalator step the handrails become available on the top of the balustrade running in the same plane as the steps and at the same speed. The interface between the stationary machine covers and the moving steps is protected by a comb plate, which is intended to prevent any entrapment by deflecting any intruding material, object, or passenger body part. Several flat steps then present themselves to the boarding passenger before the escalator rises, or falls, depending whether it is an up escalator or down escalator.



Design tip: in general, the more flat steps that there are available the easier and safer it is for passengers to adjust their balance from a walking movement to a transported movement. Three flat steps are considered adequate in most locations — space and cost can be a consideration — but four or five flat steps should be considered for high speed and/or high rise public service escalators or when required by BS EN 115-1 (BSI, 2008a) for step speeds >0.65 m/s.

At the bottom of the skirt panels, deflector devices are fitted to deflect any material, object or passenger body parts from being drawn into the gap between the moving step/pallet and skirt panel. Another safety device protects the entry and exit points of the handrail as it appears/disappears into the balustrade.



Warning: most moving walkways do not have deflector brushes. BS EN 115-1 (BSI, 2008a) only

mentions escalators in regard to having them fitted and designers should consider the risk of a wheeled vehicle such as a trolley being used on a moving walk and its ability to rotate, possibly due to contact with the deflector brush, and block egress from the moving pallet band. This situation can cause a build-up of passengers on a moving walk who have no egress route as it is blocked and can result in injury.



Design tip: stop switches for emergency situations should be provided at suitable positions along the length of the escalator. Guidance on the maximum spacing between emergency stop switches is given in BS EN 115-1 (BSI, 2008a).



Design tip: stop switches, and in particular their location, have been the subject of discussion for many years. There is no consistency amongst manufacturers as to where stop switches should be located and there is a debate as to whether making stop switches too accessible causes nuisance operation. It is true to say that studies show that large sites with many escalators suffer from nuisance tripping during school holidays. The SAFed guidelines (SAFed, 2012) recommend that stop buttons be located above handrail height.



Caution: when designing moving walks where it is known that trolleys may be used on them consider installing multiple stop switches such that a person in trouble stuck behind a trolley has access to operate a stop button. When designing moving walks where it is known that trolleys may be used ensure that an additional handrail level emergency stop switch is fitted 2–3 metres before the comb intersections at each landing, as required in Annex 1.2 of BS EN 115-1 (BSI, 2008a).

Some of the machine side components, such as the drive unit, operational and auxiliary brakes, together with other safety devices, are also indicated in Figure 10.1. The principal components of machine side are shown in Figure 10.2 below. In this example, the drive machine is situated outside of the step band to allow ease of maintenance. Power transmission from the machine to the main drive of the step band is normally via a chain. The handrail is driven from the main drive via an automatically tensioned chain. The handrail drive is designed to ensure synchronous handrail and step band speeds. Figure 10.3 provides a balustrade section view, illustrating the relationship of all the components.

The main components of the step and step chain are illustrated in Figure 10.4. Each step is located by an axle. The intermediate wheels ensure that the load is distributed evenly around the curved track section from the incline to the upper landing.

10.4 Installation planning

10.4.1 Specifying the equipment

Although an escalator or moving walk is factory built equipment, there is a large amount of information that

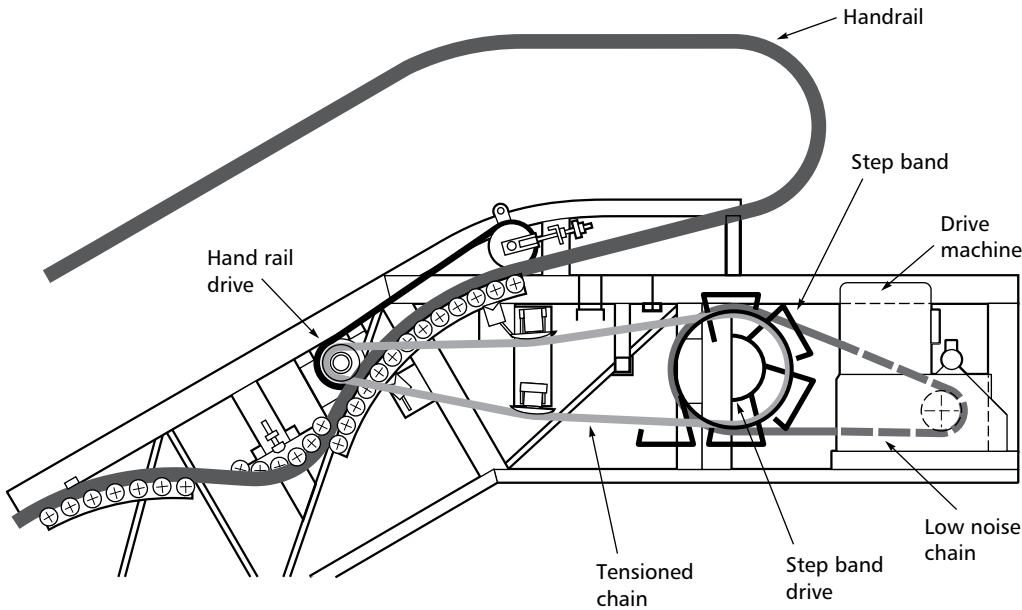


Figure 10.2 Principal components of an escalator drive system

needs to be exchanged. General guidance is given in BS 5656-2 (BSI, 2004) on the procedure and overall chronological sequence to be adopted in obtaining an installation that is satisfactory from the aspects of operation, reliability, safety and maintenance. This code of practice also provides guidance on the exchange of information between the purchaser and the escalator/moving walks supplier. A series of checklists for the various tender documents is given in Annex B to BS 5656-2 (BSI, 2004) detailing the initial exchange of information prior to and at the time of the tender and the contract inclusions and exclusions.

Specialist advice should be sought at the design stage, where unusual environments are likely to be encountered, for example:

- potential exposure to weather
- low/high temperatures and or high humidity
- hosing-down for hygiene or decontamination
- corrosive/dusty atmospheres
- the need for quiet operation
- vandal-prone installations
- transportation of shopping/baggage trolleys (moving walks only).

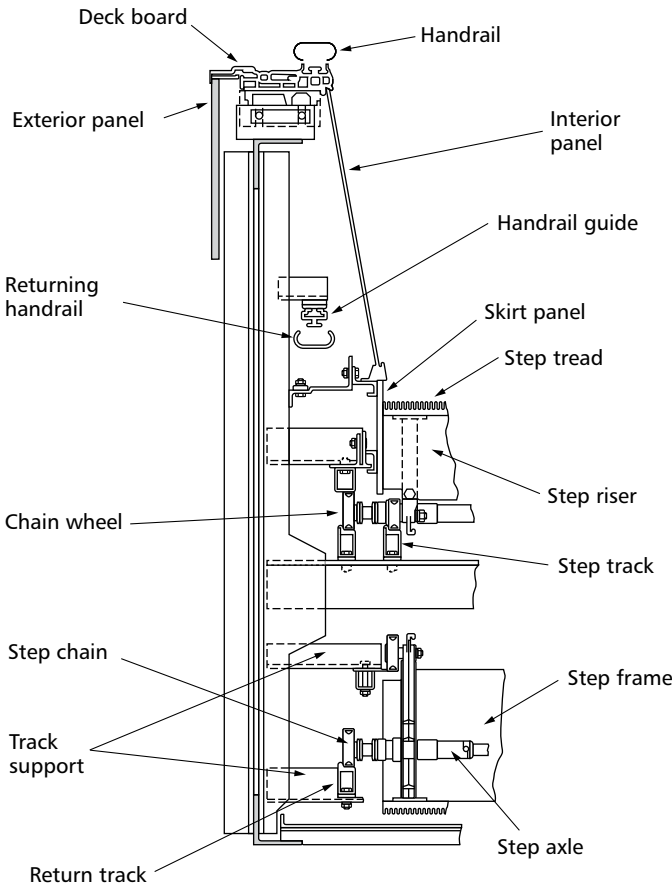


Figure 10.3 Balustrade (section view)

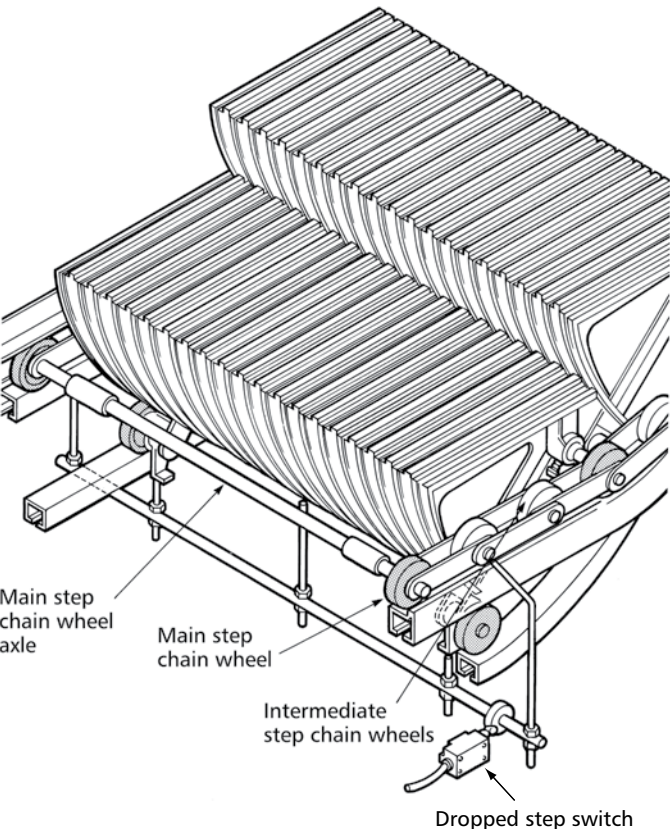


Figure 10.4 Escalator step and step chain details

The installation of equipment in these environments will increase the cost owing to the complications involved.

There are some innovations available since publication of the previous edition of this Guide. These include pit-less moving walks, where a machinery space is not required at either end and the installation can simply be laid on a flat surface and its modular components bolted together. This allows fast installation and reduces the need for major structural works. There are also new designs of moving walks that have extended travel lengths, where the access stage runs at a normal speed and then speeds up to deliver the passenger to a high speed central section. This moves passengers quickly and is attractive to long travel environments such as airports.



Design tip: it is recommended that a risk assessment in accordance with BS 5656-2 (BSI 2004) be undertaken prior to installation. This should assist in eliminating or making manageable risks such as wet environments, risk of falling into voids etc.



Design tip: where other services such as lighting, speakers and cameras are located above escalators the designer should consider how these can be safely accessed, maintained and replaced.



Caution: when installing escalators or moving walks in airy environments where voids exist and therefore the risk of a fall, it is recommended that the lower angle of inclination of 30° be specified. It is also recommended that a handrail height of 1100 mm be selected rather than the lower permissible values. This will help in minimising the risk of a fall over the side of an escalator or moving walk.



Design tip: the installation of escalators or moving walks in suspended voids is often specified by the architect. It is recommended that, where voids are going to exist, escalators be positioned such that a fall through several floor levels can be eliminated. By reducing the height of a fall the risk of death or serious injury can also be reduced.

It should be borne in mind that the design, installation and maintenance of escalators and moving walks is always subject to risk assessments being carried out and their installation will be subject to the CDM Regulations (TSO, 2015).

10.4.2 Traffic sizing

The number, speed, step/pallet width can be determined using the procedures and information in sections 2.4.4, 2.4.5 and 2.5.3(d) to meet the expected traffic demand.



Design tip: it should be noted that the theoretical passenger handling capacity of escalator installations has been downgraded from those stated in BS EN 115-1 (BSI, 1995) with the introduction of BS EN 115-1 (BSI, 2008a). Comparative capacities, which have been significantly reduced, are shown below.

Table 10.2 Theoretical handling capacities as stated in BS EN 115-1: 1998 and BS EN 115-1: 2008

Step width (mm)	Handling capacity (person/h) for stated contract speed (m/s)		
	0.5	0.65	0.75
(a) BS EN 115-1: 1998: clause 3.8			
600	4500	5850	6750
800	6750	8775	10125
1000	9000	11700	13500
(b) BS EN 115-1: 2008: Annex H			
600	3600	4400	4900
800	4800	5900	6600
1000	6000	7300	8200

10.4.3 Location

The location of escalators and moving walks is fully discussed in chapter 2, section 2.7.

Care must be taken to ensure that the alighting areas are not obstructed by either fixed furnishings or by alighted passengers whose departure from the alighting area is also obstructed, e.g. due to pedestrian traffic flow or the succeeding area being too small. The full traffic function must be considered particularly in intensive traffic locations. Particular care should be taken not to obstruct the clear unrestricted area according to BS EN 115-1 (BSI, 2008a), where successive escalators and moving walks are installed.

Clear areas are specified in BS EN 115 (BSI, 2008a) and particular attention is drawn to clause 7.3 of BS 5656-2 (BSI, 2004) where specific risks associated with environment are considered.

10.4.4 Aesthetic design

Escalators and moving walks are not enclosed like lifts and most of the equipment is in the view of the public. They offer considerable scope to the designer for the imaginative use of glass, cladding and polished metal finishes. Careful design of the lighting may also enhance the appearance. However, consideration must also be given to the following:

- Designs that create voids at the sides of the equipment or gaps between equipment such as where equipment is located in atria should be avoided where possible but managed by design risk assessment as a minimum as these present a risk of falling or entrapment to users.
- Coloured handrails require regular cleaning, using special materials, at least every two weeks if the appearance is to be preserved. Black handrails are less attractive but more practicable for public usage.
- Where glass balustrades are installed close to a wall, rubbish will collect in the space between the wall and the balustrade. This will be difficult and expensive to remove.
- Stainless steel does not suffer damage by scratching from shoes, luggage etc. and is therefore an appropriate material for intensive duty applications.
- Ambient temperature can also be a factor which affects passenger comfort and handrail reliability.

- In some recent designs, the moving equipment is observable through glass cladding. This is very effective when the escalator is lit internally, but the difficulties of cleaning the glass (externally and internally) and the equipment must be considered.
- Some manufacturers have developed curved escalators (see Figure 10.5)

10.4.5 Safe use of escalators and moving walks

The following features are some of the safety features which should be included to assist passengers in their safe use of modern escalators and moving walks:

- Yellow lines on steps: the border of the step is painted with a yellow line. This enables visually impaired passengers to see the step border and enables them to stand ensuring their feet don't straddle consecutive steps and consequently risk falling as the steps form in the transition areas. They also encourage passengers to keep their feet away from the step sides and rear edge, thereby reducing the risk of entrapment.
- Brush guards: installed above the edges at the sides of the step, and fixed to the skirting. They are effective in reducing passenger entrapments. Brush guards are not recommended on moving walks where trolleys are used as they present a hazard.
- Yellow spots on handrails: these help visually impaired passengers see the moving handrail.
- Adequate permanent lighting at the landings of at least 100 lux.
- Safety signs and warning notices to Annex G of BS EN 115-1 (BSI, 2008a)
- Guards: end barrier, intersection, outer decking, etc.

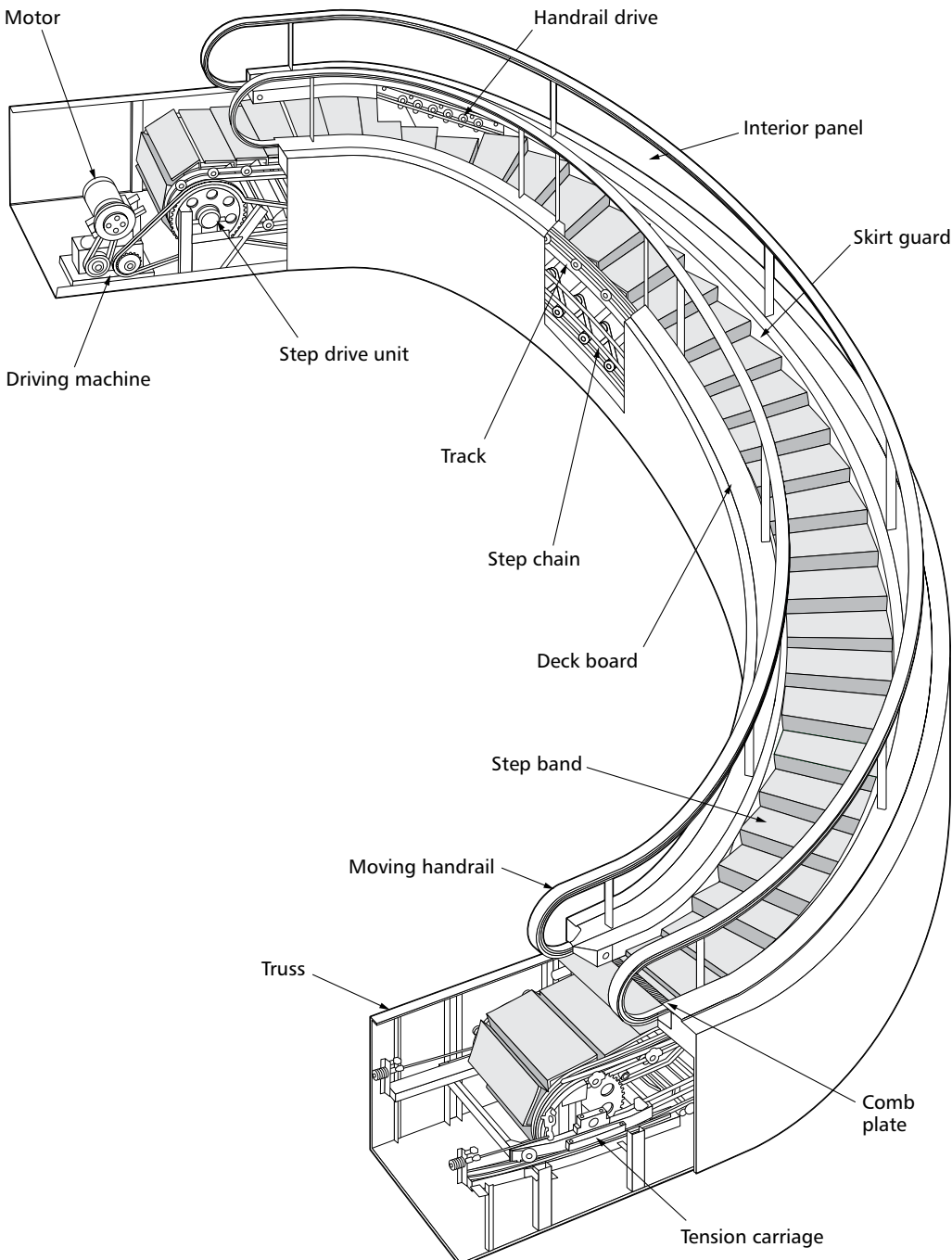


Figure 10.5 Curved escalator

- The angle of inclination of the lower inner decking should be greater than 25° and preferably greater than 27° to discourage children from climbing on the panels.
- The guard rails connecting to the escalator/moving walk balustrades should be at least 100 mm higher as recommended in BS EN 115-1 Annex A2.7 (BSI, 2008a) to prevent passengers being drawn into hazardous situations, e.g. where there is a risk of falling into voids.
- Escalators are unsuitable for use as fixed stairs and should not form part of an emergency exit route.

It is strongly recommended that persons using escalators or moving walks do not do so for the movement of goods and materials and that when work is undertaken in the environment around the escalator that ladders, scaffolds etc. are not placed on them.

An assumption has been made that persons using escalators and moving walks are able to do so unaided. However, they are also likely to be used by persons with a range of disabilities. Factors to be considered are:

- speed
- step/pallet width
- inclination
- number of horizontal steps at landings (escalators only)
- handrails
- surface finishes
- controls
- lighting
- signs and information
- landings clear space
- guarding
- environmental surroundings such as mirrors, advertisements
- use of trolleys (moving walks only).

Chapter 10 of BS 5656-2 (BSI, 2004) gives specific recommendations and guidance intended to assist persons with disabilities. These recommendations can also improve the level of safety of other users and improve circulation efficiency.

Where shopping/baggage trolleys are to be transported special measures should be put in place as detailed in Annex 1.2 of BS EN 115-1 (BSI, 2008a). The shopping/baggage trolleys must be specially designed to suit the pallets, such that they can be automatically locked into a safe position. The clear unrestricted area should be extended to 5 metres and additional emergency stop switches placed approximately 2 to 3 metres before each comb intersection. BS EN 115-1 does not recommend the use of trolleys on escalators.

For moving walks the rated speed for inclinations greater than 6° should not exceed 0.5 m/s and they should be fitted with an upper and lower transition curve.

10.4.6 Machine rooms

Machine rooms are required for remote drive escalators. Many of the requirements are similar to those for lift machine rooms. Chapter 5.4 of BS 5656-2 (BSI, 2004) and BS EN 115-1, Annex A.3 (BSI, 2008a) offer guidance.

10.4.7 Electrical supply and electromagnetic compatibility

The supplier should provide details of the full load current, starting current and its duration, maximum permissible voltage drop etc. in order to enable the size of the main supply cable to be determined. The electrical installation should conform in all respects to BS 7671: *Requirements for electrical installations. IET Wiring Regulations. Seventeenth Edition* (BSI, 2008b).

The main supply from the intake room should be separate from other building services. A temporary electricity supply may be required during the installation and its characteristics should be the same as the permanent supply. BS 5656-2 (BSI, 2004) gives further details.

The electrical installations should be in accordance with BS EN 12015 (BSI, 2014b) and BS EN 12016 (BSI, 2013b) to ensure electromagnetic compatibility. Certain locations, e.g. railway systems, have specific electromagnetic compatibility (EMC) requirements.

10.4.8 Noise

The location of escalators or moving walks should be such as to cause minimum noise disturbance, although no equipment can be totally silent or vibration-free in operation. The design of the building is significant in noise and vibration reduction. The walls, floor and ceilings of machinery spaces and machine rooms should be designed to substantially absorb the sound. Beams and structural members should not penetrate into occupied areas. If there is any doubt about the equipment then a similar installation should be checked. If the escalator or moving walks is required to operate to specific requirements this should be agreed at the contract stage. Specialist advice may need to be sought.

10.4.9 Fire protection

When fire protection systems, such as smoke detectors, sprinklers and shutters are required by the relevant fire authority the owner should provide such equipment and any necessary interfaces and arrange for the system to be tested.

Where sprinklers are used special consideration should be given to specifying the appropriate ingress protection (IP) rating of equipment that would be affected by water arising from the sprinklers

Fire shutters are provided by specialist subcontractors. When such devices are installed it is necessary for the escalator or moving walks supplier to include control interfaces to ensure their correct and safe operation.

10.4.10 Installing equipment

Generally an escalator or moving walk is delivered and installed as a single unit. This allows for maximum pre-assembly and testing at the factory, including running-in, and will ensure rapid and efficient installation on site. A typical one-piece escalator unit may be more than 16 m long, 1.6 m wide and 3 m high, and weigh up to 9000 kg. Thus careful planning is essential if costly installation difficulties are to be avoided. Therefore consideration must be given to the following:

- A clear, straight access route onto and across the site must be provided. Normally this should be at least 3 m wide, with a minimum vertical clearance of 3.5 m. Note that the 3.5 m dimension can be reduced for the installation of moving walks.
- Police approval will be needed if unloading is to be carried out on a public highway, including a possible road closure application that may take several weeks to organise due to the need for public consultation.
- Consideration must be given to permitted floor loadings along access route.
- Suitable hoisting points must be provided.

Early planning is essential, particularly in the case of installations in existing buildings.

10.5 Drive systems, energy usage and safety devices

10.5.1 Motor sizing and selection

The sizing of the drive motor depends on a number of factors:

- vertical rise of escalator or travel distance of a moving walks
- escalator or moving walk equipment efficiency
- efficiency of gearbox
- running speed
- angle of inclination of escalator or moving walks
- number of passengers assumed to occupy a step/pallet
- rise of each escalator step.

For an escalator, the required power from the motor depends on nine parameters:

- rise, R_e (m)
- escalator efficiency, η_s (%)
- gearbox efficiency, η_g (%)
- speed, s (m/s)
- inclination, θ (degrees)
- number of passengers, n
- passenger mass, m (75 kg)
- step riser, R_s (m)

— handrail power, p_h (W)

The output power (P) in kW required for the motor is given by:

$$P = \frac{[s m g n (R_e/R_s) \sin \theta] + p_h}{\eta_s \eta_g \times 1000} \quad (10.1)$$

10.5.2 Methods of starting

The majority of systems currently employ induction motors in the drive systems of escalators and moving walks. The drive motors are controlled and started by one of the following systems.

Direct-on-line start (or star-delta)

A star-delta starter is used to start the system and the motor is then directly connected to the supply during service. For maintenance speed, a second slow speed winding in the motor is used, which usually achieves one quarter (25%) of the normal running speed. The motor has two sets of windings, each with a different number of poles (in the ratio of 4:1). The main disadvantage of direct-on-line, or star-delta, systems is the large in-rush current during start up (up to seven times the full load current for direct-on-line and up to 3.5 times the full load current for star-delta), the mechanical shock to the equipment components, the very poor power factor at light loads and poor speed control. These systems are less used nowadays, having been replaced by solid state electronic drives, but are inexpensive to purchase and maintain and appropriate where equipment is switched on/off infrequently.

Inverter (VVVF) drives

There are two types of VVVF drive. Fully rated with regenerative capability or fully rated with dynamic braking resistor.

A VVVF drive, with dynamic braking resistor, uses a fully rated inverter system to start the system and then drive it up to the full speed. Then either the inverter carries on driving the motor or a contactor is used to bypass the inverter. The disadvantage with the former method is that on a heavily loaded downward moving escalator excess generated energy is wasted through the braking resistor, while the disadvantage of the latter is the high changeover current and the resulting jerk in the motor at the moment of changeover.

A feature of VVVF drives is that the speed can be varied to suit a number of different applications, such as a low speed for inspection and maintenance, very low speed for releasing trapped objects from the comb, reduced speed during periods of low or no usage. This has the advantage of reducing the power consumption as well as reducing the wear. The use of an inverter allows imperceptible acceleration and deceleration between the low speed and the running speed.

The advantages of VVVF drives are that they give a very smooth start (reducing the mechanical shock to the equipment components), they run at a very good power factor (even under no load) and they reduce the starting

current to around 1.5 times the full load current. Another advantage is that there is no need to use a pole changing two speed motor to achieve maintenance speed, as this can be done via the inverter. The main disadvantages of VVVF drives are that they occupy more space, need extra maintenance (the capacitors in VVVF drives have a limited lifetime), and generate extra heat that needs to be removed from the machinery space.

Where VVVF drives have been supplied certain suppliers make use of this facility in the braking system. The advantage of VVVF braking is that the deceleration is very smooth and the stopping distance can be controlled independent of the number of passengers on the escalator.

Soft starters

Soft starters employ power electronics (usually three pairs of back-to-back thyristors) to bring the system up to full speed, after which the thyristors are bypassed by a contactor that puts the motor direct-on-line. The in-rush current is about 1.5–2.5 times the full load current. However, for maintenance speed, there still is a need for a pole changing, two-speed motor. These systems are simple and provide a smooth start, but have a very limited functional capability compared to VVVF drives.

10.5.3 Modular escalator drives

A problem with escalator traffic is that it varies widely during the day. There are periods in the day when no one uses the escalator at all, although the escalator has to be kept running. At other times of the day, during peak periods, the escalator is heavily loaded. The motor has to be sized to cope with the maximum demand. This results in the fact that during low usage periods, the motor will run very lightly loaded. This is undesirable, as the efficiency of the system is very low under these conditions. As an answer to this problem, some companies have developed a modular drive system, which employs two or three motors coupled to the same gear box. This type of drive system is particularly appropriate for intensive duty underground railway and other transport system. The control system detects the level of loading and operates as many motors as is needed. In this way the efficiency of the system is kept high enough and the power factor does not drop to unacceptable levels. It also allows energy reduction, improved efficiency and extended life for the motors.

10.5.4 Energy usage

Manufacturers can provide figures for the energy consumed by an escalator or moving walk. Chapter 13 gives information regarding escalator and moving walks energy consumption. The type of operating control employed has an effect on energy usage. There are three types of control option: continuous, variable speed and on demand.

Continuous operation

The escalator or moving walk operates continuously at a single speed with the starting and stopping carried out manually.

This type of operation would be suitable for locations where there are continuous traffic flows.

Variable speed operation

A common method used to reduce losses is the reduction in the speed of the escalator or moving walk during periods of inactivity. The change of speed is initiated by the use of a passenger detection system such as pressure mats, photocells or passive infrared beams. The equipment reverts to its highest speed when sensors (switches under mats at landings, photo-sensors on newels, etc.) are activated by passengers on the approaches. The advantage of a system that the equipment slows the speed down in contrast to stopping is that passengers are aware of the direction of travel of the equipment, when approaching, and there is no risk that they would think that the equipment is out of service.

When the equipment changes speed after periods of low passenger activity, it is important that the transition be smooth in order to prevent passenger falls. An advantage of VVVF drives is that they provide a very smooth transition between speeds.

This type of operation would be suitable for locations where there are periods of time when there is no passenger demand.

On-demand start

The escalator or moving walks is available for use in a pre-determined direction of travel and automatically starts operating as a result of passenger demand. After a period of no passenger flow the equipment stops automatically. The starting is initiated by the use of a passenger detection system such as pressure mats, photocells or passive infrared beams. The direction of operation has to be clearly marked for the user, e.g. traffic lights at each landing.

This type of operation would be suitable for locations where there are long periods of time where there is no passenger demand.

10.5.5 Safety devices

Although modern escalators and moving walks employ electronic control, the safety line is still retained. All electrical safety devices are wired in series, forming the so-called 'safety line' or 'safety chain'. All safety devices should act directly on the final contactors, as stipulated in BS EN 115-1 (BSI, 2008a).

The concept of a separate safety line is quite important in escalators because it removes the safety critical elements from the electronic programmable systems and puts it in a separate hard-wired configuration.

Each component monitoring a safety function is called a safety device. Table 10.2 shows all events causing automatic stopping of the escalator. Some of them are not safety devices. Moreover, some of them need to be reset before the escalator can be re-started.

Today, escalators and moving walks are generally controlled by microprocessor and solid-state devices, replacing the relay controllers used in the past. These programmable electronic devices should provide the same level of safety and in the case of failure, the system should always revert to a safe state.

Table 10.2 Events causing automatic stopping of an escalator

Description	Safety device	Self-resetting
No control voltage		•
Earth fault in electrical safety device circuit		•
Motor overload	•	
Motor windings over temperature		•
Overspeed	•	
Unintentional reversal of direction	•	
Operation of auxiliary brake	•	
Breakage or elongation of step, etc.	•	
Reduction of distance between stations	•	
Entrapment of foreign bodies at comb	•	
Stopping of succeeding escalator	•	
Operation of handrail entry guard	•	
Operation of sagging step detector	•	
Broken handrail	•	
Missing step detection	•	
Brake not lifting	•	
Handrail speed defect	•	
Open inspection cover		•
Exceeded stopping distances	•	
Installation of hand winding device	•	

10.6 Modernising escalators and moving walks

Where possible when escalators and moving walks are modernised it is recommended that they be brought up to the requirements of BS EN 115-1 (BSI, 2008a). Guidance can be found in BS EN 115-2 (BSI, 2010) about improving safety of existing units.

 *Design tip:* designers should be aware of CEN standard PD CEN/TS 115-4 (BSI, 2014c), which deals with interpretations related to the EN 115 family of standards.

It is good practice when modernising an existing escalator or moving walk to try and bring the unit up to the prevailing manufacturing standard at the time of undertaking the work. In some cases it may not be possible to achieve this but every attempt to do so would be applauded. If there is some reason that affects safety that cannot be achieved clear minuted debate should take place. Safety improvements in recent years include missing step detection and this exists to prevent an escalator running with a step missing, which could cause an accident to a passenger.

There are some innovative designs available when modernising and escalator or moving walk. One manufacturer has developed a system of installing a new truss within the old truss such that an escalator or moving walk can be delivered as a compact design that may be simply lifted into position. This makes for a speedy

operation that is attractive when a unit being out of service can be disruptive. Many heavy-duty machines are bespoke modernised on a component by component basis. This is a time consuming process that is witnessed at many transport environments such as railway or underground stations.

10.7 Testing and commissioning

A more detailed explanation of testing and commissioning requirements can be found in chapter 15.

For escalators it is recommended that BS 5656-1: *Examination and test of new escalators before putting into service. Specification for means of determining compliance with BS EN115-1 (2008) + A1 (2010)* (BSI, 2013a) be adopted.

For moving walks it is recommended that BS 5656-3: *Examination and test of new moving walks before putting into service. Specification for means of determining compliance with BS EN115-1 (2008) + A1 (2010)* (BSI, 2014a) be adopted.

10.8 Operating escalators and moving walks

Safe methods of operating and managing escalators and moving walks can be found in the SAFed publication *Guidance for the safe operation of escalators and moving walks* (SAFed, 2012). Owners of escalators and moving walks have a duty of care to passengers, employees and themselves in general law to make sure that such installations are maintained in a safe condition. Simple checks can be undertaken on a routine basis, generally when restarting the unit, to try and identify any potential defects. A person need not be technically competent to notice scrape marks, gaps, strange noises, splits in handrails etc. and a regime of regular checking, supported by retaining documentary evidence, often assists the asset owner in demonstrating their duty of care.

In addition staff should be trained in starting, stopping and noting operational problems such as unattended children entertaining themselves on the unit.

Records and documentation that should be kept to demonstrate that the duty of care has been professional performed include:

- user information and documentation
- risk assessments
- staff training
- periodic thorough examinations
- supplementary tests
- maintenance records
- daily/weekly/monthly user checks
- accident reports/record
- action taken in the event of a defect being reported.

10.9 Actions after an incident involving an escalator or moving walk

Actions to be taken when escalators and/or moving walks are involved in an incident or accident can be found in SAFed publication *Guidance for the safe operation of escalators and moving walks* (SAFed, 2012)

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) (TSO, 2013) make provision as to incidents that must be reported to the enforcing authorities and the procedures required for this. This extends to certain incidents including those to persons who are not at work. Guidance is available on the HSE website (www.hse.gov.uk/riddor), which also lists the types of accidents that need to be reported and how they can be reported.

10.10 Escalator or moving walks and LOLER

Escalators and moving walks are not considered to be lifting equipment and are specifically exempted from periodic thorough examination under the Lifting Operations and Lifting Equipment Regulations (LOLER) (TSO, 1998). SAFed guidance (SAFed, 2012) recommends periodic thorough examinations take place to ensure that the unit is adequately maintained. If a safety device is found to be defective the unit should be removed from service until such time as it is made safe. The safety devices exist for a reason and it should therefore be verified that they are working properly at the time of each service and periodic thorough examination.

References

BSI (1995) BS EN 115: 1995: *Safety rules for the construction and installation of escalators and passenger conveyors* (London: British Standards Institution)

BSI (2004) BS 5656-2: 2004: *Escalator and moving walks. Safety rules for the construction and installation of escalators and moving walks. Code of practice for the selection, installation and location of new escalators and moving walks* (London: British Standards Institution)

BSI (2008a) BS EN 115-1: 2008 + A1: 2010: *Safety of escalators and moving walks. Construction and installation* (London: British Standards Institution)

BSI (2008b) BS 7671: 2008 + A3: 2015: *Requirements for Electrical Installations. IET Wiring Regulations* (London: British Standards Institution)

BSI (2010) BS EN 115-2: 2010: *Safety of escalators and moving walks. Rules for the improvement of safety of existing escalators and moving walks* (London: British Standards Institution)

BSI (2011) BS 7801: 2011: *Escalators and moving walks. Code of practice for safe working on escalators and moving walks* (London: British Standards Institution)

BSI (2013a) BS 5656-1: 2013: *Safety rules for the construction and installation of escalators and moving walks. Examination and test of new escalators before putting into service. Specification for means of determining compliance with BS EN 115-1:2008+A1:2010* (London: British Standards Institution)

BSI (2013b) BS EN 12016: 2013: *Electromagnetic compatibility. Product family standard for lifts, escalators and moving walks. Immunity* (London: British Standards Institution)

BSI (2014a) BS 5656-3: 2014: *Safety rules for the construction and installation of escalators and moving walks. Examination and test of new moving walks before putting into service. Specification for means of determining compliance with BS EN 115-1:2008+A1:2010* (London: British Standards Institution)

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11 Transportation facilities for people with disabilities

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11 Transportation facilities for people with disabilities

11.1 Access for everyone

'Accessibility enables people, including persons with disability, to participate in the social and economic activities for which the built environment is intended.'

(BS EN 81-70, Annex A (BSI, 2003a))

Transportation systems in buildings should provide independent and equal access for everyone. This chapter provides general guidance. It cannot be specific and attention is drawn to the references for further information. Expert assistance may be needed to deal with particular situations.

In general facilities designed to permit their use by disabled people assist able bodied people in their use. BS 8300: *Design of buildings and their approaches to meet the needs of disabled people. Code of practice* (BSI, 2009) gives valuable general guidance. Building Regulations Approved Document M: *Access to and use of buildings* (NBS, 2013) recommends that planning applications include an Access Statement (DRC, 2004) to indicate how people access any new building or extension to an existing building, and this should indicate any provision of building transportation systems.

11.2 Disability or Impairment?

Many people suffer from a disability (see BS EN 81-70, Annex B (BSI, 2003a)) or impairment. Examples include:

- (a) *Physical disability*: people who are unable to use stairs, or negotiate a (step) change in level due to:
 - a temporary mobility impairment, e.g. a broken leg
 - a permanent mobility impairment, e.g. loss of the use of a lower limb
 - limited range of movement and weight-bearing ability, e.g. arthritis
 - reduced strength and endurance, e.g. as a result of a heart or lung complaint.
- (b) *Sensory disability*: people who have sensory limitations due to:
 - impaired vision
 - impaired balance
 - impaired hearing.
- (c) *Intellectual disability*: people who have cognitive impairments due to:
 - learning difficulties
 - intellectual deterioration.

The motor and sensory abilities in a population can vary over a wide range. Transportation facilities in buildings are likely to be used by persons with a range of disabilities. Some individuals, in particular older people, may have more than one impairment. Some individuals are not able to use transportation facilities unaided and rely on assistance/support being provided by a companion or carer. Some individuals can be handicapped by objects they are carrying, or be responsible for other persons, which can also affect their mobility. The extent to which an individual is incapacitated by impairments and encumbrances often depends on the usability of the equipment provided. The most important issue to take into account during the selection and installation of transportation equipment is their safe use by all persons.

11.3 Summary of the Equality Act 2010

The majority of the provisions in the Equality Act 2010 (TSO, 2010) came into force from 1st October 2010, when the relevant provisions of the Disability Discrimination Act 1995, as amended by the Disability Discrimination Act 2005, were repealed.

Under the Equality Act 2010 providers are required to make reasonable changes, where needed to improve service for disabled people. There is a legal requirement to make reasonable changes to the way things are done (such as changing a policy); to the built environment (such as making changes to the structure of a building to improve access); and to provide auxiliary aids and services (such as providing information in an accessible format, e.g. an induction loop for customers with hearing aids or special computer software).

Reasonable changes are required wherever disabled persons would otherwise be at a substantial disadvantage compared to non-disabled people.

The Equality Act 2010 requires that providers must think ahead and take steps to address barriers that impede disabled people.

What is reasonable will depend on many circumstances including:

- the cost of an adjustment
- the potential benefit it might bring to others for example, ramps and automatic doors benefit people with small children or heavy luggage
- the resources of an organisation
- how practical the changes are.

11.4 Building Regulations Approved Document M

Approved Documents provide practical guidance to the requirements of the Building Regulations 2010. There is no obligation to apply the guidance if the relevant requirements for access can be met in some other way. The argument supporting any alternative solution to those given in Approved Document M (NBS, 2013) should be made in the Access Statement. Approved Document M: *Access to and use of buildings* (ADM) (also known as 'Part M'), came into effect on 1st May 2004 and now incorporates amendments from 2010 and 2013. It is in the hands of many professionals (architects, developers, designers, surveyors, chartered engineers, etc.), who faithfully follow its guidance. Amongst its guidance (on steps, ramps, stairs, handrails, lobbies, sanitary accommodation, etc.) vertical circulation is considered in clauses 3.17–3.49 of ADM for 'buildings other than dwellings', and in section 9 for passenger lifts and common stairs in blocks of flats.

ADM states that 'the objective is for people to travel vertically and horizontally within buildings conveniently and without discomfort in order to make use of the facilities'. The services provided should accommodate all disabled people, not simply those with a mobility problem. ADM ranks the equipment provision in public buildings with the order of preference — passenger lifts, lifting platforms, wheelchair platform stairlifts — as follows:

- For all buildings, a passenger lift is the most suitable form of access.
- For existing buildings, and in exceptional circumstances where a passenger lift cannot be accommodated a vertical lifting platform may be considered.
- In exceptional circumstances in an existing building, where the site or location is unsuitable for a passenger lift or lifting platform, a wheelchair platform stairlift may be considered.

A passenger lift is the most suitable means of vertical access for all and should be provided wherever possible. However, given the space constraints in some buildings, it may not always be possible to install the type and size of passenger lift that would be suitable for use by all mobility-impaired users and other options may need to be provided. The case for using each lifting device should be argued in the Access Statement (DRC, 2004).

For buildings containing flats, ADM recommends that the most suitable means of access is a passenger lift.

11.5 Equipment selection to meet user needs

The selection of the equipment to meet the needs of people with disabilities should be carefully considered to ensure it is appropriate and meets the needs of the user(s). Below are some important considerations.

11.5.1 Existing and future user needs

When selecting a lift, lifting platform or stairlift, both the existing and the future needs of the user(s) should be considered. This is important in a domestic environment, as people age and become less capable, or where a disability becomes more severe. Therefore, the installation of a seated stairlift might be unsuitable, should the user later become dependent on a wheelchair. In non-domestic environments, the use of the building can change significantly over its life affecting the facilities to be provided.

11.5.2 Rated load

If a lifting device is not dedicated to a particular user the foreseeable load may be difficult to predict. When considering foreseeable loads notice should be taken as to whether a travelling companion (attendant) is to be accommodated, what type of wheelchair might be used and if any medical or other equipment is to be carried.

The following are minimum rated load recommendations:

- 450 kg for passenger lifts for a lone user without an attendant (BS EN 81-70 (BSI, 2003a))
- 630 kg for passenger lifts for a wheelchair user and an accompanying person (BS EN 81-70 (BSI, 2003a))
- 205 kg for a lone user either standing or in a type A wheelchair on a lifting platform (BS 6440 (BSI, 2011))
- 280 kg for a type A or type B wheelchair user with an attendant on a lifting platform (BS 6440 (BSI, 2011))
- 250 kg for a type A or type B wheelchair user on a wheelchair platform stairlift (BS EN 81-40 (BSI, 2008a))
- 115 kg for a seated or standing lone user on a stairlift for private domestic use: (BS EN 81-40 (BSI, 2008a))



Note: the definition of type A and B wheelchairs can be found in section 11.5.9.

11.5.3 User position

An ambulant disabled person may stand or sit and may be using a walking aid. It should be noted that some users with walking aids cannot easily turn through 180°. Other users may be seated in a wheelchair. It is important to ensure that the user(s) can be safely transferred on and off the lifting device.



Note: chair and standing platform stairlifts are unsuitable for use in public access situations

11.5.4 Entrance facilities

Access to and from the lifting device, together with manoeuvring space at the entrances of the lifting device, should be carefully considered. Manual or automatic operation may need to be available for doors, wheelchair stairlift barriers, folding platforms and barriers or gates to open lifting platforms. Where lifting platforms with non-enclosed liftways are provided in public access situations,

interlocked gates to the platform and upper level landing must always be provided, see section 11.7.3.2.

11.5.5 Control devices

Consideration should be given to the position, type and number of controls that would suit users with differing disabilities.

For lifting platforms, control devices should conform to the requirements of BS EN 81-41 (BSI, 2010) for enclosed lifting platforms and to BS 6440 (BSI, 2011) for non-enclosed lifting platforms.

For stairlifts, control devices should conform to the requirements of BS EN 81-40 (BSI, 2008a).

Specially adapted operating devices, switches and sensors may be required to suit individual users. Dual controls to the platform may be required in certain situations. A key switch, electronic card or similar means may be necessary to restrict the use of the lifting device to authorised users in some environments.

For passenger lifts, BS EN 81-70 (BSI, 2003a) provides guidance on control devices and signals, including keypads and extra large control devices, see Appendix 11.A1.

11.5.6 Location

The suitability of the proposed location of the equipment should be checked, for example:

- the installation of a stairlift does not obstruct normal activities in and about the building
- the installation of a stairlift will not constrict or obstruct an escape route
- the location and proposed supporting structure will be strong enough to support a lifting device
- there is an unobstructed manoeuvring space of 1500 mm by 1500 mm (public access) or 1200 mm by 1200 mm (private domestic use), or a straight access route at least 900 mm wide.

11.5.7 Duty cycle

The anticipated maximum number of journeys per hour for a passenger lift is unlikely to be a problem as most passenger lifts are capable of 90 starts per hour. For lifting platforms and stairlifts, the anticipated maximum number of journeys per hour should be agreed between the purchaser and the supplier. Care should be taken to ensure the equipment is fit for its purpose with respect to the anticipated duty cycle.

11.5.8 Alarm system

New passenger lifts are fitted with an alarm system that connects to a rescue service. Existing passenger lifts without a remote alarm system should be considered for upgrading. On fully enclosed lifting platforms, users should have available a device which allows two way voice communication.

11.5.9 Type of wheelchair

Consideration should be made to the type of wheelchair that is likely to require transportation, whether it is a manual wheelchair to BS EN 12183 (BSI, 2014a), or a Class A, B or C electric wheelchair to BS EN 12184 (BSI, 2014b).

The minimum sizes of lifting devices required to meet these requirements are given in sections 11.7.2 and 11.7.3.

In some locations, such as shopping centres, specially adapted electric wheelchairs are available with baskets at the front and rear, which can have a combined length of over 1700 mm. These are larger than the standard sizes indicated above and appropriately sized lifting devices should be provided.

Some wheelchairs are very large and heavy, and precautions may need to be taken to ensure that any impacts of these vehicles with lifting device enclosures, doors, etc can be accommodated.

11.6 Environmental considerations

The environment in which a lifting device is to be installed should be carefully planned. Below are some considerations (reference should be made to section 9 of Approved Document M (NBS, 2013) and BS 8300 (BSI, 2009) for specific detail):

- Signs indicating the location of a lifting device should be clearly visible in all buildings.
- Signs that can be easily seen from the lifting device should identify each floor, and should be designed to contrast visually with the surroundings.
- Stairs should always be provided as an alternative means of vertical access designed to suit ambulant disabled people and those with impaired sight.
- Ramps of suitable gradient may be appropriate on an internal circulation route if a change of level is unavoidable.
- The location of lifting platforms and stairlifts should not restrict the means of emergency access or egress in public buildings.
- Equipment should be easily accessible for maintenance.
- Fully enclosed lifts should be provided with audible and visual indication of their arrival at a landing, both in the car and on the landing.
- Materials that are likely to cause allergic reactions, e.g. metals (nickel, chromium, cobalt), fabrics (plastic wallpapers, thick carpets etc.), should not be used in the surroundings or in the equipment.
- Adequate lighting (>50 lux) should be provided on all routes accessing lifting devices.
- Adequate lighting (>50 lux for lifting platforms and >100 lux for passenger lifts) should be provided for all lifting devices.
- Reflective surfaces should be avoided.

- Colour/tone contrasting surfaces should be employed, for example, to distinguish landing and lifting device floors and entrances.
- Landing and lifting device floors should have similar surface characteristics, e.g. texture, frictional (non-slip) characteristics.

11.7 Equipment provision

It is not intended in this section to repeat the provisions of Approved Document M (NBS, 2013) or to recite parts of the applicable standards. This section concentrates on the selection, location and installation of the equipment to provide transportation facilities for disabled people.

11.7.1 Provision to the Machinery Directive or the Lift Directive

Lifting devices that transport persons and travel at a speed greater than 0.15 m/s are certified under the Lifts Regulations 1997 (TSO, 1997) enacting the Lifts Directive (OJ, 1995). Lifting devices that transport persons and travel at a speed less than 0.15 m/s are certified under the Supply of Machinery Regulations 2008 (TSO, 2008) enacting the Machinery Directive (OJ, 2006).

Passenger lifts are classed as special machinery and the essential health and safety requirements (EHSRs) of the Supply of Machinery (Safety) Regulations 2008 (TSO, 2008) also apply, where appropriate. The common route to achieve conformity is for the installer to provide a lift that complies with the relevant harmonised standards. Alternatively, an EC-type examination certificate can be obtained by an assessment route involving a notified body.

All new passenger lifts should bear CE marking applied by the installer before they are placed in service. At the same time a test document is completed and a copy may be provided to the owner/operator together with a Declaration of Conformity. Suitable test documents can be found in BS 8486-1/2 (BSI, 2007a/b).

Lifting platforms and stairlifts are classed as machines and should comply with the Supply of Machinery Regulations 2008. As these lifting devices transport people, there are particular essential health and safety requirements (EHSRs) indicated in chapter 6 of the Machinery Directive. If the lifting device travels above 3 m it is listed as a dangerous machine in Annex IV of the Supply of Machinery Regulations 2008 and requires an EC-type examination certificate obtained by an assessment route involving a notified body.

To comply with European Directives a CE mark should be applied to the product by the manufacturer. All the applicable product standards require a test and examination document to be completed by the supplier immediately on completion of the installation and before first use. It is recommended that a copy of this document is given to the owner/end user together with the operating instructions.

11.7.1.1 Safe working on lifts, escalators and lifting platforms

After a suitable lifting device has been selected and installed there are many legislative factors that need to be considered to ensure its continued safe and reliable use. Advice on the responsibilities of both the building owner and the lift contractor can be found in BS 7255: 2012: *Code of practice for safe working on lifts* (BSI, 2012a) and BS 9102: 2014: *Code of practice for safe working on lifting platforms* (BSI, 2014c).

11.7.2 Passenger lifts

Passenger lifts are the preferred lifting device under Approved Document M (NBS, 2013). The applicable standards for passenger lifts are:

- BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts* (BSI, 2014d)
- BS EN 81-50: 2014: *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components* (BSI, 2014e)

plus:

- BS EN 81-28: 2003: *Safety rules for the construction and installation of lifts. Remote alarm on passenger and goods passenger lifts* (BSI, 2003b)
- BS EN 81-70: 2003: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Accessibility to lifts for persons including persons with disability* (BSI, 2003a)
- BS EN 81-71: 2005: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Vandal resistant lifts* (BSI, 2005a)
- BS EN 81-72: 2015: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Firefighters lifts* (BSI, 2015)
- BS EN 81-73: 2005: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Behaviour of lifts in the event of fire* (BSI, 2005b).



Note: BS EN 81-70: 2003 is currently under revision.

The passenger carrying unit is a car completely enclosed by walls, floor and roof, running in a well enclosure that may be totally or partially enclosed. The entrance doors may be manually or automatically operated, although the latter is more suitable for use by persons with disabilities. The passengers can select their destination on the car operating panel after which no further passenger actions are required.

Where a single lift is installed, it would be wise to ensure it complies with all the relevant standards for use by people with disabilities. Where more than one lift is installed, reasonable provision should be made and not all the lifts need be suitable for such use. However best practice would be to provide as much flexibility of use as possible.

Table 11.1 Lift car dimensions

Lift type	Load and minimum car dimensions*	Accessibility level	Remarks
Type 1	Load: 450 kg Car width: 1000 mm Car depth: 1250 mm	Accommodates one wheelchair user	Type 1 ensures accessibility to persons using a manual wheelchair described in EN 1218311 or electrically powered wheelchair of class A described in EN 1218412. See note to section 11.5.2.
Type 2	Load: 630 kg Car width: 1100mm Car depth: 1400mm	Accommodates one wheelchair user and an accompanying person	Type 2 ensures accessibility to persons using a manual wheelchair described in BS EN 12183 (BSI, 2014a) or an electrically powered wheelchair of class A or B described in BS EN 12184 (BSI, 2014b). Class B wheelchairs are intended for some indoor environments and capable of navigating some outdoor obstacles.
Type 3	Load: 1275 kg Car width: 2000 mm Car depth: 1400 mm	Accommodates one wheelchair user and several other users. It also allows a wheelchair to be rotated in the car.	Type 3 ensures accessibility to persons using a manual wheelchair described in BS EN 12183 or an electrically powered wheelchair of class A, B or C described in BS EN 12184. Class C wheelchairs are not necessarily intended for indoor use but are capable of travelling over longer distances and navigating outdoor obstacles. Type 3 provides sufficient turning space for persons using wheelchairs of class A or B and walking aids (walking frames, roller frames etc).

*Car width is the horizontal distance between the inner surfaces of the structural walls, measured parallel to the front entrance. Car depth is the horizontal distance between the inner surfaces of the structural walls, measured perpendicular to the width.

The dimensions of passenger lifts are defined in BS EN 81-70 (BSI, 2003a). The smallest suitable size is 1000 mm by 1250 mm (minimum rated load of 450 kg), which can accommodate a single wheelchair, without a companion. A summary of other suitable car dimensions and rated loads is given in Table 11.1.

Figure 11.1 illustrates the main dimensions and features of a passenger lift to meet the requirements of BS EN 81-70. Although the clear opening width of the entrance doors is shown as 800 mm, this is a minimum and larger openings, e.g. 900 mm should be considered.

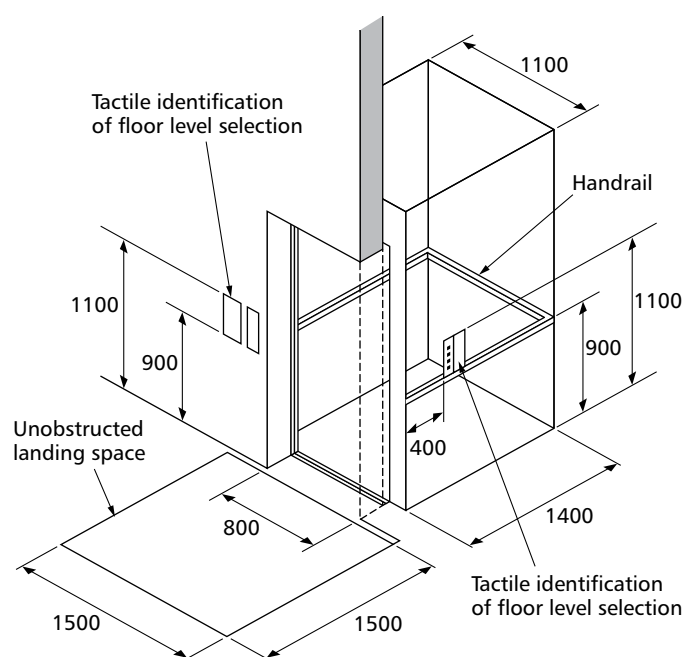


Figure 11.1 Principal features of a passenger lift for use by persons with limited mobility

Existing lifts may have been installed to earlier versions of (BS) EN 81, or even BS 2655 and BS 5655. To meet the requirements of the Equality Act, some, or all lifts, in a

building may need to be upgraded. Full compliance with BS EN 81-70 may be impossible. For example, it may not be possible to position the car operating panel 400 mm from a return wall. In such cases 'reasonable provision' should be made to comply as closely as possible. To show due diligence, the reasons for any deviations should be recorded in the Access Statement.

It should be noted here that existing lifts do not have to be retrospectively upgraded to the latest lift standards. However, BS EN 81-80: *Rules for the improvement of safety of existing passenger and goods passenger lifts* (BSI, 2003c) draws owner's attention to the importance of reviewing the safety and suitability of existing lifts.

11.7.3 Lifting platforms

Where passenger lifts cannot be installed then a lifting platform may be considered. Lifting platforms can be installed with a minimal loading demand and structural alterations into new and existing buildings.

Standards applicable to vertical lifting platforms are:

- For lifting platforms with enclosed liftways: BS EN 81-41: 2010: *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Vertical lifting platforms intended for use by persons with impaired mobility* (BSI, 2010)
- For lifting platforms with non-enclosed liftways: BS 6440: 2011: *Powered vertical lifting platforms having non-enclosed or partially enclosed liftways intended for use by persons with impaired mobility. Specification* (BSI, 2011a)

Due to the restricted operating speed of lifting platforms, consideration should be given to a maximum travel distance of 10 m.

Lifting platforms have a maximum rated load of 500 kg,

Lifting platforms are designed particularly to transport wheelchairs. This determines the minimum platform sizes as given in BS EN 81-41 and BS 6440; these are summarised in Table 11.2.

Table 11.2 Minimum dimensions of lifting platforms

Principal use	Minimum useable plan dimensions (width × length)
Type A and B wheelchairs with an attendant and adjacent entrances	1100 mm × 1400 mm
Type A and B wheelchairs	900 mm × 1400 mm
Lone user, either standing or in a type A wheelchair	800 mm × 1250 mm

The maximum platform area that is permitted is 2.0 m², excluding hand rails.

For lifting platforms with straight on/off configuration doors/gates should have a minimum 800 mm effective clear width. For lifting platforms with adjacent entry configuration (minimum useable platform size 1100 mm by 1400 mm) doors/gates should have a minimum 900 mm effective clear width.

Lift operation controls have been a topic of much discussion. The Supply of Machinery Regulations 2008 (TSO, 2008) (which implement the Machinery Directive (OJ, 2006)) confuses the situation as regards controls at landing and in the carrier. Section 6.2 of the Regulations clearly indicates that carrier controls should be of the ‘hold-to-run’ type, whilst section 6.4.2 has a requirement (which in order to comply and not leave the carrier stranded between floors) that non-hold-to-run controls should be used at landings. As far as the disabled user is concerned the operation of lifts is made much easier through the use of non-hold-to-run controls. It is recommended that non-hold-to-run controls are used throughout, providing that the design of the machine and its application does not decrease the operational safety. Where, for example, the product is used in a school environment or an open public area without any key locking, then the inherent safety of hold-to-run controls should be adopted at all control stations without exception (even though this is contrary to the Machinery Directive).

The lifting platform should only be allowed to travel under the direct control and sight of the operator; this is particularly important with non-enclosed lifting platforms.

Carrier and landing call stations should be positioned such that the centreline of the lowest button is a minimum of 900 mm from the floor and the highest button is a maximum of 1100 mm to its centreline above the floor. All controls should be located to give a minimum lateral space between the centre lines of any buttons to a corner in the platform or outside the landing of 400 mm from any return wall (see BS EN 81-41 (BSI, 2010)).

There are six common types of drive system. These are rack and pinion, rope or chain, screw and nut, traction, guided chain, and hydraulic. The most common types used are hydraulic and screw and nut.

11.7.3.1 Lifting platforms with enclosed liftways

The minimum dimensions of enclosed lifting platforms are given in Table 11.2.

Figure 11.2(a) illustrates a lifting platform where there is a total enclosure at the lower level and a full enclosure at the upper level; Figure 11.2(b) shows a partial enclosure at the upper level. The height of the upper enclosure including the door is dependent on the travel. For up to three metres travel, the height of the enclosure and door should be at least 1.1 m, and over three metres travel, the height of the enclosure and door should be at least 2.0 m (see BS EN 81-41 (BSI, 2010)).

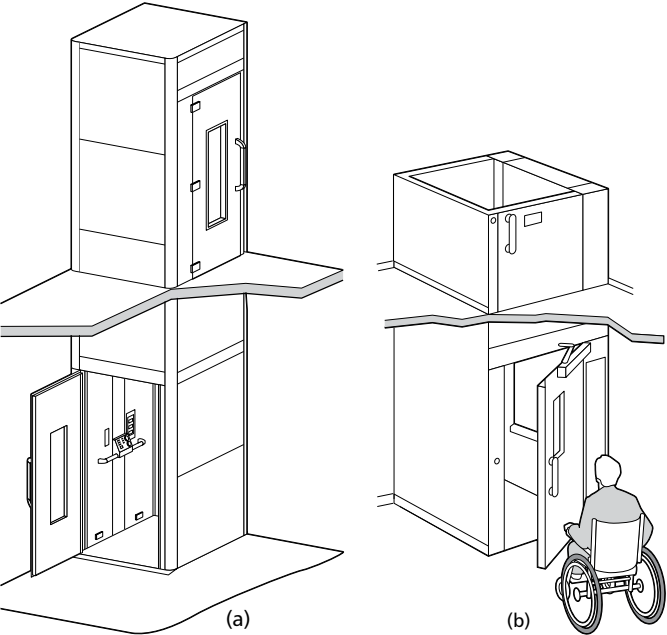


Figure 11.2 Illustration of a lifting platforms with (a) fully enclosed liftway, (b) partially enclosed upper enclosure

Consideration should be given to the use of powered doors (which if used causes the position of the landing call station to be remote from the door). Vision panels are required on all doors, size and design of glazed area may be influenced by factors such as modesty screening visual impairment, aesthetics and fire protection requirements.

If the lifting platform penetrates a fire separation barrier, the liftway enclosure may require fire protection. This is normally constructed by others in the form of an additional external shaft or shell to the liftway to give the required fire rating. The external shell requires careful detail of the closing to the fire door frame of the liftway enclosure together with other unprotected areas of the liftway enclosure.

Future developments

At the time of writing BS EN 81-41 is under revision and some changes to the standard are being proposed, which will include tighter requirements for powered door operators and the inclusion of traction drive.

A CEN working group has started work on a new standard (EN 81-42) to embrace platform lifts with fully enclosed carriers; this product is commonly known as a slow speed lift and will allow the use of latched controls.

11.7.3.2 Lifting platforms with non-enclosed liftways

Non-enclosed lifting platforms are often installed to overcome changes in level, with a travel distance that is no more than 3.0 m. Non-enclosed lifting platforms have the benefit of minimal impact on the building design, preventing the lift dominating the built environment, whilst being obvious in its presence for those who need to use it. They are quickly and simply installed with a minimum of disruption to existing buildings.

These platforms can be used by all manner of persons, handicapped in the use of other vertical circulation devices (stairs, ramps etc) for many different reasons (e.g. physical handicap, objects being carried, responsible for others etc). It should be recognised that the designed solution may need to provide safe access onto and from the lift as well as transit between levels for all these conditions, many of which may be unforeseen. The design of the lift should take into account all conceivable impairments, encumbrances and situations which could be foreseen.

Attention should be paid to the safe running clearances required to the platform as detailed in BS 6440 (BSI, 2011a).

Lifting platforms with non-enclosed liftways in public access situations

The minimum dimensions of non-enclosed or partially enclosed lifting platforms are given in Table 11.2.

Figure 11.3 illustrates two examples of lifting platforms with non-enclosed liftways.

The platform construction should include protection to a height of 1100 mm on all sides, including access sides. On platforms travelling over 1 m, the platform protection should be in-filled such that it does not allow a 100 mm sphere to pass through any openings in the guarding. Upper level protection should consist of an interlocked imperforate gate to a height of 1100 mm. Adjacent balustrades should be designed to close to the gate frame without leaving any gaps greater than 100 mm.

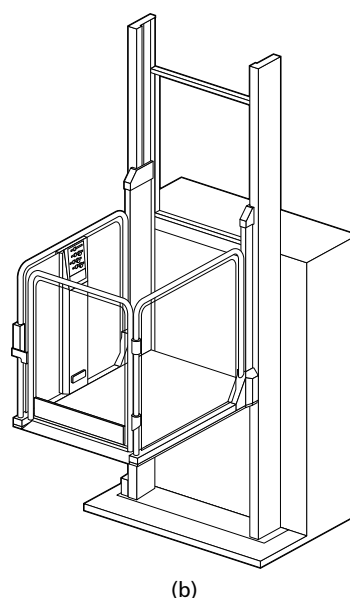
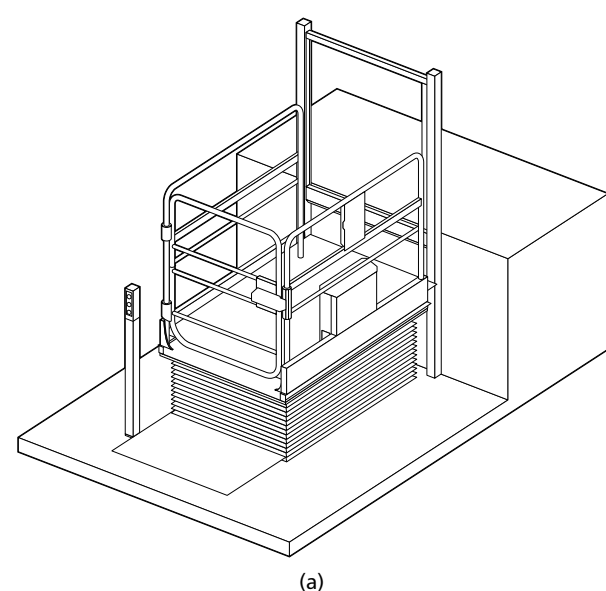


Figure 11.3 Lifting platforms with non-enclosed liftways; (a) scissor type with bellows protection, (b) cantilever type with under-surface protection

Lifting platforms with non-enclosed liftways in domestic situations

Where the non-enclosed lifting platform is to be used in a domestic environment for an identified wheelchair user then protection to the platform should be as follows:

- *For travel up to 500 mm:* access and non-access sides that are not protected by a flush full height adjacent surface should be protected from wheelchair roll-off by a minimum 100 mm high guarding.
- *For travels between 500 mm and 1000 mm:* non-access sides that are not protected by a smooth full height adjacent surface should be protected with a 900 mm high guard rail. Lower access sides should be protected by a minimum 100 mm high guarding.

The above options require that the user is seated and that the lift is protected against unauthorised use by some form of key locking.

For travels above 1000 mm protection to access and non-access sides of the platform should be as referenced in BS 6440 (BSI, 2011a).



Note: the smooth full height adjacent surface should be a minimum of 1100 mm above the upper landing level as referenced in BS 6440 (BSI, 2011a).

The lower level guarding to the platform access sides often folds down to provide part of an access ramp.

Upper level protection is required when the step height from the lifting platform floor and the upper landing is greater than 220 mm. This protection can either consist of an upper level gate or a bridging step system as referenced in BS 6440 (BSI, 2011a), see Figure 11.4 below.

11.7.4 Domestic 'through-the-floor' lifting platforms

With today's enlightened emphasis on design in the home for lifetime living, the use of a through-the-floor lift enables users with many disabilities to continue to enjoy their own home environment. The flexibility of design of the

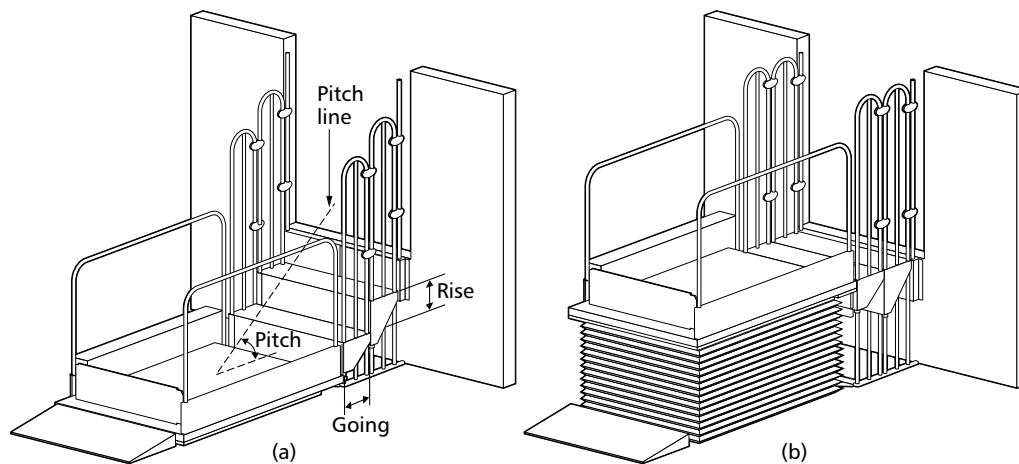


Figure 11.4 Lifting platform with bridging step; (a) lower position, (b) raised position

wheelchair through-the-floor lift means that it can be used by a semi-ambulant user (by means of a fold-down seat) but also provide a wheelchair lifting facility that may be required later in the user's life. Stairlifts can be unsuitable due to the staircase space and geometry, or where the user's disability makes the use of a stairlift impracticable (e.g. if the user is wheelchair dependent). In such cases, the through-the-floor lift provides a suitable alternative.

A variety of carriage sizes are available including smaller car sizes for seated-only users. Predominantly the lifts available are designed for wheelchair and seated users, and do not allow the use by standing users.

Through-the-floor homelifts provide the following benefits:

- small footprint
- no enclosure giving optimal space utilisation; the lift can be parked at the opposite floor to that being used thus freeing up circulation space
- minimalistic design
- low cost in use
- simplicity of operation
- maintains the user's independence and dignity.

The applicable standard for vertical lifting platforms for domestic use is BS 5900: *Powered homelifts with partially enclosed carriers and no liftway enclosures. Specification* (BSI, 2012b).

BS 5900 specifies requirements for the design, construction, and installation of powered domestic lifts that are designed for use by persons with impaired mobility travelling between fixed floor levels in private dwellings. It applies to lifts that serve two floors only and that have partially enclosed cars without lift-well enclosures. Typically these lifts will travel above 3 m and fall under Annex IV of the Supply of Machinery (Safety) Regulations 2008 (TSO, 2008) and will have an EC type examination certificate to the regulations drawn up by a notified body. Further assurances of compliance can be achieved when the manufacturer has obtained independent certification to BS 5900 by a notified body, which will include proof of fire testing of a representative sample.

The lifting platform can have a rated speed up to 0.15 m/s and a maximum rated load of 500 kg. The most common

type of drive is direct acting hydraulic, which has many inherent safety features. Alternative drives are rope or chain.

The passenger carrying unit is a partially enclosed car, which runs in a totally open space (see Figure 11.5). It has many safety features that make it, by design, as safe as an enclosed car.

A key factor in the specification of both lift type and controls is the capability of the user. Advice is often provided by healthcare professionals on both the current and future needs of the user. It is important that this consideration is made at the outset of specifying the equipment. A variety of control systems are available to suit the broad range of needs in the disabled community. Simplicity without compromising safety should always be adopted, to which end the push-and-go controls lend themselves in many situations

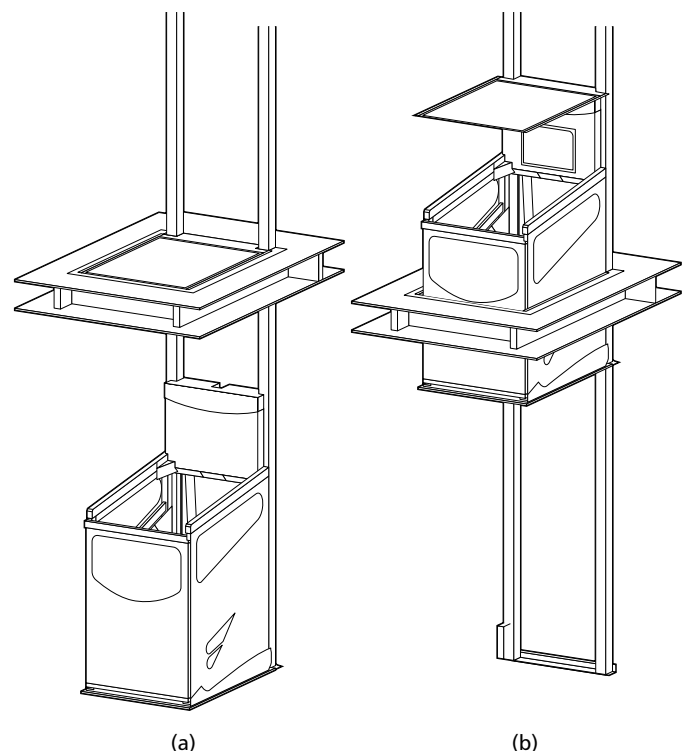


Figure 11.5 Domestic through-the-floor lifting platform; (a) lower position, (b) in transit

11.7.5 Stairlifts

Another popular aid in overcoming obstacles to vertical circulation are stairlifts. There are three types of stairlifts: wheelchair platform, chair stairlifts and standing (perch) stairlifts.

The wheelchair stairlift is suitable for use in both public and domestic environments, whereas the chair and standing stairlifts should only be used in domestic environments.

The applicable standard for stairlifts is BS EN 81-40: *Powered stairlifts for seated, standing and wheelchair users moving in an inclined plane intended for use by persons with impaired mobility* (BSI, 2008a).

A stairlift runs up the side of a stairway and care should be taken neither to obstruct normal circulation on the stair for other users nor to obstruct the means of escape in an emergency. Stairlifts can follow the contour of the stairwell and can be provided with extended travel at the ends of the stair to enable easy boarding/alighting and parking. Alternatively a swivel seat can assist the safe transfer of the user on and off the stairlift. Most stairlifts provide travel across one flight of stairs, but some stairlifts, particularly in private dwellings, cover several flights. Boarding/alighting points are usually provided at each landing.

Chair and standing stairlifts place only a small load on the building structure and can be installed relatively inexpensively. Wheelchair platform stairlifts require greater consideration of the structural implications due to the higher imposed loads. The maximum rated speed of all stairlifts is 0.15 m/s and should always be equipped with hold-to-run controls.

Six types of drive systems are available: rope suspension, rack and pinion, chain, screw and nut, friction/traction and ball and rope.

11.7.5.1 Wheelchair platform stairlifts

Wheelchair platform stairlifts are the last choice lifting device under Approved Document M for public buildings, see Figure 11.6(a).

The platform size when installed in buildings with public access is required to be 800 mm wide by 1250 mm long. For installations in private dwellings the width can be reduced

to 700 mm. Their location should be chosen carefully (see 11.5.6).

Wheelchair platform stairlifts are designed for a minimum rated load of 250 kg/m² of the clear loading area.

11.7.5.2 Stairlifts for seated persons

Stairlifts for seated persons have a rated capacity for one person, i.e. a rated load not less than 115 kg. A range of dimensional adjustments to the stairlifts various components are available to suit the user. See Figure 11.6(b).

11.7.5.3 Stairlifts for standing persons

Stairlifts for standing persons, see Figure 11.6(c), have a rated capacity for one person, i.e. a rated load not less than 115 kg. The minimum dimensions of the platform are 325 mm by 350 mm. These lifting devices are only suitable for private dwellings.

11.8 Escalators and passenger conveyors

Lifts are the preferred method of vertical travel for wheelchair users and persons with assistance dogs, but wheelchair users can generally use horizontal passenger conveyors and inclined passenger conveyors with an inclination of up to 6°, either unaided, or with a companion. Passenger conveyors with inclinations greater than 6° and escalators, are not suitable for use by persons with assistance dogs (unless the dogs are carried), or by wheelchair users. Their use in this way is unsafe for the disabled user and is a risk to able bodied users travelling with them. Signs should be provided to indicate the location of alternative facilities, which should be situated nearby.

Escalators can be used safely by many persons with disabilities. Some guidance is given in BS 5656-2 (BSI, 2004).

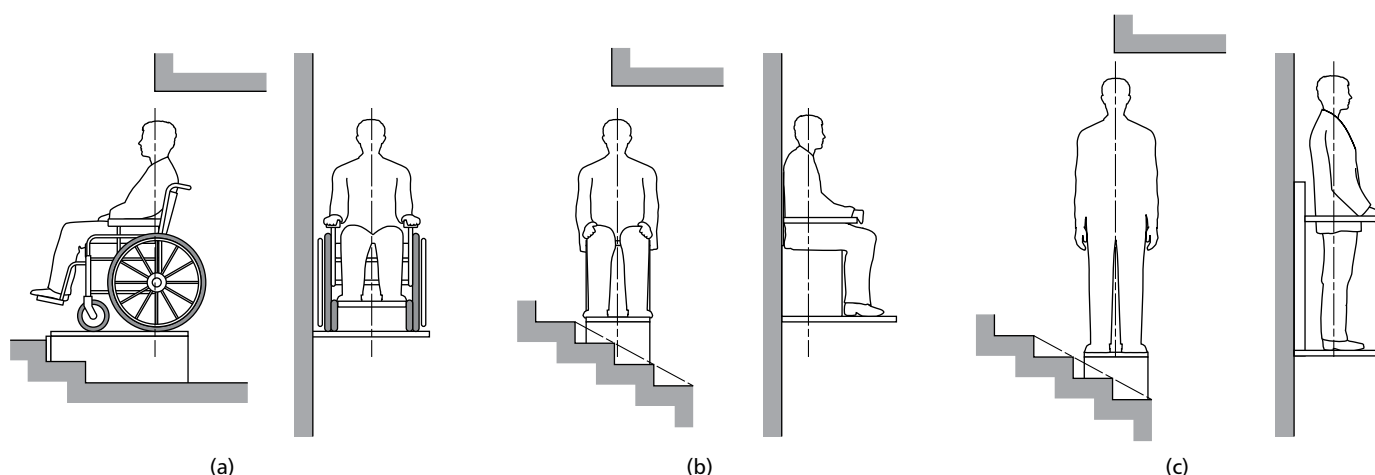


Figure 11.6 Types of stairlift; (a) wheelchair, (b) seated, (c) standing

11.9 Egress for persons with disabilities

A great deal of attention has been paid to making buildings accessible to everyone and enable circulation around the building (see chapter 2), but little attention has been given to how to enable people to escape in an emergency. In the UK, lifts should not be used for escape from fire, regardless of lift type or building height. The able bodied use the escape stairs provided. In well managed public buildings, people with disabilities are recommended to assemble in 'refuge spaces' placed on or close to each floor and await rescue. Rescue may then be manually achieved using an evacuation chair. In the domestic situation it may be necessary that an upper level room is specified to form a refuge.

The only lifts in a building that can be used during a fire are specially designed firefighting lifts to BS EN 81-72 (BSI, 2015) and evacuation lifts to BS 9999: *Code of practice for fire safety in the design, management and use of buildings* (BSI, 2008b). See also chapter 5, section 5.9.2, and chapter 6, section 6.5.

BS 9999 deals with such elements as refuges, stairways, ramps, lifts, signs and the use of lifts to evacuate disabled people. A firefighting lift can be used, under the supervision of the building management, to evacuate disabled people,

until the arrival of the fire service, who may then assume responsibility for the evacuation of any remaining persons.

Evacuation lifts are being provided to BS 9999 in many public facilities such as sports stadia, entertainment centres, public halls etc., where large numbers of disabled people are expected. The lift should be used routinely as a passenger lift (but not for goods) and should always be available. The specification for an evacuation lift is similar to, but not the same as, a firefighting lift. For example, an evacuation lift cannot be used as a firefighting lift.

In a private domestic dwelling, where a through-the-floor lift is installed, the upper level refuge should have the integrity of its fire protection preserved no matter where the lift is parked.

11.10 Selection of lifting devices

Table 11.4 provides a summary of the different types of lifting devices available for the transportation of people with disabilities. It is recommended that the detailed text in this chapter be consulted and the appropriate standard(s) obtained when considering a specific design. Specialist assistance may be necessary.

Table 11.4 Summary of lifting devices suitable for the transportation of disabled people

Lifting device	Travel	Rated speed (m/s)	Rated load (kg)	Platform size (mm) (width × depth)	Applicable standards	Relative cost
<i>(a) Buildings other than dwellings</i>						
Lift	Unlimited (typical = full travel)	0.4 – 6.0 and higher	450	1000 × 1250	BS EN 81-20: 2014 BS EN 81-50: 2014 BS EN 81-28: 2003 BS EN 81-70: 2003 BS EN 81-71: 2005 BS EN 81-72: 2003 BS EN 81-73: 2005	High
			630	1100 × 1400		
			275	2000 × 1400		
			1600	2100 × 1600		
			and larger	and larger		
Lifting platform	Unlimited (typical = 6.0 m)	0.15 (max.)	205 (min.)	800 × 1250	BS EN 81-41: 2010 BS 6440: 2011	Medium
			500 (max.)	900 × 1400		
				1100 × 1400		
Wheelchair stairlift	Unlimited (typical = flight of stairs)	0.15 (max.)	250 (min.) 350 (max.)	800 × 1250	BS EN 81-40: 2008	Low
<i>(b) Dwellings</i>						
Lift	As (a) above	As (a) above	As (a) above	As (a) above	As (a) above	As (a) above
Domestic homelift	Two storeys (typical = 3.0 m)	0.15 (max.)	115 (min.) 500 (max.)	Various to suit user requirements	BS 5900: 2012	Medium
Wheelchair stairlift	Unlimited (typical = flight of stairs)	0.15 (max.)	150 (min.) 350 (max.)	700 × 900 750 × 1000 800 × 1250	BS EN 81-40: 2008	Low
Seated stairlift	Unlimited (typical = flight of stairs)	0.15 (max.)	115 (min.)	N/A	BS EN 81-40: 2008	Lowest
Standing stairlift	Unlimited (typical = flight of stairs)	0.15 (max.)	115 (min.)	325 × 350	BS EN 81-40: 2008	Lowest

References

- BSI (2003a) BS EN 81-70: 2003: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Accessibility to lifts for persons including persons with disability* (London: British Standards Institution)
- BSI (2003b) BS EN 81-28: 2003: *Safety rules for the construction and installation of lifts. Remote alarm on passenger and goods passenger lifts* (London: British Standards Institution)
- BSI (2003c) BS EN 81-80: 2003: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of safety of existing passenger and goods passenger lifts* (London: British Standards Institution)
- BSI (2004) BS 5656-2: 2004: *Escalator and moving walks. Safety rules for the construction and installation of escalators and moving walks. Code of practice for the selection, installation and location of new escalators and moving walks* (London: British Standards Institution)
- BSI (2005a) BS EN 81-71: 2005: *Safety rules for the construction and installation of lifts. Particular applications to passenger lifts and goods passenger lifts. Vandal resistant lifts* (London: British Standards Institution)
- BSI (2005b) BS EN 81-73: 2005: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Behaviour of lifts in the event of fire* (London: British Standards Institution)
- BSI (2007a) BS 8486-1: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Electric lifts* (London: British Standards Institution)
- BSI (2007b) BS 8486-2: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Hydraulic lifts* (London: British Standards Institution)
- BSI (2008a) BS EN 81-40: 2008: *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Stairlifts and inclined lifting platforms intended for persons with impaired mobility* (London: British Standards Institution)
- BSI (2008b) BS 9999: 2008: *Code of practice for fire safety in the design, management and use of buildings* (London: British Standards Institution)
- BSI (2009) BS 8300: 2009 + A1: 2010: *Design of buildings and their approaches to meet the needs of disabled people. Code of practice* (London: British Standards Institution)
- BSI (2010) BS EN 81-41: 2010: *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Vertical lifting platforms intended for use by persons with impaired mobility* (London: British Standards Institution)
- BSI (2011) BS 6440: 2011: *Powered vertical lifting platforms having non-enclosed or partially enclosed lifeways intended for use by persons with impaired mobility. Specification* (London: British Standards Institution)
- BSI (2012a) BS 7255: 2012: *Code of practice for safe working on lifts* (London: British Standards Institution)
- BSI (2012b) BS 5900: 2012: *Powered homelifts with partially enclosed carriers and no liftway enclosures. Specification* (London: British Standards Institution)
- BSI (2014a) BS EN 12183: 2014: *Manual wheelchairs. Requirements and test methods* (London: British Standards Institution)
- BSI (2014b) BS EN 12184: 2014: *Electrically powered wheelchairs, scooters and their chargers. Requirements and test methods* (London: British Standards Institution)
- BSI (2014c) BS 9102: 2014: *Code of practice for safe working on lifting platforms* (London: British Standards Institution)
- BSI (2014d) BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts* (London: British Standards Institution)
- BSI (2014e) BS EN 81-50: 2014: *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components* (London: British Standards Institution)
- BSI (2015) BS EN 81-72: 2015: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Firefighters lifts* (London: British Standards Institution)
- DRC (2004) *Access Statements: Achieving an inclusive environment by ensuring continuity throughout the planning, design and management of buildings and spaces* (London: Disability Rights Commission)
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- TSO (2010) *Equality Act 2010* (London: The Stationary Office) (available at <http://www.legislation.gov.uk/ukpga/2010/15>) (accessed May 2015)

Appendix 11.A1: Summary of the principal requirements of BS EN 81-70

This appendix provides a short summary of the principal requirements of BS EN 81-70 (BSI, 2003) when applied to BS EN 81-20/50 (BSI, 2014a/b) lifts. Some of the concepts may be useful when considering other transportation facilities for disabled people.

BS EN 81-70 provides recommendations for lifts, constructed to the BS EN 81 series of standards, relating to the design and positioning of fittings, controls and indicating equipment as well as the use of materials to maximise contrasts between controls and doors and the surrounds. The primary aim is to ensure that the design does not obstruct or impede the use of the lift by disabled people and to enable the unassisted use of lifts by all people including those with disabilities.

The landing area should be free of obstacles and sufficiently large to allow the free movement of persons, wheelchairs and accompanying persons, when entering or leaving the lift car with landing call buttons positioned 900 mm to 1100 mm above the floor level.

The lift should be able to provide a stopping accuracy of ± 10 mm and a levelling accuracy of ± 20 mm.

Automatic doors should be at least 800 mm clear width and protected with full height non-contact, infra-red (or similar) safety edges (see section 7.8.6).

It is important, particularly on groups of lifts, that the door operation allows suitable dwell times for passenger who may have restricted mobility, to reach and enter the lift and an adjustable dwell time between 2 and 20 seconds should be provided accordingly. Typically this is set to 5 seconds. (It should be noted that extended dwell times will have a significant effect on the traffic handling capacity of a lift system (see section 3.11). This can result in increased costs to install extra equipment or the need to provide special signalling to enable anyone to call a lift with extended door dwell times.)

Control features such as advanced door opening should be avoided in hospitals and nursing homes or other environments where wheelchairs or trolleys etc. could be inconvenienced by the momentary presentation of a ledge as the doors open approaching floor level.

The lift car platform area should be large enough to meet the requirements of all persons. Special considerations may need to be made to accommodate some types of electrically driven wheelchairs.

Light colours are recommended inside the car to reduce the claustrophobic effects of small lifts and to optimise light levels within the car. Colour should be used to provide clear demarcation between the floor of the car and the landing entrance for users with visual impairment.

Functional, easily cleaned surface finishes are recommended, together with a half-height mirror which creates an impression of increased car size.



Caution: full height mirrors can be confusing for visually impaired passengers and therefore there should be a clear band of at least 300 mm between the bottom of a mirror and the floor.

A handrail along one side of the lift is essential together with large, easily operated push buttons. All control buttons in the lift car should be placed at between 900 mm and 1200 mm (1100 mm preferred) above the lift car floor level, and not less than 400 mm from the front or rear wall. The provision of a tip-up seat improves comfort for the elderly and infirm.

All push buttons should be provided with tactile, and possibly also Braille markings, either on or adjacent to the buttons. Since many visually impaired people are unable to read Braille it is recommended that Braille markings should only be used in addition to tactile markings.

In addition to the visual enhancements, voice synthesised announcements, of sufficient sound level to overcome background noise, should be included to announce door actions (opening and closing) as well as the floor level and direction of travel as the lift arrives at a landing. Emergency signals received from a fire alarm or building management system can also be announced by the voice synthesiser.

The inclusion of inductive loops is required in conjunction with the voice synthesiser and emergency communication unit to assist passengers who use hearing aids.

Provision of a 24-hour communication link is required in accordance with the Lifts Regulations 1997 (TSO, 1997). This is normally satisfied by utilising an auto-dial telephone unit although a new standard, BS EN 81-28 (BSI, 2003) now provides additional recommendations on the design and minimum performance requirements of suitable systems. In premises that are attended 24 hours a day, consideration should be given to programming the auto-dial telephone system to call an attended telephone on the premises. This will minimise the possibility of false alarms being registered with the lift maintenance company, and also improve the response time to make a direct contact with any trapped passengers, enabling reassurance to be provided until release can be effected.

In environments where the lifts may be used by elderly or infirm passengers such as nursing homes, the use of an additional alarm push button mounted at low level should be considered. This will enable access to the alarm facility for passengers that may have fallen or collapsed in the lift car.

When designing lifts to provide access for persons with disabilities, reference should be made to Building Regulations Approved Document M (NBS, 2013).

12 Electrical systems and environmental conditions

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12 Electrical systems and environmental conditions

12.1 Introduction

In incorporating a new lift system into a given building, both the building designer and the lift contractor should consider not only the interface of the lift system with the building and its users, but also the more particular requirements of the lift system itself in terms of its environment, its dependence upon other services and future maintenance needs. This is recognised in one of the assumptions made in drawing up BS EN 81-20 (BSI, 2014a) where the following is included in the assumption at 0.4.2:

‘Negotiations have been made between the customer and the supplier and agreement reached about:

- environmental conditions such as temperature, humidity, exposure to sun or wind, snow, corrosive atmosphere;
- other aspects related to the place of installation;
- the dissipation of heat from the components / equipment of the lift which would require ventilation of the well and/or the machinery space / location of equipment;
- information concerning the aspects relating to noise and vibrations emitted by the equipment.’

These items for negotiation frame the discussion of this chapter where, along with the electrical supply and a consideration of electromagnetic compatibility (EMC), this chapter provides some guidance. It should be noted that assumptions stated in standards such as BS EN 81-20 are informative (assumptions are not normative requirements) and help to define the basis of the standard and how it should be applied as is made clear in PD CEN/TR 81-12 (BSI, 2014a).

It should be noted that recommendations contained in various standards covering lift systems, e.g. British Standards, other standards covering the design of the building, and the Building Regulations (TSO, 2010) can sometimes give rise to issues which need resolution between these documents. Therefore, careful reference must be made to all the applicable regulations and standards.

12.2 Electrical power supplies for lifts

The provision of power supplies and electrical systems for lifts must be considered in relation not only to the power supply requirements of the lift systems but also to other building electrical systems which may interact with the lift installation.

BS EN 81-20 makes clear that, while the requirements of the standard apply to circuits fed from the main switch of

the power circuit, the switch for the car lighting circuit and the switch for the lift well lighting circuit:

‘national requirements relating to electricity supply circuits apply as far as the input terminals of the switches. They apply to the whole lighting and socket outlet circuits of the machine room and the pulley room.’

In the UK, ‘national requirements’ will usually mean BS 7671 (+ A3: 2015) (BSI, 2008). BS 7671 specifically excludes lifts covered by parts of BS 5655 and BS EN 81. It should be noted that the inclusion of the lift well lighting under BS EN 81-20 is a change from BS EN 81-1/2 (+ A3: 2009) (BSI, 1998a/b).

Clause 8.1 of BS 5655-6: *Lifts and service lifts. Code of practice for the selection, installation and location of new lifts* (BSI, 2011a) provides useful guidance on the specification of the main electrical supply for lifts. BS 5655-6 recommends that the lift circuit is fed from the intake room and that the electrical supply to the lift(s) is kept separate from other building services.

In particular, BS 5655-6 describes the information to be exchanged between the lift contractor and the electrical designer. The lift contractor should declare various details to allow the electrical designer to provide an adequate electrical supply:

- nominal voltage (with tolerances), number of phases, frequency and characteristics of electrical supplies
- full load current
- starting (acceleration) current and its duration
- maximum permissible voltage drop
- any other relevant details which might include, for example, the rated number of lift starts per hour, specified ambient temperature range, other requirements for power supplies including the need for secondary supplies for firefighting or evacuation lifts, diversity factors where there is a group of lifts etc.

This information is required to enable the lift electrical designer to make a suitable design of the electrical supply. This design should result in adequately rated supplies to meet all operational demands, including meeting maximum power demands for simultaneous starting and stopping of lift cars.

BS 5655-6 also recommends that the lift contractor specifies the size and type of fuses (or circuit breaker) to be fitted in the lift main isolating switch. The selection of the fuse size by the lift contractor depends on a number of parameters relating to the motor and drive system used. As mentioned in BS 5655-6, the value of the prospective short circuit current (the highest value of fault current which could flow

if a phase were shorted to earth) at the lift isolating switch is required to be advised to the lift contractor by the electrical designer. This is required to enable the lift contractor/designer to complete the electrical design of the lift including selection of fuse or circuit breaker.

Lift equipment is designed to run on the electricity supplies as defined by the lift contractor. Installation of voltage regulators that are not approved by the lift equipment manufacturer and similar devices between the mains supply and the lift equipment may cause damage to and failure of lift equipment. So it is important that the use of such systems is discussed and agreed with the lift contractor as part of negotiation.

Where voltage reduction systems are applied to existing installations, their suitability must be discussed with the lift contractor. BS 7255 (BSI, 2012a) includes the following within clause 4.6: 'The owner should notify the lift contractor before they make any modifications to the electrical supply, e.g. voltage reduction systems.' There are many potential pitfalls in the application of voltage reduction techniques to existing installations. In such circumstances, expressed and implied warranties on the lift equipment may be invalidated if the lift equipment installer has not agreed to such modification to the electricity supply.

Typical schedules for the electrical system requirements can be drawn up for the lift installation with cross-references to associated services (see Appendix 12.A1 for typical schedules for the machine room, lift car and lift well respectively). This information could be exchanged and agreed between the parties involved in specifying, designing and installing the lift systems and lift's services. At each interface it should be made clear who is responsible for designing and supplying the relevant equipment and systems. It should also be agreed what facilities are considered essential.

Secondary power supplies are typically required to be provided on lifts such as firefighting and evacuation lifts by standards such as BS EN 81-72 (BSI, 2003, 2015) for the design of firefighters' lifts, and standards for the design of buildings for fire such as BS 9991 (BSI, 2011b) and BS 9999 (BSI, 2008b). These standards, along with BS 7671 (+ A3: 2015) (BSI, 2008a), have recommendations on the provision and protection of both the primary and secondary supplies. See chapter 6 for more on the primary and secondary supply requirements of firefighting and evacuation lifts.

Installation methods for lifts may require temporary supplies at both a standard 110 volts (55-0-55, centre tapped to earth) safety supply in accordance with BS 7375 (BSI, 2010a) and a 400 V (–6% +10%), three-phase supply to be available. The power capacity of the three-phase supply should be such as to allow the lifts to be commissioned and tested. Inadequate power capacity will cause delays and may require re-tests when the correct supply is available. If the lift electricity supply source is changed (e.g. temporary construction site supply to permanent supply for the building) after the lift test then the supply should be tested at the lift isolator and a new supply safety certificate should be issued by the supply installer. It might be necessary for some elements of the lift test (e.g. for earth continuity testing/verification of conditions for protection by automatic disconnection of the supply, and/or for the drive system) to be repeated.

12.3 Lift power factor correction

Power factor correction (PFC) is a technique used usually where there are AC motors connected directly to the three phase supply (i.e. without an electronic drive). Then PFC helps to keep the power factor of the lift while running greater than 0.9 and hence helps to reduce the current drawn from the electrical supply.

Many lifts use variable frequency drives and these do not require additional power factor correction as their power factor is good. Lifts using variable voltage AC (VVAC) drives and DC static converter drives (SCD) have such a wide range of power factor over their speed and load range that it is not practicable to provide power factor correction to bring the power factor up to or greater than 0.9 for all these conditions.

So PFC is not often fitted but, where it is fitted, it should be in the machine room or machinery space; fitting it remotely from the lift machine may cause overloading of the capacitors and possible resonance effects. When using automatic power factor correction equipment it is essential to ensure that there is sufficient inductive impedance between the lift and this equipment to prevent voltage notching due to capacitor charging tripping out the drive protection on lift drives.

12.4 Protection of supplies

Lifts must be protected against malfunctions in the power supply feeding the lift installation as shown in Table 12.1 and a typical schedule of voltage drop checks in Table 12.2.

12.5 Standby power

The risk of electrical supply disruption, owing to a variety of causes, as discussed above should be considered in the provision of electrical supplies for lifts. Historically, the UK has enjoyed an extremely reliable electrical power supply. However, to borrow a phrase from the investing world, past performance may not be a good predictor of future results. It is outside the scope of this Guide to consider such issues in depth and readers are invited to explore discussion elsewhere (Hitchin, 2014) but it is worth noting that the power supply network, over the period for which this Guide will be current and further into the future, faces a number of challenges that may have implications for the security of supply:

- many conventional power stations may be retired to meet various commitments to reduce CO₂ emissions thereby reducing the baseline generating capacity (also given that new generating plant has a long design and construction lead-time and so cannot be provided quickly)
- the growth of renewable generation capacity which might not be continuously available
- the proliferation of micro-generation changing the characteristics, of and possible de-stabilising, the network
- demand might not reduce as quickly as hoped due to the implementation of energy saving initiatives.

Table 12.1 Protection of supplies

Fault	Cause
Absence of voltage	Loss of voltage may be due to a system fault where power has been isolated by the operation of a protective device or due to loss of mains supply. On restoration of power, the lift returns to service automatically provided that there is no fault with the lift. The lift controller should ensure that normal controls and safety devices function correctly when power is restored.
Voltage drop	A drop in voltage may be caused by a weak supply (i.e. high impedance source) and/or a particular mode of operation of plant and equipment in the building and may be exacerbated by voltage reduction systems in the supply to the lift. Such conditions may exist when many independent loads are switched at the same time. Table 12.2 provides a checklist to help determine the cause. If the power distribution system for the building is incorrectly designed, the problem may occur every time there is multiple switching of loads. When correctly designed, the electrical supply to the lift installation should not suffer a drop in voltage outside the limits agreed with the lift contractor for all modes of operation of all of the services in the building.
Loss of a phase	Loss of continuity of a conductor or loss of a phase can be the result of a broken conductor, or the operation of a single fuse. The lift control equipment should detect this condition and shut down. Normal operation can be resumed when the three-phase supply is restored and any lift control and/or motor protection has been reset.
Phase reversal	This can occur when alterations are made to the main electrical distribution system in a building. Where this could cause a dangerous malfunction (where motors are connected directly to supply and not through an electronic drive), means should be provided to detect an accidental phase reversal.

Table 12.2 Typical schedule of voltage drop checks

Item	Check required	Comments
1	Reliability of external supply	If the supply is subject to voltage fluctuations consider the installation of a voltage stabiliser to feed the lift
2	Operation of other loads on the power distribution system*	Carry out load flow study
3	Operation of other independent loads*	Consider interlocked or sequential starting controls
4	Volt drop on lift feeder cables*	Size cables to ensure that under the worst operating conditions the voltage drop is always within limits agreed with the lift designer

* May require dynamic load flow study of the power distribution system. Note that these items can be exacerbated by the presence of voltage reduction systems resulting in occasional faults.

Consequently, the risks of supply disruption in the future may be greater than in the past. Where there are systems in the building that need to be able to operate if the primary supply fails (such as for business continuity or evacuation), many buildings, particularly large ones, have provisions for standby power. The cost of providing a standby supply is usually high in relation to its expected operating life. The tendency, therefore, is to keep the standby capacity to a minimum to meet only essential loads.

Essential loads may include firefighting plant, partial or full lighting, consumer power supplies, computer power supplies, lifts, HVAC plant etc. The standby supply should be sized to meet all the demands of the dynamic loads (electrical) attached. The general design considerations in the previous sections should be noted. In addition the following should be considered in relation to the provision of standby power for lifts:

- the initial load acceptance of a generator on change-over may be much less than the full-load rating (e.g. in the region of 60%)
- controlled sequential starting of lifts and possible reduced speed running of lifts (other than firefighting or evacuation lifts)
- limited or special-purpose mode of operation of the lifts (if a full service is not required)

— the effect of regenerated energy if the lift(s) regenerate(s) energy onto its supply since generators are typically limited in their ability to absorb such energy and so may need to be sized either to accept the regenerated energy or alternative measures agreed to absorb it

— electronic drives can produce harmonic current levels which are not compatible with alternators designed to supply lighting loads

— where there are several lifts or groups of lifts, the lift contractor should specify the type and number of control cables to be run between lifts for standby supply control purposes.

Any operational restrictions imposed on the lift installation when operating under standby power should be clearly identified and agreed between the lift contractor and the purchaser. Where a lift requires cooling or heating equipment to operate to allow the lift to function then these should be supplied from the standby supply. The lift contractor should indicate the supply requirements of the lifts (see section 12.2) including issues such as those identified above to enable the designer of the standby power system to size the equipment required.

12.6 Secondary power supplies for firefighting and evacuation lifts

The provision of secondary power supplies is essential for firefighting lifts so they are required by both BS 9999 (BSI, 2008b) and by BS EN 81-72 (BSI, 2015) (see chapter 6, section 6.3.5). Secondary power supplies are often provided for evacuation lifts to meet clause G.2.2 of BS 9999, which also allows the provision of a separately fused protected circuit fed directly from the main incoming electrical supply to the building located in a fire protected enclosure (see chapter 6, section 6.6.3). Where the secondary power supply and electrical distribution fall under the definition of safety services in BS 7671 (+ A3: 2015) (BSI, 2008a), which would usually be the case for firefighting lifts and evacuation lifts, then the requirements in chapter 56 of BS 7671 would be applicable.

The secondary supply allows continued operation of the firefighters' or evacuation lift in the event of failure of the primary supply — whether by fire in the building or for some other reason. The secondary supply may be by the provision of a separate supply from a separate substation and there are advantages to this solution; however, this may be subject to additional requirements and approvals. It is more usual to use a generator as the secondary supply as this does not rely on special approvals from the electricity supply company. BS 8519: *Selection and installation of fire-resistant power and control cable systems for life safety and fire-fighting applications. Code of practice* (BSI, 2010b) provides some important guidance on the sources of supply and cable routing/protection which should be considered.

Figure 12.1 below is a schematic reproduced from BS 8519 in relation to a standby generator used as secondary supply. Reference should be made to BS 8519 for further details, which include the following recommendations.

The standby generator should start automatically and be adequately sized to maintain in operation the maximum life safety and fire-fighting load for at least 3 hours without the need to replenish the fuel. The generator starting electrical supply should also be independent of the primary source of supply (i.e. it should incorporate a battery backup).

The standby generator should be capable of providing the supply to the critical life safety and fire-fighting load within 15 s of the failure of the primary supply.

Many of the considerations for the standby supply discussed in section 12.5 apply also so are not repeated here.

Figure 12.2 is a schematic from BS 8519 in relation to another source of supply being used as the secondary supply. There is a number of further issues to be considered with such a specialised system and reference should be made to the requirements of BS 8519 and the electrical supply company. Issues to be considered include (but are not limited to):

- earthing arrangements (the secondary supply may not be provided with an earth terminal)
- segregation of equipment related to the two supplies

- change-over equipment must break the neutral conductor.

Irrespective of the source of supply, the secondary supply should have sufficient capacity to operate the firefighting lift or evacuation lift for a suitable period; typically 2 hours for a firefighting lift. The changeover from primary to secondary power should be automatic on loss of the primary supply and an indication should be provided in the fire service access level lobby to indicate to firefighters when the secondary supply is being used. The use of a generator results in delay after the failure of the primary supply, which is due to detecting the loss of the primary supply, starting the engine and then running the alternator up to synchronous speed to changeover.

Whatever the source of the secondary supply, the type of supply selected, the level of independence between the primary and secondary supplies (to avoid the risk of common mode failures), and the location of equipment and routing of cables are all matters for the building designer taking into account national regulations and an assessment of factors such as the design of the building and reliability of the electrical supplies.

The secondary supply, changeover equipment, cable routes for both the control wiring and the power supplies should be protected against fire for the same time as the lift well (typically 2 hours) and against water. Where multiple lifts are used for these essential duties, the cable routes should be physically separate for each lift or subgroup of lifts. Consideration should also be given as to how the integrity of the fire protection is to be maintained throughout the life of the building.

Other requirements can be found in BS 7671 and BS 8519, including further guidance on the protection of supplies and cables and the selection of cables to ensure continued operation of firefighting lifts in the arduous environmental conditions possible during firefighting.

12.7 Isolating switches, lighting and socket outlets

Harmonised standards require that each lift has a main switch capable of breaking the supply to the lift on all live conductors. The mains switch should be provided in the machine room directly accessible from the entrance, or in the control panel where there is no machine room, or in the emergency and test panel if the control panel is in the lift well.

The main switch should be lockable in the 'off' position, and readily identified and accessible from the machine room entrance(s). Where the machine room is common to more than one lift, it is required that the main switch of the lift concerned can be identified easily, e.g. the main switch and major lift equipment components identified by large, clearly visible numbers or letters. It should be possible on groups of interconnected lifts, to isolate an individual lift without affecting the supervisory control of the remainder.

Where the machine room has more than one point of access or if the lift has several machinery spaces each with its own

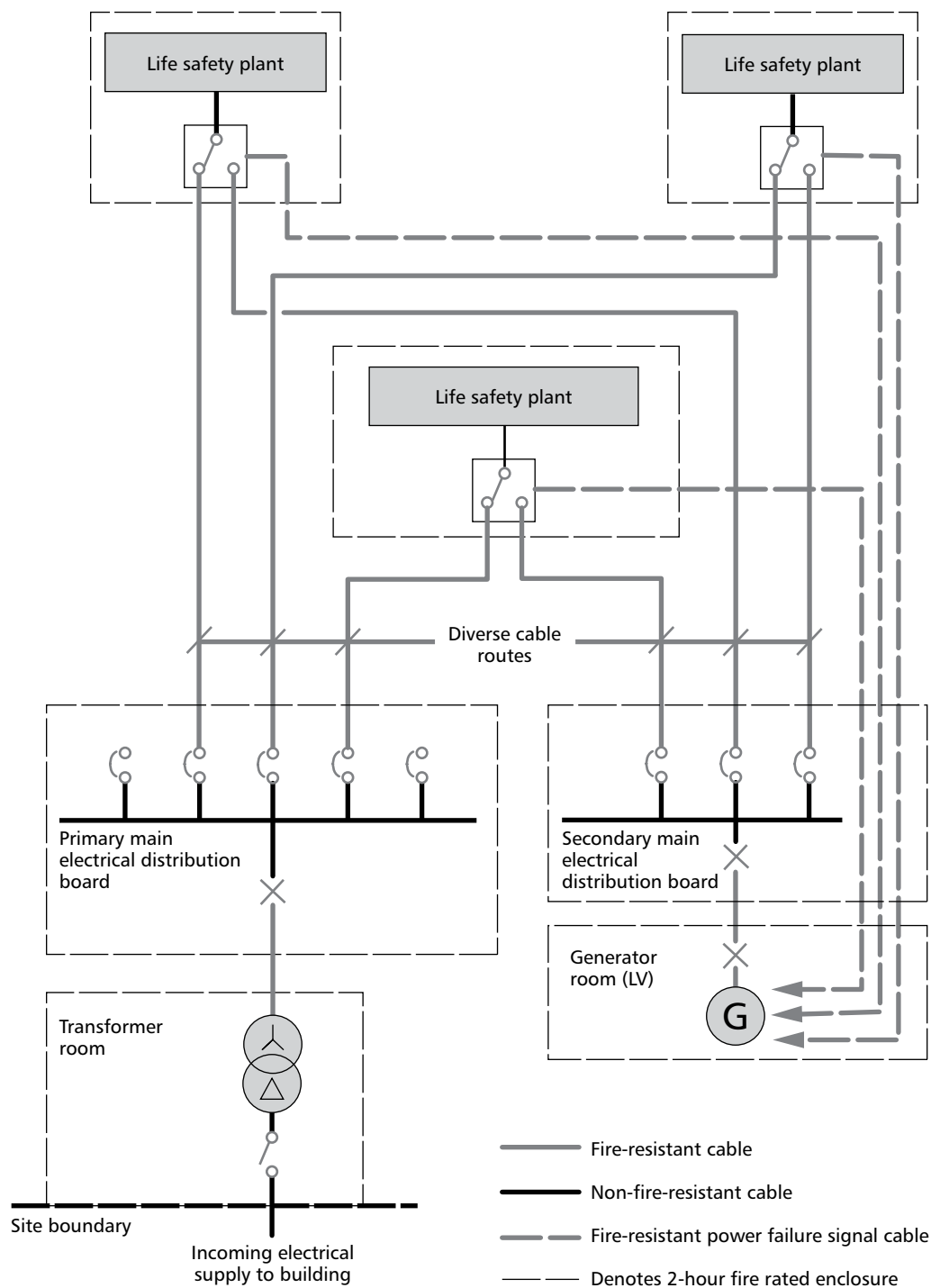


Figure 12.1 Example of dual supply: mains with standby LV generation (reproduced from BS 8519 (BSI, 2010) by permission of the British Standards Institution)

point of access, BS EN 81-20 (BSI, 2014a) allows the supply to be isolated by a contactor controlled either by a safety contact or by a device for disconnecting electrical equipment (BS EN 60204-1 (+ A1: 2009) (BSI, 2006)). The use of such a solution allows the supply to be isolated at points where work is to be carried out without returning to the main switch to make the isolation.

The lift main switch is dedicated to the lift and it should not isolate:

- the lift car lighting or ventilation
- the lift car roof socket outlet
- the machinery space, machine room or pulley room lighting
- the lift well lighting

— pit, pulley room, machinery space or machine room socket outlets.

It is also recommended that the main switch does not isolate the emergency alarm device (often an auto-dialler powered from a separate supply to that of the lift) or intercom.

The lighting supply to the car, the well, machinery spaces/pulley rooms, emergency and test panel, and the supply to socket outlets in the pit, the car top and in machinery spaces, should be from a circuit separate from the lift power supply, e.g. a nearby distribution board, or taken from a point on the supply side of the main switch. These circuits should be controlled by a fused switch (or circuit breaker) in the machine room. For multiple lifts with a common machine room, a separate fused switch (or circuit breaker) should be provided to the lighting supply for each car. Lift

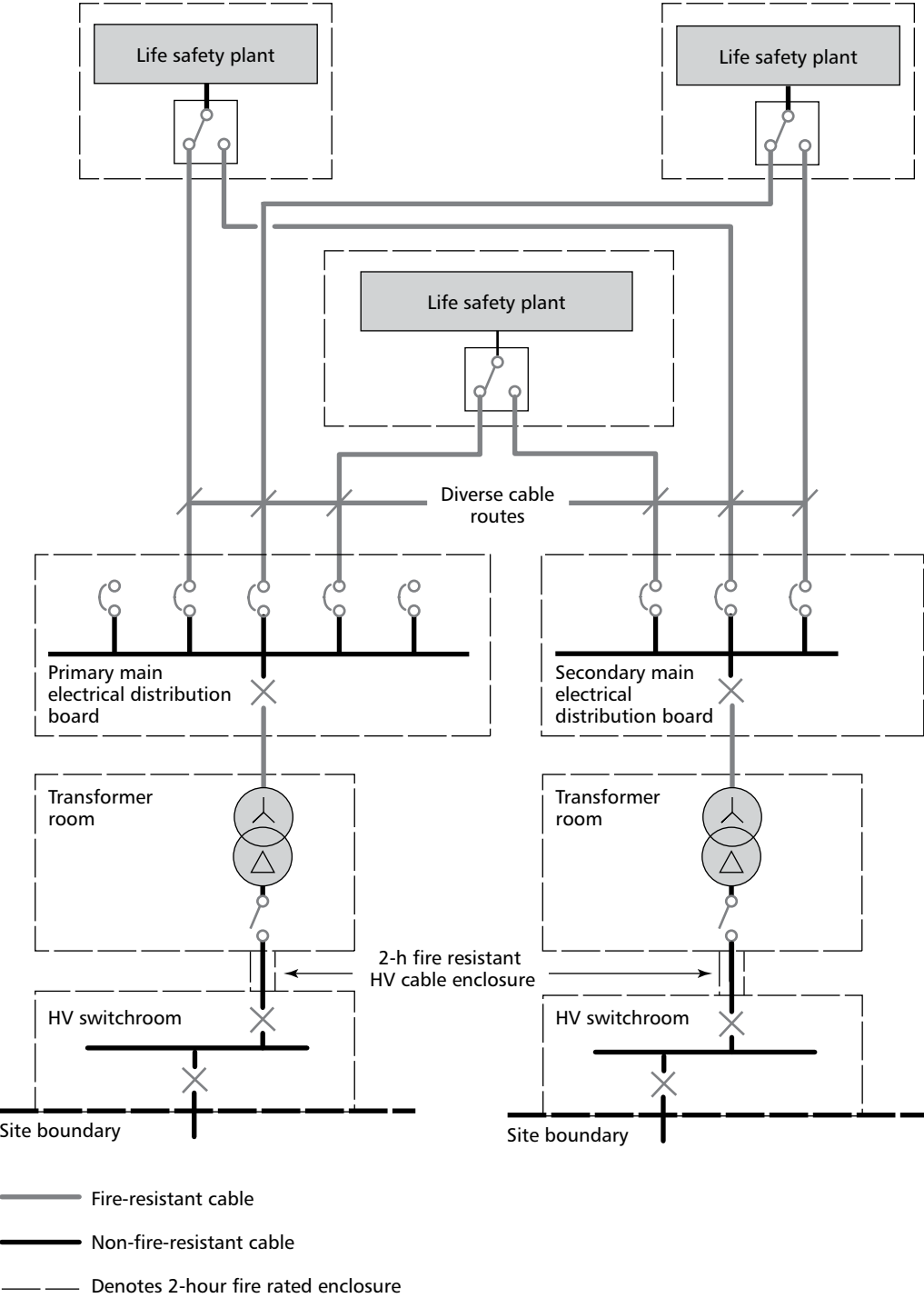


Figure 12.2 Example of dual supply: mains with standby primary utility supply (reproduced from BS 8519 (BSI, 2010) by permission of the British Standards Institution)

well lighting should be controlled from the pit and near than main switch, i.e. two-way switching (or three way switching if also to be controlled from the car top).

Socket outlets are required in pulley rooms, on the car roof, and in the machinery spaces. These are SP+N+E and come under national regulations and so, in the UK, would usually be 230 V, 13 A socket outlets; preferably fed from an RCD. Where the machine room is large, it may require several switched 13 A socket outlets to enable effective maintenance.

It is recommended that a consumer unit be fitted, dedicated to the lift installation’s small power and lighting circuits. All isolators and switches must be clearly and indelibly marked and identifiable when viewed from the entrance to the machine space (if directly visible from that point).

12.8

Electromagnetic compatibility and harmonic distortion

12.8.1

Electromagnetic interference

The lift installation will be subject to varying degrees of interference caused by voltage disturbances on the mains power supply (i.e. switching surges), induced voltages in control cabling and radio-frequency interference. The lift installation must not malfunction in an unsafe manner as a result of such interference, no matter how caused.

The system designer has a duty to minimise the possibility of interference being caused to the lift installation while

the lift manufacturer is responsible for ensuring that the equipment is properly designed and protected to prevent malfunctioning should any interference occur.

The complete lift installation must comply with the UK Electromagnetic Compatibility Regulations 2006 (TSO, 2006) implementing the EMC Directive (OJ, 2004). Product-specific requirements relating to the emission of, and immunity from, electromagnetic interference are given in BS EN 12015 (BSI, 2014b) and BS EN 12016 (BSI, 2013) respectively. Both standards are harmonised under the EC EMC Directive while BS EN 12016 is also harmonised under both the Machinery Directive (OJ, 2006) and the Lifts Directive (OJ, 1995). Both the system designer and the lift manufacturer should comply with the requirements of these standards.

The components used to make up the lift installation need to satisfy all of the requirements of the various standards concerning interference. In some instances, this may be enough to satisfy the demands for the installation. However, where lifts may be installed close to sensitive electronic equipment such as that found in laboratories, hospitals, operating theatres, computer rooms, communications facilities etc., additional design measures may need to be taken over and above compliance with the harmonised standards.

Notwithstanding any such tests and individual component compliance, the lift manufacturer should confirm in writing any limitations on the use of radio equipment in the vicinity of the lift installation. In particular, whether hand-held radio transmitters may be used adjacent to the lift controllers during maintenance work when covers are removed or panel doors are open. Similar assurances are also required for the use of hand-held radio transmitters either inside or on top of the lift car. Consideration must also be given to the effect of fixed radio or microwave transmitters mounted on the roof near to the lift machine room. These are usually outside the control of the lift contractor so it would be for the building designer to advise the lift contractor of such installations in proximity to the lift installation and for negotiation between them to determine a satisfactory solution. It would usually be unacceptable to locate such equipment within lift machine rooms.

12.8.2 Harmonic currents

Since lifts, especially those with variable speed AC drives, present non-linear loads, all lift controllers and their associated motor drives draw non-sinusoidal currents. These include harmonic currents that will generate harmonic voltages on the power distribution system. The magnitude of the harmonic voltages will be dependent on the impedances of the distribution system and of the power source. These harmonic voltages can cause damage to other equipment if they exceed the limits specified by the electricity supply authority or the power system designer.

Lift installations which incorporate solid-state controllers (see sections 8.3.3 and 8.3.4) will draw significant harmonic currents, which should not exceed those permitted by the electricity supply authority. These limits relate to the maximum kV·A rating of the device drawing the harmonic current. The Energy Networks Association's Engineering Recommendation G5/4-1 (ENA, 2009) sets down limits for the magnitude of the individual current harmonics and the

voltage distortion. Lifts are required to comply with the harmonised standard BS EN 12015 (BSI, 2014b), which includes main harmonic limits based and which states that: 'lifts, escalators and moving walks are considered as professional equipment as defined by EN 61000-3-2 therefore the requirements of EN 61000-3-12: 2005 shall be applied as well to a system (equipment) less than 16 A per phase'. Lifts system with harmonic distortion within these limits should usually be acceptable under G5/4-1.

Where multiple controllers are provided to control multiple lifts, and they are fed from the same supply, an assessment should be made of how the individual harmonic currents for each individual load will add up. However, in determining the total it should be noted that the arithmetic sum of the individual harmonic load currents is modified by a 'coincidence factor'.

In many large installations, harmonic filtering equipment will be needed for the lift controllers to ensure that the harmonic currents drawn do not exceed the supply authority's specified limits. However, filters should not be introduced without considering their adverse effects. For example, under certain load conditions they may cause damage to, or malfunctioning of, other equipment connected to the power distribution system, particularly power factor correction capacitors.

Information on the magnitude of the harmonic currents drawn by the lift controllers should be conveyed to the manufacturers of any standby power plant. Failure to do so could cause damage to, and/or malfunctioning of the standby power system.

12.9 Cabling and wiring

12.9.1 Cable sizing

The supply cable to the lift installation should be sized by the electrical designer to satisfy the separate requirements in BS 7671 (+ A3: 2015) (BSI, 2008a) for voltage drop, current carrying capacity, and the ability to withstand bursting and heating effects of short circuit current. The exchange of information between the electrical designer and lift contractor required for this was discussed in section 12.2. The following provides further discussion of aspects affecting the cable sizing criteria.

When determining an acceptable voltage drop, it is essential to take account of conditions of the power distribution system for its worst operating conditions at:

- (a) start up
- (b) abnormal or emergency conditions.

The power distribution system may be particularly heavily loaded under these conditions and normal voltage variation limits may be exceeded. The maximum variation allowed for the equipment connected to the system should not exceed the calculation for the worst case situation.

Lift motor starting currents can be high. The maximum voltage drop during starting should not allow the voltage across the motor terminals to fall below that required for the pull-out torque needed to get the connected mechanical

load up to speed. It is most important that the minimum and maximum allowable voltage limits are provided by the lift manufacturer for both the power supply to the controller and to the lift motor.

Note: it is for this reason that the supply voltage to lift installations should not be reduced without discussion with the lift contractor and a test of the lift’s ability to operate on the worst case supply voltage and worst case lift loading (typically starting and accelerating a fully loaded lift car).

Warning: most computer programs for cable sizing do not take account of the increase in fault current that synchronous or induction motors contribute to faults. There is no allowance that can be included in these programs. The calculated results will therefore be lower than measured (e.g. a rooftop plant room with large fans and pumps fed from a switchboard in the rooftop plantroom will experience higher short circuit currents than those calculated taking into account its supply feeders from the ground or basement transformers).

When assessing the current carrying capacity of a cable supplying one lift, BS 5655-6 (BSI, 2011a) allows the cable size and fuse ratings on the supply side of the lift main isolating switch to be selected taking into account the overload current protection provided by the lift contractor within the lift installation.

When assessing the current carrying capacity of a cable supplying more than one lift, a diversity factor may be applied to the full load current of each lift. Examples are given in Table 12.3, which is included as guidance in BS 5655-6. Where the supply cable feeds more than four lifts, the lift contractor should be consulted. The use of other diversity factors, provided by or agreed with the lift designer, may be used and which could reflect factors such as variations in lift current with load patterns and the local re-absorption of current regenerated from other lifts fed from the same supply cable.

Table 12.3 Example diversity factor for lifts (source: BS 5655-6 (BSI, 2011))

Number of lifts	Diversity factor
1-2	1.0
3	0.9
4	0.8

Supply cables for lift installations and their ancillary services, lighting and socket outlets should be segregated from other building services. BS 5655-6 recommends that the lift circuit from the intake room should be separate from other building services. Supplies for firefighting and evacuation lifts should be segregated so that the rest of the building supply can be isolated in the event of fire in all or part of the building and to allow the additional protection of those supplies.

As noted in section 12.6, further considerations apply to the selection of supply cables for firefighting lifts including adequate volt drop and current carrying capacity during raised ambient temperatures possible during firefighting operations.

12.9.2 **Wiring interfaces**

The initial specification must identify clearly the interfaces between wiring directly associated with the lift installation and wiring for other services. These are likely to include:

- intercom and communication systems
- hands-free alarm communications in lift cars
- warden call alarm systems (in sheltered accommodation)
- remote emergency bells/sounders (*Note:* not a requirement of BS EN 81-20)
- connections required for equipotential bonding and earthing
- remote monitoring and signalling to building management systems
- heating and ventilation of the machine room and lift well (see sections 12.10 and 12.11)
- lift well lighting
- lift well socket outlets
- fire alarms and detection equipment
- security systems.

Precise information should be provided wherever such interfaces occur to ensure that the correct signals will be transferred. A schedule of interfaces (see Table 12.4) is recommended so that all the relevant parties can comment on the proposed system and confirm that the required signals are compatible.

12.9.3 **Maintenance safety and records**

BS 7255: *Code of practice for safe working on lifts* (BSI, 2012a) includes recommendations for electrical supplies and equipment. These are based on the principle that the safety of those working on the electrical parts of lifts depends on the safety and integrity of the electrical supplies. Consequently, the responsibilities for the owner include ensuring that the supply conforms to the relevant requirements of BS 7671 (+ A3: 2015) (BSI, 2008a), that the main switch is adequate and meets basic requirements and that the electrical supply is periodically inspected following IET Guidance Note 3: *Inspection and testing* (IET, 2015) or equivalent guidance. The responsibilities for persons working include recommendations for working safely on isolated equipment and, where necessary, live working. There is further guidance in BS 7255, Annex D, on earth continuity testing and verification of conditions for protection by automatic disconnection of the supply, which refers to BS EN 60204-1 (+ A1: 2009), section 18 (BSI, 2006).

The electrical supply designer should consider risks that maintenance staff may encounter during the routine maintenance of the lift installation; in particular, work in the lift well and on the car top. This is of particular importance when the lift control equipment or machine is located within the well or some other machine space. The designer should identify what provision is to be made for isolation of supplies and for safety in the event of mains failure while working on the lift installation.

Table 12.4 Typical interface schedule

Data transferred	Transfer from	Transfer to	Comments
Power supply (voltage, phases, frequency, prospective short circuit current)	Local isolator (rating)	Lift controller	Interface at isolator (load current)
Lift car lighting (voltage, phases, frequency)	Local isolator at controller	Lift controller (load current)	Fused before isolator; interface at isolator
Lift car power (voltage, phases, frequency)	Local isolator at controller	Lift controller (load current)	Fused before isolator; interface at isolator
Earthing and bonding (cross sectional area of cable)	Earth bar in machine room	All metalwork	Interface at earth bar bonded to earth
Standby power in operation (contacts close when generator is supplying load)	Standby generator controls (volt-free contacts)	Lift controller Indicator at FSAL for firefighting lift	Interface at lift controller

Note: the schedule should be extended to cover all interconnections between the lift installation and other services and/or plant in the building

The technical dossier provided with each new lift installation should conform to BS EN 13015 (+ A1: 2008) (BSI, 2001). Maintenance and operating personnel should be given essential information about the system including drawings showing the associated power distribution system feeding the lift showing power source(s), points of isolation, device ratings and distribution boards associated with the lift installation. These must be kept up to date and should be made available for all those undertaking work on the installation in accordance with the recommendations in BS 7255.

While BS 7255 relates to safe working on lifts, its counterparts are BS 7801 (BSI, 2011c) for safe working on escalators and moving walks and BS 9102 (BSI, 2014b) for safe working on lifting platforms. They are structured similarly to BS 7255 and should be consulted if such equipment is of interest.

12.10 Machinery space environment

Throughout this discussion, the term ‘machinery space’ has been used. This can be the traditional machine room, housing almost any type of lift machine (geared traction, gearless traction, hydraulic etc.) and controller, and machine-room-less where the machine and controller may be located in the lift well or on a lift landing. Whichever is used, the requirements discussed apply to these spaces.

12.10.1 Heat produced from lift equipment

As outlined in section 12.1, aspects such as the dissipation of heat from lift equipment, which would require ventilation of the lift well and/or the machinery space, are assumed to be subject to negotiation, i.e. discussion and agreement between the lift contractor and building designer. The lift contractor should declare the heat to be dissipated from the equipment and the required ambient temperature limits; the building designer is then responsible for ensuring that those requirements are met to ensure reliable lift operation. Adjustments may be necessary when the precise operating conditions for the building are later established. For example, solar heat gain through windows, or waste heat

from other parts of the building rising up the lift well to the machine room, can considerably affect temperatures.

The machine and control equipment of a lift can generate significant quantities of heat such that special ventilation and cooling facilities are needed for machinery spaces. Equipment supplied by different manufacturers will vary in terms of the amount of heat generated and the appropriate values should be obtained from the lift contractor. Some guidance is given in Table 12.5, which indicates that lifts with a large rated load can be more efficient. However, this should be used as a guide and must not be used in preference to specific information from the lift contractor which should always be obtained.

Table 12.5 Estimation of heat losses dissipated in the machine space

System type	Range of motor rating (kW)	Range of heat losses (% of motor rating)
Geared VVVF	7.5 to 30	40 to 28
Gearless VVVF	7.5 to 40	38 to 26
Gearless permanent magnet synchronous motor	3 to 90	28 to 14
Hydraulic	4 to 20	70 to 30

The majority of hydraulic equipment presently available utilises an electric motor and screw driven pump, submerged in the oil reservoir tank (see section 7.3.4). The waste heat generated by hydraulic lifts is usually considerably more than that from a comparable electric traction lift (exceptions being where a counterbalance or hydraulic accumulation is used or where energy is regenerated rather than being dissipated as heat) and the problem of heat disposal is often made greater because the location of the machine room or machinery space. Unlike electric traction lifts, this heat is not dissipated directly into the machinery space, but into the oil reservoir itself. This has the effect of reducing the oil viscosity.

12.10.2 Ambient temperature limits

BS EN 81-20 (BSI, 2014a), as with BS EN 81-1/2 (+ A3: 2009) (BSI, 1998a/b) before, assumes that the ambient temperature of machine rooms and machinery spaces will be maintained between 5 °C and 40 °C. This is not a normative requirement and so it is to be expected that the

lift contractor will specify the minimum and maximum design temperatures for the lift, which might not be 5 °C and 40 °C, along with the maximum heat dissipation of the lift equipment.

It should be considered that the lift machinery, and especially the control equipment, will have a longer and more reliable working life if the temperature is maintained well below the upper limit and therefore require cooling to be provided. An additional benefit is improved working conditions for maintenance personnel.

For new lifts, the harmonised standards require the lift to be removed from service at a landing to allow passengers to leave the car should the design temperature of electrical equipment provided with temperature monitoring devices be exceeded. The design temperature is that which is declared by the lift contractor.

Although the value of maximum temperature varies between lift equipment manufacturers, 40 °C is a reasonable initial assumption for an upper limit. The actual value should be checked with the lift contractor prior to finalising the design of the cooling and ventilation systems for the machinery spaces. It should be noted that non-compliance with the manufacturer's equipment operational temperature limits may invalidate any actual and implied warranties for the affected equipment.

Incident solar radiation through windows, onto landing doors and entrances, or onto controller cabinets located on the lift landings, has been known to cause unsafe high surface temperatures and door distortion, or to cause the removal of the lift from service as described above. Such locations may need the use of reflective window surfaces and other means to control the incident level of radiation.

Hydraulic lift machine rooms are often placed in architecturally convenient locations, such as basement areas or stair cores. In such locations, the ambient temperature may drop considerably, which has a thickening effect upon the oil. Consequently, the lift contractor might specify a higher minimum ambient temperature, e.g. 15 °C. To provide adequate natural cooling of hydraulic power units, the lift contractor might specify a maximum temperature lower than 40 °C as noted earlier.

12.10.3 Ventilation

The harmonised standards require that machinery spaces and pulley rooms must not be used to provide ventilation of rooms other than those belonging to the lift, i.e. the stale air from other parts of the building should not be exhausted into them. Suitable ventilation should be provided such that the equipment is protected from dust, harmful fumes and humidity. There is useful guidance in BS EN 81-20 (BSI, 2014a) in informative Annex E, section E.3.

For machine-room-less lifts installed in low to medium rise buildings where the machine is installed within the lift well, the provision of ventilation to the lift well may be sufficient for all ventilation requirements. However, in some environments, e.g. an exterior location such as a car park, then the ambient temperature should be considered and air conditioning may be required.

Machine rooms for some lifts in high rise buildings may not have (adequate) access to natural ventilation from outside the building. For high-rise buildings with machine rooms on the roof, natural forced ventilation is highly unlikely to provide adequate cooling in hot climates where the outside ambient temperature is above 25 °C on a cloudless day. For these cases, it may be necessary to provide adequate forced air cooling or air conditioning.

12.10.4 Cooling and heating

Where natural ventilation is not appropriate for the building design or adequate to maintain the machinery spaces within their required temperature limits (see section 12.10.2) such as for large multiple lifts and intensive duty hydraulic lifts, suitable heating and/or cooling will be required to the machinery spaces.

Cooling equipment should be dimensioned in order to maintain the required ambient temperature range (see section 12.10.2) with the heat dissipation declared by the lift installer (see section 12.10.1). This should be arranged to avoid 'hot spots', such as the regions near a lift machine or a bank of resistors adjacent to a control panel.

Heating to lift machine rooms should be available at all times and for this reason local electric heating is widely used, often in the form of thermostatically-controlled tubular heaters. Where cooling is also required, packaged heat pumps may offer a cost-effective solution.

Ideally, the heating and cooling plant should be located in a separate room so that it can be maintained without entry to the machine room. Where this is not possible and building services personnel are required to work within lift machine rooms, maintenance of the air handling equipment located in machine rooms must be carried out under the supervision of the lift maintenance company or by competent persons trained in working around lift equipment. BS 7255 (BSI, 2012a) provides more guidance on relevant training and competence requirements for such personnel.

Machine rooms that rely on heating and cooling equipment to control the temperature should be provided with a remote alarm to draw immediate attention to system failures.

In rare instances, lift control panels may require their environment to be more closely controlled than is usually the case. In some cases this may be limited to the control panel itself and panel coolers would be provided. These usually take the form of small proprietary direct expansion air conditioners mounted on top of each panel blowing cooled air downwards through the cabinets.

Oil cooling should be considered, where the duty of a hydraulic lift is likely to result in the dissipation of considerable amounts of heat into the hydraulic oil. This is best provided by the lift contractor as an integral part of the hydraulic power unit. However, removal of the heat should be considered as part of the building design as the simple addition of cooling equipment within the machine room without a means to remove this heat is likely to be ineffective in reducing machine room temperatures. Oil cooling is usually achieved by passing the oil through either a radiant fin cooler on its return to the reservoir or through a fan

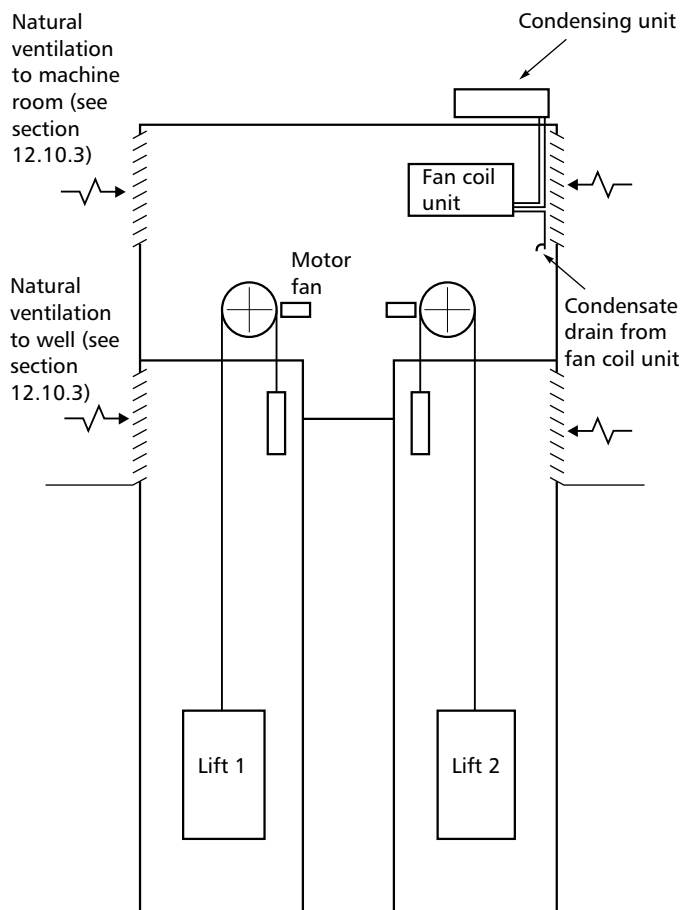


Figure 12.3 Schematic of typical combination heating, ventilating and air conditioning system applied to a rooftop machine room

cooler. The radiator should be mounted outside the machine room unless there is a large volume of cooling air to remove the energy. Similarly, a fan cooler should expel its hot air outside the machine room.

In addition to the implications for reliability and oil viscosity from running hydraulic lifts at higher temperatures, a further issue to be considered is that, as oil temperatures increase, the noise produced by the flow of hydraulic oil through valve blocks increases.

Building designers should also take account of the possible need for standby heating and ventilating equipment. If the building has an integrated heating and ventilating system, they should make suitable arrangements to cope with lift operations when other building services are shut down, e.g. at weekends. Precautions against failure of air conditioning or cooling plant may also be necessary where lift operation depends on these, e.g. in busy buildings or critical applications such as hospital theatre lifts or firefighting lifts.

12.10.5 Lighting

Machine room, pulley room and machinery space electric lighting should provide at least 200 lux at floor level in working areas (50 lux to move between these areas), should be permanently installed and controlled from switches (two-way or intermediate, if appropriate) adjacent to all of the access doors. Access to machine and pulley rooms and machinery spaces is required to be permanently lit. The provision of emergency lighting should be according to the

requirements of the lift contractor and as required by BS 5266-1 (BSI, 2011), not only to permit escape but also to enable the undertaking of procedures such as hand-winding or passenger release during a power failure.

12.11 Lift well environment

Harmonised standards require that the well be suitably ventilated and not used to provide the ventilation of rooms other than those for the service of the lifts. There has been a note in BS EN 81-1/2 (+ A3: 2009) (BSI, 1998a/b) (and therefore not a requirement) in relation to ventilation openings and this does not appear in BS EN 81-20 (BSI, 2014a). It is therefore for the building designer to assess the ventilation requirements of the lift spaces, as for other spaces in the building, and to ensure that they are suitable ventilated. While there may be generally sufficient ventilation for persons in the well via clearance gaps in the door entrances, ventilation requirements should be assessed if required for cooling of lift machinery in the well (see section 12.10), and in the case of trapped passengers in the lift car (see section 12.12). BS EN 81-20 provides some guidance on this matter in section E.3 of informative Annex E.

For lifts with speeds in excess of 2.5 m/s, wind noise and transient changes in lift well air pressure may occur due to lift car movement if pressure relief vents are not provided in the lift well walls. This can cause landing door rattle, wind whistle in lobbies and poor ride comfort. It is recommended that measures to address this are discussed and agreed between the lift contractor and building designer.

For conformity to harmonised standards, lift well lighting should be installed so as to provide a minimum light intensity of 50 lux on the car top and in the pit at all positions of the car travel through the lift well. When control equipment and machinery is located in the well then the lighting level at the working location for those devices must be 200 lux. These should be controlled from the machinery space by a switch with a warning pilot light and by a switch within the lift well, either at the bottom entrance or at pit level. In any case the well lighting switch should be accessible from the entrance to the well. The lift well lighting should incorporate emergency lighting to provide illumination in the event of power failure.

A further consideration for the lift well, especially on taller buildings, is the chimney (or stack) effect. This is a well-known phenomenon caused by the difference in density between bodies of air at different temperatures; warmer air has a lower density and so rises above cooler, denser air. This is clearly very useful for natural ventilation and is the driver of natural ventilation within a stopped lift car (see section 12.12). However, the chimney or stack effect also has implications for the design of buildings incorporating lifts, see Figure 12.4.

Chimney (stack) effect in buildings is driven primarily by the difference in temperature between the air inside and outside the building, and the height difference between the building and the neutral pressure level (NPL). In summer, the external temperatures might exceed those inside the building where the cooler, denser air will tend to cause a downward movement of air in the building. The reverse

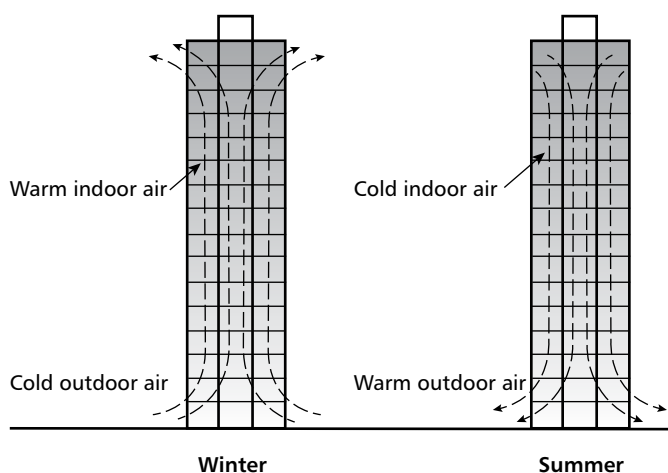


Figure 12.4 Illustration of the chimney (stack) effect in buildings

would be the case where external temperatures are lower as in winter when the effect might be more marked if the temperature difference is greater.

12.12 Lift car environment

The provision of sufficient ventilation within a lift car is deemed an 'essential health and safety requirement' under The Lifts Regulations 1997 (TSO, 1997). The harmonised standards include requirements for the minimum ventilation apertures in the upper and lower parts of the car — at least 1% of the available car area.

Consideration should be given to the effects of breakdowns, especially if people might be trapped inside the car for a prolonged period and especially if the environment of the car in the lift well is subject to factors such as solar gain, low ambient temperature, elevated temperatures and/or humidity; or if those trapped are more vulnerable to effects of entrapment. Although outside the scope of this chapter, the response time to release trapped passengers should also be considered. All these considerations, if relevant, should be discussed and agreed as part of negotiation (see section 12.1). Readers interested in the ventilation of stationary lift cars are referred to work such as Smith (2013).

A small fan extracting air from the car into the lift well may be provided to supplement natural ventilation through the ventilation apertures due to the chimney (stack) effect. It is prudent to ensure that the fan is able to operate on a back-up battery supply in case passengers are trapped as a result of mains supply failure.

Heat gains from light fittings should be considered, especially spotlights which can dissipate substantial amounts of heat. If spotlights are used, an emergency 'off' switch should be provided to reduce the lighting to an emergency level. Solid state LED units provide good illumination with low power consumption. Likewise the use of high frequency low energy fluorescent lighting could be considered to minimise energy consumption.

For external observation lifts, the effects of solar heat gain must also be considered. This may be sufficient to require the provision of comfort cooling during normal operation. Similar considerations apply to lift cars subject to either high or low ambient temperatures. During winter periods lift car heating may need to be provided. In the event of a

breakdown, the loss of comfort heating/cooling could be dangerous to the occupants and the provision of a maintained electrical supply or even duplicate plant should be considered. Where comfort cooling is provided to the lift car, consideration should be given to the disposal of the condensate. This could provide a hazard to health if allowed to collect in the base of the lift well and should therefore be addressed as part of the building design.

12.13 Human comfort conditions

There are many elements of the lift installation that have an influence on the ride quality and noise experience in a lift car. These are typically related to the guidance (guide rails, brackets and fixings) design and installation quality which strongly influence ride quality but elements such as guide shoes, machine, drive system, car design, rotating pulleys etc. also affect ride quality. The resultant noise and vibration characteristic of a given type of lift equipment is also dependant on its environment. For low transmitted noise and vibration applications (e.g. theatres) the client and architect should liaise closely at the design stage with the proposed lift supplier.

BS 5655-6, in relation to quiet operation, has some useful guidance in clause 5.5 including the following:

'The location of lifts should be such as to cause minimum disturbance. Dwelling spaces and especially bedrooms should not be sited adjacent to machine rooms. Beams and structural members associated with the lift installation should not penetrate into such areas; similar considerations might apply to office buildings and other quiet areas. Building design has the greatest role to play in noise reduction and the design of the building structure should take account of this.'

12.13.1 Noise

In the past, the making and comparison of measurements of sound level has sometimes been difficult owing to variations in how these were made. BS ISO 18738-1 (BSI, 2012b) provides a standardised definition for measuring and reporting sound levels.

BS ISO 18738-1 defines the sound pressure level, L_{pA} , as the sound pressure level using frequency weighting 'A' as defined in IEC 61672-1 (IEC, 2002). BS ISO 18738-1 specifies that the maximum and L_{Aeq} (average sound pressure level) sound pressure levels should be reported from 0.5 m after the lift has started until 0.5 m before the lift stops.

The positions at which measurements are made should be noted on a drawing showing the principal noise-producing elements of the lift machinery. No measurements should be closer than one metre from any wall or floor surface.

Criteria for in-car noise levels should take into account lift speed, as high-speed lifts are subject to wind noise. In-car noise criteria should also cover noise resulting from door operations. In hydraulic lifts, the oil flow can generate wide-band high frequency noise which is coupled to the lift car via the cylinder. This can worsen as oil viscosity reduces, i.e. as temperature and/or lift duty increases. The addition

of a silencer on the valve output can reduce this noise level in the car by up to 8 dB(A).

Door noise, when measured at 1.5 m from the centre of the floor and 1.0 m from the door face with a precision grade sound level meter set to 'fast' response, should not exceed 65 dB(A). Noise levels in the car running at the rated speed in the cycle, when measured as above, should not exceed 55 dB(A) for lift speeds of 0.5–2.0 m/s and should not exceed 60 dB(A) for lift speeds of 2.0–7.0 m/s.

The acceptable level of noise in lobbies will vary according to the function of the building. Noise ratings (NR values) for various areas within buildings are given in CIBSE Guide A (2015). NR values are dependent on the frequency spectrum of the noise and there is no constant relationship between noise ratings (NR) value and sound pressure levels in dB(A). However, for practical purposes, the NR is approximately equal to dB(A) – 6.0. The recommended NR for reception areas in offices and hotel lobbies is NR35–40. For public areas in banks, building societies etc, NR35–45 is recommended. For circulation spaces between wards in hospitals, NR35 is recommended.

Lift noise, when measured at 1.5 m from the floor and 1.0 m from the door face should generally not exceed 55 dB(A) at any time during the lift cycle. For lifts opening directly into office spaces (i.e. where there is no lift lobby), this limit should be reduced to 50 dB(A). However, there may be situations where levels up to 65 dB(A) may be acceptable and this should be checked between the client and contractor on each particular project.

It is also necessary to ensure that the sound reduction properties of the lift machine room construction, including doors, hatches, ventilation openings etc, are adequate to prevent the escape of noise at values which exceed the acoustic design criteria for the surrounding areas.

12.13.2 Vibration

Human response to vibration is greatest at low frequencies. Furthermore, human susceptibility to vibration differs between horizontal and vertical vibration and this should be taken into account when specifying acceptable limits of vibration.

Measurements and analysis should be carried out in accordance with BS ISO 18738-1 (BSI, 2012b), which defines methods for the measurement of lift ride quality that have been adopted as standard by the lift industry. It should be noted that BS ISO 18738-1 does not provide guidance or requirements on acceptable levels of noise or vibration as made clear in its scope which includes the following:

'This part of ISO 18738 specifies requirements and methodology for the measurement and reporting of lift ride quality during lift motion. It does not specify acceptable or unacceptable ride quality.'

Although BS ISO 18738-1 offers no guidance on acceptable levels, the following are offered as typical suggestions:

- (a) Horizontal vibration frequency range 1–80 Hz inclusive: maximum (RMS) acceleration level should not exceed 0.08 m/s².

- (b) Vertical vibration: at maximum speed: maximum (RMS) acceleration level should not exceed 0.08 m/s² in the frequency range 1–80 Hz
 - during acceleration/deceleration and start/stop periods: the maximum (RMS) acceleration level should not exceed 0.1 m/s² in the frequency range 1–80 Hz.

The above limits apply to lifts with speeds up to 4 m/s. Lifts having higher speeds will be subject to increased vibration limits. For lift speeds in the range 4–7 m/s, a multiplier of 1.5 may be used for all acceleration level limits.

These measurements are taken using computer controlled measuring equipment that allows direct comparison of ride quality from installation to installation. The use of Fourier analysis techniques also allows the fine resolution in the frequency domain not given by 1/3rd octave filters. This is essential for the identification of any troublesome sources of vibration in the lift.

12.13.3 Acceleration and deceleration

'Ride quality' is also a function of the acceleration and deceleration speed profiles and it may be considered necessary to specify criteria for these characteristics. To avoid excessive discomfort for persons with disabilities, pregnant women and older people it is suggested that lift acceleration and deceleration values should not exceed 1.2 m/s². Acceleration and deceleration values are obviously linked to optimum lift response times and, to some extent, it may be necessary to compromise between comfort and travel times. The highest values that should be considered are 1.4 m/s². Where lifts travel times are not required to be optimised for traffic design, even lower values are recommended for the comfort of these groups; 1.0 m/s² or even 0.8 m/s² are appropriate for lift rated speeds less than 1.6 m/s. The specification of lower acceleration rates is advantageous as it allows the peak torque required to be provided by the machine to be reduced and this may have an impact on drive system selection (and cost) and also on energy efficiency.

12.13.4 Jerk

Passenger and ride comfort will also be affected by the jerk, i.e. the rate of change of acceleration and/or deceleration. Acceptable jerk values for lift performance are dependent on the lift speed and acceleration. Their values are linked to optimum lift response times and it may again be necessary to compromise between comfort and travel times. It is suggested that jerk values 50% numerically larger than the numerical acceleration/deceleration values should be used with a maximum value of 2.0 m/s³.

12.13.5 Lighting at landings

Harmonised standards require the luminance of electric or natural lighting to be at least 50 lux at floor level at each landing served. This is to ensure adequate lighting for persons entering and egressing the lifts car safely. This level is required even with the lift car lights switched off. The provision of emergency lighting and other requirements should be according to standards covering the building design and building regulations.

12.14 Environment for maintenance

12.14.1 General

In designing the transportation system, it is necessary to ensure that the environment is suitable for the satisfactory operation of the lift. Consideration must also be given to those provisions necessary to ensure a safe and suitable environment for those persons involved in maintaining and inspecting the installation. Many of these considerations are identified in legislation, and resulting guidance associated with the legislation, such as: the Health and Safety at Work etc. Act (HMSO, 1974), the Workplace (Health Safety and Welfare) Regulations 1992 (HMSO, 1992), the Provision and Use of Work Equipment Regulations 1998 (TSO, 1998a) etc. In addition to these, various standards such as BS 7255 (BSI, 2012a), BS 7801 (BSI, 2011c) and BS 9102 (BSI, 2014b) provide authoritative guidance for lifts, escalators and moving walks, and lift platforms respectively. For new lifts installed to harmonised standards, the building fabric and building services requirements for the lift installation, including the machine rooms, wells and pulley rooms, is defined.

12.14.2 Lift well and machine rooms

Harmonised standards prescribe the general requirements for safety of the lift well, machine and pulley rooms. These standards also require that the lift well, machine and pulley rooms must not be used for purposes other than lifts. BS EN 81-20 (BSI, 2014a) has the following:

‘5.2.1.2.1 The well, machine and pulley rooms shall not be used for purposes other than lifts. They shall not contain ducts, cables or devices other than for the lift.

The lift well, machine and pulley rooms may, however, contain:

- a) equipment for air-conditioning or heating of these spaces, excluding steam heating and high pressure water heating. However, any control and adjustment devices of the heating apparatus shall be located outside the well.
- b) fire detectors or extinguishers, with a high operating temperature (e.g. above 80°C), appropriate for the electrical equipment and suitably protected against accidental impact.

When sprinkler systems are used, activation of the sprinkler shall only be possible, when the lift is stationary at a landing and the electrical supply of the lift and lighting circuits are automatically switched off by the fire or smoke detection system.

NOTE Such smoke, fire detection and sprinkler systems are the responsibility of the building management.’

The prohibition on non-lift services in the lift well is an element that is written into the articles of the Lifts Directive (article 6) (OJ, 1995). Consequently it is not possible to seek a deviation from a Notified Body for non-lift services in the lift well.

Fire extinguishers should be suitable for electrical fires and be stable over a period of time, and should be mounted so as to be suitably protected against accidental impact. The inclusion of some mention of sprinkler systems is new in BS EN 81-20. However, the condition attached to the use of

sprinkler systems is onerous as it must be ensured that, before release of the sprinklers, the lift car has been stopped at a landing (with doors open to permit escape of passengers) and the power removed from the lift (and other supplies feeding equipment in the lift well and machine room affected). In the case of firefighters lifts to BS EN 81-72 (BSI, 2015), machinery spaces and the lift well must not contain sprinklers.

Harmonised standards require and define the provision of lighting for machinery spaces to ensure an intensity of 200 lux at working areas (see section 12.10.5) and for permanent electric well lighting to ensure an intensity of illumination of at least 50 lux (see section 12.11). As noted previously, under BS EN 81-20, lift well lighting falls under that standard and so could be installed by the lift contractor. Responsibility for subsequent maintenance of the well lighting for lifts installed according to BS EN 81-20 could then be by the lift contractor but for older lifts to previous standards it is unclear where the responsibility lies. This is because, generally, only the person maintaining the lift is likely to notice the failure of lamps. A supply of replacement lamps should be kept on site to reduce the delay in replacing failed lamps. In modern buildings, fluorescent lamps are the most common and maintenance will be simplified if lamps of the same type are used for both the lift well and machine room.

It should be noted that decorative lighting that is not part of the lift installation should not be designed to be located in the lift well. It is not certain that a Notified Body for the Lifts Directive will provide a design examination certificate for such an installation.

For lift wells that are partially enclosed, such as observation lifts, no exception is made in BS EN 81-20 for permanent lighting which is required.

Attention should be given to the internal wall surfaces of the well. The walls of the well may be constructed of brick, concrete or blockwork, and dry-lined internal facings may also be employed. Each of these can give rise to dust. This should be limited by painting the walls with a suitable proprietary surface treatment as recommended in clause 5.3.5 of BS 5655-6 (BSI, 2011a). Painting the internal surface of the well will not only inhibit the spread of dust but will also provide a clean and safe working environment. For maximum visibility white paint should be used.

In the case of all types of lifts with entrances accessing directly into car parks, particular attention must be paid to providing adequate ventilation of the car, well and pit. This is to avoid the possible build-up of toxic gases in the lift car and well. BS EN 81-20 includes the following in informative Annex E at E.3.2:

‘However for technical needs and in some cases for human needs, the air tightness of the well and the entire building, the environmental conditions, particularly higher ambient temperature, radiation, humidity, air quality, will result in the need for a permanent or on demand ventilation aperture(s) and/or (combined with) forced ventilation and/or fresh air entry. This can also be necessary when transporting certain items such as motorized vehicles where exhaust fumes can be hazardous. This can only be decided on a case by case basis.’

12.14.3 Lifts with limited pit depth and/or headroom

The safe maintenance of lifts installed with limited pit depth or headroom is primarily a safety concern for those working on them. Harmonised standard BS EN 81-1 (+ A3: 2009) (BSI, 1998a) defines minimum refuge spaces at clause 5.7.1.1 d) in respect of headroom and 5.7.3.3 a) in respect of the pit.

Note: when these standards are withdrawn, the refuge spaces in BS EN 81-20 will be used and these may be larger. Where these spaces cannot be provided on a new lift, in addition to approval from a Notified Body, approval, or derogation, from the Department of Business, Innovation and Skills (BIS) is required to enable the lift to be installed legally.

The Lift Regulations 1997 (TSO, 1997) provide that BIS (the Department of Business, Innovation and Skills — the relevant government department for the UK) may grant derogations on the manner in which essential health and safety requirement 2.2 (EHSR 2.2) may be achieved. EHSR 2.2 is set out at Schedule 1 of the Regulations and states:

‘The lift must be designed and constructed to prevent the risk of crushing when the car is in one of its extreme positions.

The objective will be achieved by means of free space or refuge beyond the extreme positions.

However, in specific cases, in affording Member States the possibility of giving prior approval, particularly in existing buildings, where this solution is impossible to fulfil, other appropriate means may be provided to avoid this risk.’

BIS defines that the ‘free space or refuge’ can be met by provision of the relevant rectangular block mentioned in applicable harmonised standards, e.g. BS EN 81-1 (+ A3: 2009) (BSI, 1998a), clause 5.7.1.1(d) in respect of headroom and 5.7.3.3(a) in respect of the pit. Note that when these standards are withdrawn, the refuge spaces in BS EN 81-20 (BSI, 2014a) will be used and these may be larger.

It is clear from EHSR 2.2 and the guidance from BIS that derogation is intended to be used mainly for new lifts in existing buildings. It follows from the above that BIS would grant prior approval only in very exceptional circumstances for a new building. New buildings must be designed, except in very exceptional circumstances, so as to provide enough space for compliant lifts and that this should be priority over other such considerations such as cost or architectural preference. In such a situation, consultants and building designers should be cognisant of section 9 of the Construction (Design and Management) Regulations (TSO, 2015) and in particular 9(2):

‘(2) When preparing or modifying a design the designer must take into account the general principles of prevention and any pre-construction information to eliminate, so far as is reasonably practicable, foreseeable risks to the health or safety of any person—

(a) carrying out or liable to be affected by construction work;

(b) maintaining or cleaning a structure; or

(c) using a structure designed as a workplace.’

and at 9(3):

‘(3) If it is not possible to eliminate these risks, the designer must, so far as is reasonably practicable—

(a) take steps to reduce or, if that is not possible, control the risks through the subsequent design process;

(b) provide information about those risks to the principal designer; and

(c) ensure appropriate information is included in the health and safety file.’

In this context, provision of sufficient building space for the lift to have adequate permanent refuge spaces for those maintaining the lift is clearly a higher priority in the hierarchy (since it addresses the crushing hazard) than requiring the lift contractor to mitigate the risks passed to them from the building designer.

From the perspective of the maintenance contractor, lifts installed under the Lifts Regulations 1997, i.e. since 1 July 1999, whose pit or headroom clearances do not meet the harmonised standards should be subject to a Notified Body approval. To enable the lift to be maintained safely, these details should be made available to the lift contractor. BS 7255 (BSI, 2012a) should also be consulted. In the event that the lift has been installed without these approvals or that it is not provided with adequate provisions to protect the pit and headroom clearances, then the lift maintenance contractor could reasonably refuse to maintain the lift. Similarly, the competent person under the Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) (TSO, 1998b) could also reasonably refuse to carry out a thorough examination.

12.14.4 Machine-room-less installations

Maintenance of control equipment and machinery in a machine-room-less installation is undertaken in the machinery spaces and on a landing for emergency access and movement control panels. All such locations should be illuminated to a level of at least 200 lux for safe working. Sufficient working area should be allowed for maintenance and the safe passage of building occupants. Emergency operation of the lifting machine typically occurs at the top landing and lighting in the lift lobby should be sufficient to undertake maintenance and emergency procedures. All intervention cabinets should be clearly marked and any emergency instructions displayed inside the cabinet. Consideration should be given to the location and safe storage of the landing door emergency unlocking key and its ready access to authorised persons only.

12.14.5 Physical requirements

Harmonised standards define key dimensions of the machine room, machine room door and trap requirements as well as the requirement for the lifting beams. Where machine rooms are built on different levels, permanent ladders and removable guard rails should be fitted if there is a change of level greater than 500 mm. It is recommended that the floors and walls of the machine room are treated with dust inhibiting paint.

12.14.6 Maintenance of third party equipment

Equipment associated with the lift installation, such as fire and smoke detectors, fire extinguishers, air conditioning plant, communications systems etc., requires maintenance by persons not normally authorised to work in lift environments. Arrangements must be made to accompany these persons. However, wherever possible, arrangements should be made to allow these activities to be carried out safely by, for example, locating plant outside lift areas, or in the case of fire and smoke detectors, providing a means of withdrawing them from the well for testing.

12.15 Lightning protection

The bonding of lift guide rails and other lift components to the lightning protection system (LPS) should be carried out with great care.

Protection of buildings and their contents is covered in BS EN 62305, Parts 1 to 4. BS EN 62305-4 (BSI, 2011e) gives schemes for the protection of electrical and electronic systems within structures and BS EN 62305-3 (BSI, 2011f) deals with physical damage to structures and life hazard and mentions lifts.

In informative Annex E: *Guidelines for the design, construction, maintenance and inspection of lightning protection systems* of BS EN 62305-3, clause E.6.2.2: 'Equipotential bonding of internal conductive parts' states:

'Metal installations, i.e. water, gas, heating and air pipes, lift shafts, crane supports etc. shall be bonded together and to the LPS at ground level.'

The term lift shafts is an ambiguous term, but assuming that it means all the components in the lift well then the only location where the lightning protection system and the lift earthing system should be allowed to come into close connection should be at the building main earth terminal in the electrical incoming room. This is a point of low impedance. The connection to the lift well (shaft) can be simply achieved at the main incoming earth bus bar as this is the point where the LPS connection and the lift earthing system are both made, assuming the metalwork in the lift well is properly connected to the lift earthing system.

Care should also be taken to avoid running lightning protection conductors in close proximity to and parallel to guide rails. This reduces the risk of induced currents in the guide rails. Similarly, BS EN 62305-4 requires that power and data circuits are protected against surges, the addition of such protection to the lift installation needs to be done with care and in liaison with the lift installer. This is particularly true where the lift may be connected to building management and other systems in the building.

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Appendix 12.A1: Schedules for electrical systems requirements

Table 12.A1.1 Typical schedule for electrical system requirements: machine room

Requirements	Interface and notes
Power supply for lifts:	
— single supply for firefighting lift	Supply monitored by building management system (BMS)
— single supply for each lift or a single supply to feed each group of lifts	Supply monitored by BMS
— single supply for lift well and machine room power and lighting	Supply monitored by BMS
Power for lift machine room:	
— Small power socket outlets	See BS 5655
Lighting:	
— lift well lights	Prominent means of isolation
— lift car lights	Prominent means of isolation
— lift car (top) maintenance socket outlet	Prominent means of isolation
— emergency lighting	Emergency lighting to enable safe hand-winding operations during a power outage
Environmental control:	
— heating	May be linked to central controls
— ventilation	May be linked to central controls
— cooling	Check if required for internal motor rooms or those subject to high solar gains
Earthing and bonding:	
— all metal work to be bonded and connected to machine room earth bar	Separate machine room earth bar cabled to main building earth
Fire detection and alarm:	
— smoke, rate of rise detectors, manual break-glass stations and sounders	Integrated with main building fire alarm system
Communications:	
— car intercom	Linked to internal building intercom system
— external communications (telephone)	Emergency dial-out feature through public network. Where this may be abused the dial-out may be barred to a single number or routed through the main reception or security desk serving the building
— automatic dial-out	Where remote monitoring of the lift installation for performance and/or alarms is required, an automatic dial-out facility will be necessary using the public network
Fire service	Separate communication between lift motor room, lift car, firefighting lobbies and control rooms
Monitoring and controls:	
— control for reduced lift service (i.e. reduced speed and acceleration when power is limited)	Signal from standby power supply to prevent simultaneous starting and overload, reduce speed and acceleration or other means to limit the lift load current
Status indication and alarms	Interface to BMS and automatic call-out for maintenance

Table 12.7 Typical schedule for electrical system requirements: lift car

Requirements	Interface and notes
Lighting†:	
— normal and emergency lighting	Emergency standby battery system (specify minimum lighting levels required)
— car top	Consider emergency lighting switch in case of additional car top lighting
Controls†:	
— car destination controls	Operation through the lift controller. Is 'key holder' override required?
— door hold controls	
— alarm control	
— maintenance controls (on car top)	Maintenance switch and push
Indication†:	
— position	Operation through lift controller
— selected floor	Operation through lift controller
— overload/car out of service	Operation through lift controller
— remote alarm	Depends on type of communication system
— intercom, telephone, other communications	Machine room and building system
Audio system	Building or lift public address (pa) system
Firefighting communications	Linked to fire service access level lobby and machinery space
Ventilation	Forced ventilation if required
Power	Maintenance power outlet on car top

† These items interface with requirements for special finishes and decor

Table 12.8 Typical schedule for electrical system requirements: lift well

Requirements	Interface and notes
Lighting:	
— permanent well lighting	Controlled from machinery space close to the main switch from and pit with warning pilot light
Power:	
— socket outlet in lift pit	
Earthing and bonding:	
— guide rails and metal landing door surrounds bonded to earth	Connect to building earth system
Heating:	Provided if necessary where there is a risk of condensation; automatic controls or connection to central system
Monitors:	
— pit water flood detector if necessary	Remote alarm
Fire detection:	
— smoke detector	Linked to fire alarm system; detector located at top of the well

13 Energy consumption of lifts, escalators and moving walks

Principal author

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13 Energy consumption of lifts, escalators and moving walks

13.1 Energy consumption and energy efficiency

13.1.1 General aspects

The European Union is increasingly dependent on external energy sources, but has little influence on the energy supply (oil, gas etc.). This is particularly so for the UK. It is possible to reduce energy dependency by improving the energy efficiency of lifts, escalators and moving walks.

The European Community publishes Energy Directives, which in turn give rise in the UK to changes to the Building Regulations. Only passing mention is made of the energy consumption of lifts, escalators or moving walks. This is in part due to the small energy demand (averaging about 5%) made by vertical transportation equipment compared to a building's total energy consumption, and in part to the fact that the lift industry (generally) provides energy efficient products. Examples include counterbalanced lifts and auto-start escalators and moving walks. This does not mean that owners of vertical transportation equipment should do nothing as action may be helpful to save costs and to comply with legislation

The total power consumption over the entire life cycle of any equipment consists of the power consumed to manufacture, install, operate, dismantle and dispose. Of these phases the operational phase is probably the most significant. Figure 13.1 illustrates for lifts the relationship

of their energy consumption in comparison to other energy users in an office building.

Where possible, designers should aim to minimise transportation requirements through good building layout during the design stage (see chapter 2). The number and type of transportation equipment installed in a building is determined by the traffic requirements of the building occupants. Energy cannot be sensibly saved by reducing the number of units installed. However, energy consumption can be minimised through good equipment design, appropriate selection to meet the traffic demands and efficient operational control of the transportation equipment (see chapter 3).

Increased energy efficiency can sometimes involve higher initial capital costs, for instance by specifying energy regeneration. However, this initial capital outlay may be recovered through energy savings over the life time of the equipment.

Thus each application warrants a full cost analysis and possibly modelling to select energy efficient equipment at the design stage. Importantly, capital and operational costs have been reduced as variable speed drives become cheaper.

Obviously, the utility supply company's tariff structure can affect the final cost of the electricity consumption and even may not permit energy regeneration. Figure 13.2 (Al-Sharif et al., 2004) illustrates a lift with a regenerative drive showing what can be achieved when regeneration is possible.

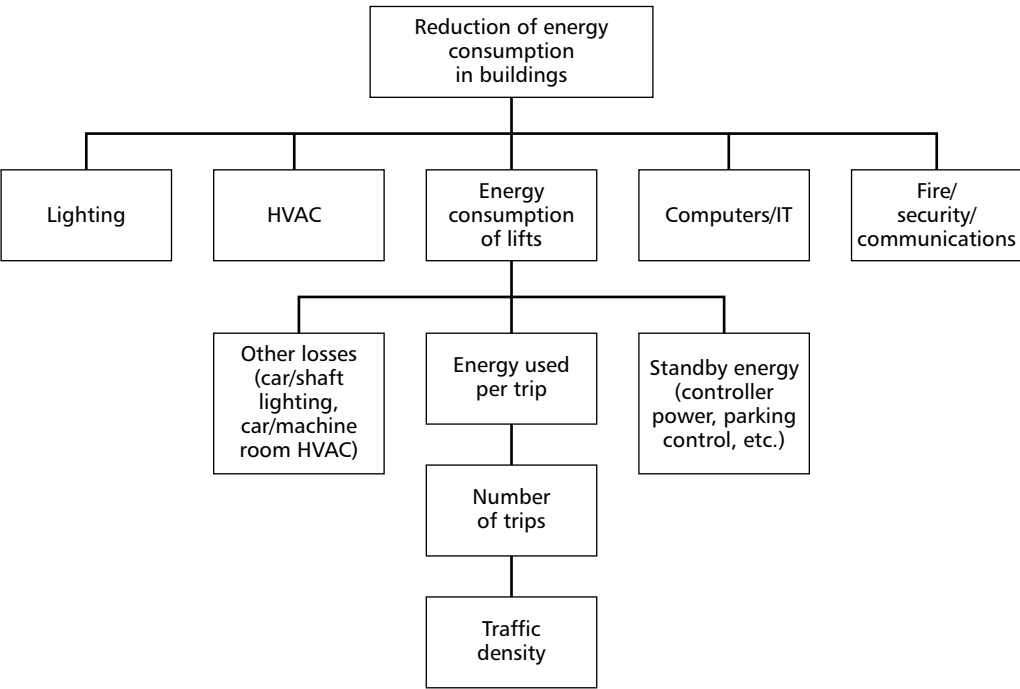


Figure 13.1 Relationship of lifts to other energy consumers in an office building

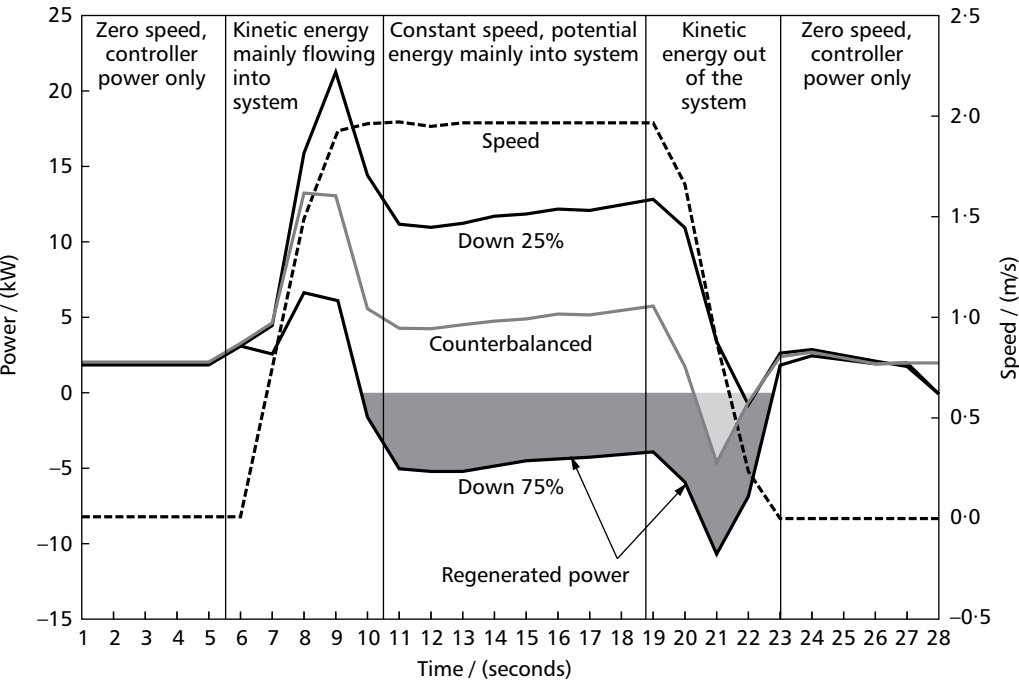


Figure 13.2 Speed and energy consumption of a lift carrying different loads

13.1.2 Reference standards and classification

Lifts and escalators/moving walks provide transportation in buildings. They differ in many ways. Lifts move only vertically and, occasionally, on an incline. Escalators move on an incline and moving walks move both horizontally and on the incline.

Escalators/moving walks fall under the European Machinery Directive (OJ, 2006) and are regulated in the UK by the Supply of Machinery (Safety) Regulations 2008 (TSO, 2008). Escalators/moving walks are factory built and the manufacturer is responsible for compliance with any regulations. They also have close control on all energy aspects and can offer a range of products for which it is possible to declare a precise energy take.

Lifts fall under the European Lift Directive* (OJ, 1995) and are regulated in the UK by the Lifts Regulations (TSO, 1997). Lifts are assembled on site from a number of manufactured components and the installer is responsible for compliance with any regulations. Although the installer can select energy efficient components the quality of the installation and the way a building is operated significantly affect energy consumption.

The International Standards Organisation, Technical Committee ISO/TC 178: Lifts, escalators and moving walks (Working Group 10) has developed and published three standards in the ISO 25745 family, under the general title *Energy performance of lifts, escalators and moving walks*:

- Part 1: *Energy measurement and verification*
- Part 2: *Energy calculation and classification for lifts (elevators)*
- Part 3: *Energy calculation and classification for escalators and moving walks*

These have been adopted in the UK.

* Directive 2014/33/EU, re-cast of directive 95/16/EC

BS EN ISO 25745-1: 2012: *Energy performance of lifts, escalators and moving walks. Energy measurement and verification* (BSI, 2012) provides an agreed international method of energy measurement for lifts.

BS EN ISO 25745-2: 2015: *Energy performance of lifts, escalators and moving walks. Energy calculation and classification for lifts (elevators)* (BSI, 2015a) provides an internationally agreed colour coded set of performance levels for running, idle and standby for lifts.

BS EN ISO 25745-3: 2015: *Energy performance of lifts, escalators and moving walks. Energy calculation and classification for escalators and moving walks* (BSI, 2015b) provides an internationally agreed method to estimate the energy consumption.

The end users of buildings in the UK demand energy efficient products and increasingly have to comply with energy regulations in order to obtain a BREEAM† rating. Many buildings have to indicate their classification by the use of Display Energy Certificates

13.1.3 Arrangement of sections

As lifts are significantly different to escalators and moving walks they will be treated separately in this Guide; section 13.4 deals with lifts and section 13.5 deals with escalators and moving walks.

13.2 Symbols

13.2.1 Lift symbols

E_{rc}	Measured or estimated running energy consumption of the ISO reference cycle (two trips) (W·h)
E_{spr}	Specific running energy for ISO reference cycle (mW·h/kg·m)

† BRE Environmental Assessment Method (<http://www.breeam.org>); other building classifications exist, such as LEED (Leadership in Energy and Environmental Design), Green Star etc.

j	Rated jerk (m/s^2)
k_L	Load factor per trip
n_d	Number of trips per day*
P_{id}	Power used when the lift is in idle mode (W) (measured after door operations have ceased when stopped at a landing)
P_{st}	Power used when the lift is in standby mode (W) (measured after 5 minutes of inactivity.)
Q	Rated load of the target installation (kg)
R_{id}	Ratio of idle time when consuming P_{id} (value<1)
R_{st}	Ratio of standby time when consuming P_{st} (value<1)
s_{rc}	One-way travel distance of ISO reference cycle to BS EN ISO 25745-1 (m)
%S	Percentage average travel distance per trip for a target installation
t_{av}	Time to travel the average travel distance for the target installation, including door times (s)
t_d	Time for the opening, opened and closing times of the lift doors at the landings (s)
v	rated speed (m/s)

13.2.2 Escalator and moving walk symbols

E_{tot}	Energy consumption of unit including ancillary energy ($\text{kW}\cdot\text{h}$)
E_{anc}	Energy consumption of ancillary equipment ($\text{kW}\cdot\text{h}$)
E_{main}	Energy consumption of unit without ancillary energy ($\text{kW}\cdot\text{h}$)
E_{stby}	Energy consumption in standby condition ($\text{kW}\cdot\text{h}$)
E_{as}	Energy consumption in auto start condition ($\text{kW}\cdot\text{h}$)
E_{ss}	Energy consumption in slow speed condition ($\text{kW}\cdot\text{h}$)
E_{nold}	Energy consumption under no load condition ($\text{kW}\cdot\text{h}$)
E_{ld}	Energy consumption due to the transport of passengers ($\text{kW}\cdot\text{h}$)
P_{anc}	Power consumption of ancillary equipment (kW)
P_{stby}	Power consumption to operate in standby condition (kW)
P_{as}	Power consumption to operate in auto start condition (kW)
P_{ss}	Power consumption to operate in slow speed condition (kW)
P_{nold}	Power consumption to operate in no load condition (kW)
P_{nlhr}	Power consumption for hand rail in no load condition (kW)
P_{nlsp}	Power consumption at step/pallet in no load condition (kW)
t_{anc}	Period of ancillary equipment in observation period (h)
t_{stby}	Period of standby condition in observation period (h)
t_{as}	Period of auto start condition in observation period (h)
t_{ss}	Period of slow speed condition in observation period (h)
t_{nom}	Period under nominal speed in observation period (h)
C_F	Correction factor for η applied to units in downward direction
H	Vertical distance between the upper and lower finished floor levels (m)
L	Distance between the comb intersection lines (m)

* A 'trip' is a movement from one floor to another

m	Average weight of passenger (kg)
N	Number of transported persons in observation period
α	Maximum angle to the horizontal in which the steps, the pallets or the belt move (degree)
η	Efficiency due to load conditions
μ	Friction coefficient due to load conditions

13.3 Signing convention



Warning: this sign indicates something that should be avoided.



Caution: this sign alerts the designer to an important consideration.



Design tip: this sign offers a useful design opportunity.



Note: draws attention to important text.

13.4 Energy consumption of lifts

13.4.1 Measuring the energy consumption of lifts

Different estimates for the energy consumption of lifts as a percentage of the energy consumption of the whole building have been suggested, but none of these studies have been sufficiently comprehensive to provide reliable data. To determine the energy consumption of a target installation actual measurements need to be made.

BS EN ISO 25745-1 specifies an accurate method to measure the energy and power consumed by a lift. The measurements are practical to apply in the field and repeatable, when performed by a trained, competent person and they utilize commonly available measuring equipment.

BS EN ISO 25745-2 provides an internationally agreed colour coded set of performance levels for running, idle and standby for lifts.



Warning: what follows is a summary of the requirements of these standards and readers are advised to read and understand the standards in full before attempting to apply their provisions.

13.4.1.1 Operational modes

The BS EN ISO 25745-1 defines three operational modes (conditions): running, idle and standby.

- The running mode is when the lift is moving in either an up or down direction.
- The idle mode is when a lift is stationary at a floor following a run before the standby mode is entered
- The standby mode is when a lift is stationary at a floor and may have reduced the power consumption to a lower level set for that particular lift.



Note: a lift in the standby mode usually has its doors closed with parts of the electrical system de-energized or operating at reduced power.



Caution: for units with power back-up systems, the lift should be connected and operating on the main power with back-up power outputs disabled while the measurements are taken.

The standby mode may be identical to the idle mode if parts of the electrical system are not de-energized or are not able to operate at reduced power.

The standard requires the standby energy to be measured 5-minutes after the lift's last activity. However, some lifts can have further energy reduction modes (e.g. sleep modes). In these cases, measurements can be taken at appropriate times after the doors have closed and without the lift moving from the floor, e.g. at no more than 30 minutes after the last activity.

13.4.1.2 Measuring running energy

BS EN ISO 25745-1 specifies the measurement of the energy consumed by a running lift when making a reference cycle* defined as:

'cycle during which the empty car is run from the bottom terminal landing, to the top terminal landing, and then back to the bottom terminal landing including two complete door cycles'

The ISO reference cycle thus obtains an energy expenditure value for the movement of an empty car from the bottom terminal floor to the top terminal floor and back to the bottom terminal floor (or vice versa), including door operations, see Figure 13.3. The total energy consumed is made up of four components:

- energy to travel from the bottom terminal floor to the top terminal floor
- energy consumed when the lift is stationary at the top terminal floor including that used to operate the doors
- energy to travel from the top terminal floor to the bottom terminal floor
- energy consumed when the lift is stationary at the bottom terminal floor including that used to operate the doors.

The energy consumed per ISO reference cycle is presented in $\text{mW}\cdot\text{h}$ and given the symbol E_{rc} .

Full details of the measurement set-up, instrument type and accuracy, etc. are given in the Standard.

13.4.1.3 Measurement of idle power

The idle power is measured for a period of one minute starting immediately after finishing an ISO reference cycle. The power measurement is presented in watts and given the symbol P_{id} .

* Referred to in this Guide as the ISO reference cycle

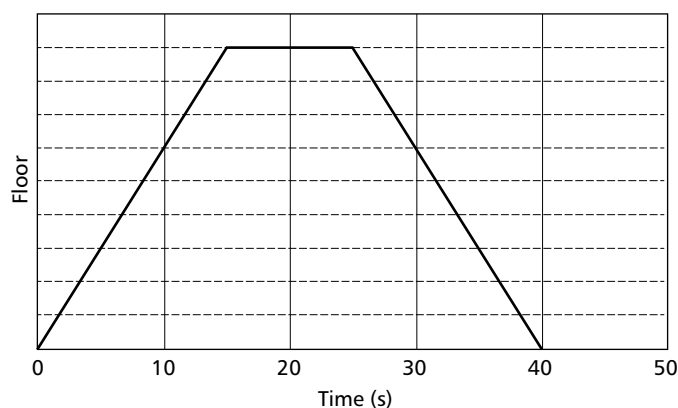


Figure 13.3 ISO reference cycle

13.4.1.4 Measurement of standby power

The standby power is measured for a period of one minute after maintaining the empty car at a terminal landing for five minutes after the finish of the ISO reference cycle. The power measurement is presented in watts and given the symbol P_{st5} .

13.4.1.5 Verification

BS EN ISO 25745-1 also specifies a lift energy verification check to determine that the energy usage has not significantly changed over the life of the installation. To allow for a quick, simple procedure, only the current is measured, as this is the most likely element of energy consumption that will change with equipment ageing or modification. The procedure is to measure and record the main and auxiliary currents when the unit is running and when the unit is in standby. After the initial full energy measurements have been made, periodic checks may be performed at any time during the operating life of equipment, to determine whether the energy consumption of the equipment has changed. If these current values are substantially the same it can be reasonably assumed the installation has maintained its installed efficiency. Full details of the measurement set-up, instrument type and accuracy, etc. are given in BS EN ISO 24745-1.

13.4.1.6 Performance level for running energy

In order to compare different new systems (offered by suppliers) or to determine improvements when a modernisation is proposed the energy consumed can be normalised to obtain a specific running energy. An idea for normalisation for the energy consumed by a lift was first proposed by Lam, So and Ng (2006). They divided the total energy (E_{rc}) used by the rated load (Q) of the lift and the distance travelled (s_{rc}).

Relating this to the ISO reference cycle gives:

$$E_{\text{spr}} = \frac{1000 E_{\text{rc}}}{2 Q s_{\text{rc}}} \quad (13.1)$$

This normalisation method relates the load carried over a travel distance to the energy consumed, i.e. the dynamic situation. It also gives an explicit value for the lift system with reference to the building in which it is installed.



Caution: the same equipment installed in different buildings may produce different values.

Normalised values of energy consumption allow comparisons to be made between different tenders for new systems or when upgrading is being considered

BS EN ISO 25745-2 provides a colour coded classification for the running mode as shown in Table 13.1. This is based on determining the specific running energy value.

13.4.1.7 Example 13.1

As an example, the running energy consumed by a lift with a rated capacity of 1500 kg and a terminal to terminal travel distance of 75 m was 170 W·h. Thus, using equation 13.1, the specific energy is 0.76 mW·h/kg·m. This gives a running performance level of 2.

13.4.1.8 Performance level for idle and standby

BS EN ISO 25745-2 provides a colour coded classification for the idle and standby mode as shown in Table 13.2. This is based on power measurements.

13.4.1.9 Example 13.2

Suppose the lift in Example 13.1 had its idle power measured as 500 W and its 5-minute standby power as 300 W, then it would have an idle performance level of 5 and a standby performance level of 4.

13.4.1.10 Summary of measurements

Table 13.3 illustrates the measurements and the relative performance levels using Examples 13.1 and 13.2.

A consultant or an end user can request a supplier to supply the values given in Table 13.3 prior to purchase. Actual measurements can be made at commissioning. This enables a client to establish the energy characteristics of a specified lift installation and to compare it with a different configuration, or in the case of a modernisation the 'before' and 'after' scenarios.

13.4.2 Estimating the energy consumption of lifts

It is often necessary to select the best performing lift installation in terms of energy efficiency, for example, to gain the first credit in the BREEAM classification system.

Table 13.1 Performance levels for running (source: BS EN ISO 25745-2, Table 5 (reproduced by permission of BSI))

Specific running energy for the average running cycle (mW·h/kg·m)	≤ 0.72	≤ 1.08	≤ 1.62	≤ 2.43	≤ 3.65	≤ 5.47	> 5.47
Performance level	1	2	3	4	5	6	7

Table 13.2 Performance levels for idle/standby (source: BS EN ISO 25745-2, Table 6 (reproduced by permission of BSI))

Idle/standby power (W)	≤ 50	≤ 100	≤ 200	≤ 400	≤ 800	≤ 1600	> 1600
Performance level	1	2	3	4	5	6	7

Table 13.3 Summary of results

Item	Value
Running energy	170 W·h
Idle power	500 W
Standby power (5-minutes)	300 W
Specific running energy	0.76 mW·h/kg·m
Performance levels:	
— running	2
— idle	5
— standby	4

Previous energy consumption calculation methods, such as that suggested in the 2010 edition of this Guide (CIBSE, 2010), have been inaccurate. A more accurate method has been developed by the International Standards Organisation and is given in detail in BS EN ISO 25745-2 (BSI, 2015a). A simplified form of the calculation method is given here.

13.4.2.1 Given data

The ISO method relies on knowledge of three data sets: known data, measured data and estimated data.

Known data for the target installation is the design data. These data are:

- rated speed
- rated load
- acceleration
- jerk value
- terminal floor to terminal floor distance
- number of stops
- time for the opening, opened and closing times of the lift doors at the landings
- counter balancing ratio.

Measured data are obtained using the method specified in BS EN ISO 25745-1 (BSI, 2012), either from an actual target installation or a test tower facility set to emulate the target installation. These data are:

- running energy consumption
- (standing) idle energy consumption
- (standing) standby energy.

In the absence of measured data, values obtained by simulation may be used.

Estimated data is an indication of the activity of the installation. This can range from very low to very high activity. This data is represented by the number of trips per day.

13.4.2.2 Estimated daily energy consumption

The estimated daily energy consumption (E_d) of a lift is the sum of the running consumption (E_{rd}) and the standing (idle/standby) consumption (E_{sd})*:

$$E_d = E_{rd} + E_{sd} \quad (13.2)$$

13.4.2.3 Estimated daily running energy consumption

The daily running consumption (E_{rd}) is dependent on the energy used for an average trip that the target lift makes multiplied by the number of trips in a day (n_d). The daily running consumption (E_d) in W·h is given by:

$$E_{rd} = \frac{n_d \times \%S \times k_L \times E_{rc}}{2} \quad (13.3)$$

The number of trips per day (n_d) for a target installation is either specified (e.g. provided by the developer/architect), known (e.g. from a 'trip' counter on an existing installation), can be estimated, or taken from Table 13.4. The number of trips defines the usage category for any calculations. Table 13.5 indicates typical usage by category.

The running energy consumption (E_{rc}) used to perform the ISO reference cycle is given by the measurement made according to BS EN ISO 25745-1 (BSI, 2012). This running energy measurement is for an empty car travelling the distance between the terminal landings (s_{rc}). The distance actually travelled for an average trip (s_{av}) is less than the distance between the terminal landings. To correct for this the average distance can be expressed as a percentage of the distance (s_{rc}), i.e. as $\%S = s_{av}/s_{rc}$. Values are given in Table 13.6.

The percentage average travel distance ($\%S$) is thus based on the usage category selected and the number of possible stops (landings served) in the target building. To obtain a value for the average travel distance multiply the one way travel distance s_{rc} by $\%S$.



Caution: the value suggested for three stops may need to be reviewed, if the traffic movement between the two terminal floors is dominant. In

Table 13.5 Typical usages by category

Category	Examples (days per week)
1	Small residential blocks (7), disable access (7)
2	Residential care (7), goods (5), library (6), entertainment centres (7), stadia (intermittent)
3	Office car parks (5), general car parks (7), residential (7), university (5), hotels (7), low rise hospitals (7), shopping centres (7)
4	Office (5), airports (7), high rise hospitals (7)
5	HQ office (5)

Table 13.6 Percentage of average travel distance ($\%S$) (source: BS EN ISO 25745-2, Table 2 (reproduced by permission of BSI))

Number of stops	Usage category		
	1–3	4	5
Percentage average travel distance (%)			
2		100	
3		67	
>3	49	44	39

this case the average travel distance may tend towards 100%.



Note: the number of stops (landings served) for the target installation is a known data.

The running energy measurement is made with an empty car. In operation the lift will carry passenger loads from zero to full rated load. In general the average loading is low. To correct for this the running energy needs to be corrected by a load factor (k_L).



Note: the best operating condition is with a balanced load.

The value for the load factor (k_L) can be calculated using equations 13.4a to 13.4e below, where the value for percentage average car load ($\%Q$) is taken from Table 13.7 according to the usage category and the rated load. The rated load (Q) of the target installation is known data.

Traction lifts:

— counter balanced to 50%:

$$k_L = 1 - (\%Q \times 0.0164) \quad (13.4a)$$

range 0.97–0.74

Table 13.7 Average car load (source: BS EN ISO 25745-2, Table 3 (reproduced by permission of BSI))

Rated load (kg)	Usage category		
	1–3	4	5
Percentage of rated load ($\%Q$)			
≤ 800	7.5	9.0	13.0
801 to 1275	4.5	6.0	8.2
1276 to 2000	3.0	3.5	5.0
>2000	2.0	2.2	3.0

* Symbol definitions and units are given in section 13.2

Table 13.4 Categorized number of starts per day (source: BS EN ISO 25745-2, Table 1 (reproduced by permission of BSI))

Usage category*	1	2	3	4	5
Usage intensity	Very low	Low	Medium	High	Very high
Number of trips per day (n_d)	50	125	300	750	1500
Typical range	<75	75<200	200<500	500<1000	1000<2000

* BS EN ISO 25745-2 has a usage category 6, which is greater than 2000 trips per day; this is omitted as it is likely to arise only in extreme circumstances.

- counter balanced to 40%:

$$k_L = 1 - (\%Q \times 0.0192) \quad (13.4b)$$

range 0.96–0.69.

Hydraulic lifts:

- with no counter balancing:

$$k_L = 1 + (\%Q \times 0.0071) \quad (13.4c)$$

range 1.02 – 1.11

- with 35% counter balancing of the car weight:

$$k_L = 1 + (\%Q \times 0.01) \quad (13.4d)$$

range 1.02 – 1.16

- with 70% counter balancing of the car weight:

$$k_L = 1 + (\%Q \times 0.0187) \quad (13.4e)$$

range 1.04 – 1.30.

The first three equations (13.4a–13.4c) represent common traction and hydraulic lifts. The parameters given in these equations were developed from work carried out by ISO/TC178/WG10 using a computer model of a lift system. The range shown is for the lowest and highest %Q values in Table 13.7. It should be noted that a load in a traction lift (up to balance) reduces energy usage and in a hydraulic lift always increases energy usage.



Warning: the estimation of the energy used to travel the average distance s_{av} is obtained in equation 13.3 by the evaluation of the term $(\%S \times E_{rc})$. However, shorter travels include the start-up/stopping phases, but a shorter running phase. This evaluation by simple proportion is thus subject to error. BS EN ISO 25745-2 provides a method to overcome this error by the evaluation of the energy consumed for a short cycle. This method is more appropriately used by lift suppliers, who can use it to generate a table of energy consumption for any distance of travel for a target lift, rather than for users of this Guide. If a value for the energy consumption for the average travel is available then it should be used to solve equation 13.3 by substituting it for the term $(\%S \times E_{rc})$.

13.4.2.4 Estimated daily standing energy consumption

$$E_{nr} = \left(24 - \frac{n_d}{3600} t_{av} \right) (P_{id} R_{id} + P_{st} R_{st}) \quad (13.5)$$

The first bracketed term in equation 13.5 is the time the lift is not running (t_{nr}), i.e. standing.

The idle power and the standby power are measured values obtained by the method given in BS EN ISO 25745-1 (BSI, 2012). The idle power is measured with an empty car and when door operations have ceased. Standby power is measured after five minutes of inactivity.

The ISO method considers systems that may stay in a second standby mode for up to 30 minutes. This not considered here.

The values for R_{id} and R_{st} can be taken from Table 13.8.

Table 13.8 Time ratios in idle and standby modes (BS EN ISO 25745-2, Table 4 (reproduced by permission of BSI))

Time ratios (<1)	Usage category				
	1	2	3	4	5
R_{id}	0.13	0.23	0.36	0.45	0.42
R_{st}	0.87	0.77	0.64	0.55	0.58

The time (t_{av}) to travel the average distance (s_{av}) is given by equation 13.6:

$$t_{av} = \frac{s_{av}}{v} + \frac{v}{a} + \frac{a}{j} + t_d \quad (13.6)$$

13.4.3 Example calculations

13.4.3.1 Example 13.3

A traction lift in an office building during week day operation with the parameters:

- rated load: 1500 kg
- rated speed: 2.50 m/s
- travel: 75 m
- number of stops: 20
- counterbalancing: 50%
- acceleration: 1.0 m/s²
- jerk: 1.25 m/s³
- door times: 8.0 s

Data determined by measurement or simulation:

- daily trips: 750 (ISO category 4)
- idle power: 500 W
- standby power after five minutes: 120 W
- ISO reference cycle energy: 170 W·h

Data from tables:

- average travel distance: 44% (from Table 13.6)
- average car load: 3.5% (from Table 13.7)
- load factor (k_L) 0.94 (from equation 13.4a)
- idle/standby time ratio: 45/55 (from Table 13.8).

Calculation

From equation 13.3:

$$E_{rd} = \frac{n_d \times \%S \times k_L \times E_{rc}}{2}$$

$$E_{rd} = \frac{750 \times 0.44 \times 0.94 \times 170}{2} = 26\,367 \text{ W}\cdot\text{h}$$

$$s_{av} = 0.44 \times 75 = 33 \text{ m}$$

$$t_{av} = 33/2.5 + 2.5/1 + 1/1.25 + 8 = 24.5 \text{ s}$$

Using equation 13.5:

$$\begin{aligned} E_{nr} &= \left(24 - \frac{n_d}{3600} t_{av}\right) (P_{id} R_{id} + P_{st} R_{st}) \\ &= \left(24 - \frac{750}{3600} 24.5\right) (500 \times 0.45 + 120 \times 0.55) \\ &= 5500 \text{ W}\cdot\text{h} \end{aligned}$$

Hence, from equation 13.2:

$$E_d = 26\,367 + 5500 = 31\,867 \text{ W}\cdot\text{h}$$

This is 32 kW·h per day (equivalent to about 0.6 p per trip).

From Table 13.2:

Standby performance level = 3

From equation 13.1:

$$\text{Specific energy} = \frac{1000 \times 170}{2 \times 1500 \times 75} = 0.76$$

From Table 13.1:

Running performance level = 2

If the energy consumed to travel the average distance of 33 m was known to be 86 W·h, then:

$$E_{rd} = \frac{750 \times 0.94 \times 86}{2} = 35\,815 \text{ W}\cdot\text{h}$$

(from 31 867 W·h).



Design tip: an example spreadsheet format is shown in Appendix 13.A1.

13.4.3.2 Example 13.4

A hydraulic lift in a residential building with parameters:

- rated load: 500 kg
- rated speed: 0.6 m/s
- travel: 13 m
- number of stops: 5
- counterbalancing: 0%
- acceleration: 0.3 m/s²
- jerk: 0.5 m/s³
- door times: 8.0 s

Data determined by measurement or simulation:

- daily trips: 30 (ISO category 1)
- idle power: 50 W

— standby power after five minutes: 31 W

— ISO reference cycle energy: 91 W·h

Data from tables:

— average travel distance 44% (from Table 13.6)

— average car load 7.5% (from Table 13.6)

— load factor (k_L) 1.05 (from equation 13.4c)

— idle/standby time ratio: 13/87 (from Table 13.8)

Calculation:

$$\begin{aligned} E_{rd} &= \frac{n_d \times \%S \times k_L \times E_{rc}}{2} \\ &= \frac{30 \times 0.44 \times 1.05 \times 91}{2} = 631 \text{ W}\cdot\text{h} \end{aligned}$$

$$s_{av} = 0.44 \times 13 = 5.7 \text{ m}$$

$$t_{av} = 5.7/0.6 + 0.6/0.3 + 0.3/0.5 + 8 = 20.1 \text{ s}$$

Using equation 13.5:

$$\begin{aligned} E_{nr} &= \left(24 - \frac{n_d}{3600} t_{av}\right) (P_{id} R_{id} + P_{st} R_{st}) \\ &= \left(24 - \frac{30}{3600} 20.1\right) (50 \times 0.13 + 31 \times 0.87) \\ &= 797 \text{ W}\cdot\text{h} \end{aligned}$$

Hence, from equation 13.2:

$$E_d = 631 + 797 = 1428 \text{ W}\cdot\text{h}$$

This is 1.4 kW·h per day (equivalent to about 0.7 pence per trip).



Caution: the figures given in Tables 13.6, 13.7 and 13.8 are based on the median values for the usage category. If the usage is discovered to be at the lower or higher end of a category then using the median value may be inaccurate. Thus if the actual number of trips is not close to the median it is suggested that values are obtained from the tables by interpolation. If the usage is in another category entirely then the estimation may be invalid.

13.4.4 Determining a BREEAM rating for a lift

Many buildings, especially public and large buildings require an energy classification. Often an intending purchaser or tenant can be influenced in their occupancy decision by a building's rating. Tables 13.9 and 13.10 show extracts from section Ene06: 'Energy efficient transportation systems' of the BREEAM Technical Manual SD5076 (BRE, 2014), which should be referred to for full details.

If a lift(s) is installed in a building the number of credits available is three. Thus for a lift to fully contribute to a building's classification it must achieve three BREEAM credits.

13.4.4.1 BREEAM: Credit 1

See Table 13.9.

Table 13.9 BREEAM Credit 1 for lifts, escalators and moving walks (reproduced from BREEAM Technical Manual (BRE, 2014))

One credit — Energy consumption
1. Where lifts, escalators and/or moving walks (transportation types) are specified: a. An analysis of the transportation demand and usage patterns for the building has been carried out to determine the optimum number and size of lifts, escalators and/or moving walks. b. The energy consumption has been calculated in accordance with BS EN ISO 25745 Energy performance of lifts, escalators and moving walks, Part 2 : Energy calculation and classification for lifts (elevators) and/or Part 3: Energy calculation and classification for escalators and moving walks, for one of the following: i. At least two types of system (for each transportation type required); OR ii. An arrangement of systems (e.g. for lifts, hydraulic, traction, machine room-less lift (MRL)); OR iii. A system strategy which is 'fit for purpose'. c. The use of regenerative drives should be considered, subject to the requirements in CN3.3. d. The transportation system with the lowest energy consumption is specified.

Criterion 1a requires an analysis to determine the optimum number and size of lifts. This can be achieved by following and documenting the practice described in chapter 3 of this Guide. BREEAM allows 'the transport analysis can be in the form of a written statement justifying the selection'. Examples given are (1) where a single lift is provided in a low rise building for the purpose of providing disabled access only or (2) where a goods lift is selected based on the size of the goods it is intended to carry. Another example could be the selection of a hydraulic lift on the basis of a cost benefit analysis of its lower installation cost and its very low usage (energy cost).

Criterion 1b requires a calculation as described in section 13.4.2 for one of three situations and criterion 1d requires the selection of the system with the lowest energy consumption.

Criterion 1c encourages the use of regenerative drives subject to condition CN3.3: 'A regenerative drive should only be considered where it produces an energy saving greater than the additional standby energy used to support the drives. Regenerative drives will typically be appropriate for lifts with high travel and high intensity use'. There may be other reasons why a regenerative drive may be unsuitable. This is discussed in section 13.4.5: *Drive system*.

13.4.4.2 BREEAM: Credits 2 and 3

See Table 13.10.

Criteria 3a, 3b and 3c are design requirements made on the supplier, and can be relatively easily achieved for a new installation. It is unlikely that a modern lift does not meet these criteria. Their efficacy, however, will be supplier dependent. Where modernisations or refurbishments are

Table 13.10 BREEAM Credits 2 and 3 for lifts (reproduced from BREEAM Technical Manual (BRE, 2015))

Two credits — Energy efficient features
2. Criterion 1 is achieved. Lifts 3. For each lift, the following three energy efficient features are specified: a. The lifts operate in a standby condition during off-peak periods. For example the power side of the lift controller and other operating equipment such as lift car lighting, user displays and ventilation fans switch off when the lift has been idle for a prescribed length of time. b. The lift car lighting and display lighting provides an average lamp efficacy, (across all fittings in the car) of > 55 lamp lumens/circuit watt. c. The lift uses a drive controller capable of variable speed, variable-voltage, and variable-frequency (VVVF) control of the drive motor. 4. Where the use of regenerative drives is demonstrated to save energy, they are specified.

being considered, criterion 3c may be problematical as the whole drive system may need to be replaced. To gain the two credits both criteria 3 and 4 must be achieved.

13.4.5 Factors affecting lift energy consumption

There are several factors that may be offered for consideration at the design and specification stage that affect energy consumption that might attract initial higher installation costs but result in lower operating costs over the lifetime of the installation. Most of these factors are part of the supplier's design and should not be part of a specification, else the supplier may be deprived of the ability to create innovative designs.



Warning: all suppliers should adopt best practice and should have considered all aspects of energy efficiency as a part of their overall design.

Many factors affect the energy consumption of lift systems including the examples below.

- **Mechanical system:** drive sheave efficiency (traction, etc.), idler sheave efficiency, roping (reeving) ratio (1:1, 2:1), guidance system (rails/slider/rollers), counterbalancing ratio, compensation system, etc.

The lack of a gear box might appear energy saving. However, modern gearbox efficiencies can be as high as 70–90%.

All lift systems need to overcome friction in the guide rails, guide shoes, etc. and air resistance to the car moving in the well. For low speed systems the purchaser may be offered slipper guide shoes instead of roller guide shoes.

- **Drive system:** motor efficiency including any cooling fans, gear efficiency (if any), drive regeneration, acceleration/deceleration profile, creeping/levelling time, brake consumption, etc. (Drive systems are fully discussed in chapter 8.)

- The main types of electric traction drive systems available today are based on variable voltage, variable frequency (VVVF) technology with or without regeneration back to the supply, the latter being very energy efficient. Regenerating lift drive systems return energy back to the supply through the supply metering system. However, not every meter can record this reverse power and deduct units from the total. A special meter has to be fitted by agreement with the utility company (maybe at an additional cost). Where this is not possible arrangements might be made for the regenerated power to be used by other energy 'sinks' in the building, such as lighting, HVAC etc. (see Figure 13.1). It is important to remember that regeneration can cause the supply voltage to rise at the lift input terminals, unless it is connected to a low impedance supply.

Hydraulic drives are considered to be the less efficient than traction systems, as the conventional hydraulic drive is unable to recover any of the energy consumed to drive the lift up on the return journey down. However, new systems overcome this problem. One system uses a pressurised accumulator to collect some of the energy back during the down trip. Another system uses a VVVF pump system to control oil flow more accurately.

The drive control system can allow the drive to operate efficiently by profiling the movement between stops in an optimal manner. The values selected for speed, acceleration and jerk (often dictated by the traffic design and ride comfort requirements) can affect the energy consumption. Some drive systems can optimise the energy used for the next journey dependent on the car load, direction of travel and distance to be travelled.

- *Control system:* controller (traffic and drive) consumption, door system (drive, passenger detection etc.), traffic (dispatcher) efficiency.

The drive and traffic controller uses energy (standby power) even when the lift is not moving. A system of powering off a controller during low traffic conditions should be considered similar to the motor-generator (MG) set shut-down sequence used on older Ward-Leonard systems. Energy is also used for car and machine room lighting, heating, cooling, etc. If the car lighting can be reduced when the lift is idle significant energy savings are possible. Well lighting can often be left on and consideration should be given to automatically turning it off after (say) one hour.

The traffic control algorithm (see chapter 9) can have an influence on how the traffic demand is handled. For example, under heavy demand conditions, a hall call allocation system can be inherently more energy efficient as it groups passengers travelling to the same floors together. It is also possible for the traffic controller to provide an algorithm designed for energy saving operation.

Another method to reduce energy usage is to remove lifts from service outside the peak periods. This has the effect of increasing the car occupancy levels and hence brings the lift system closer to a balance condition. There can be an increase in passenger waiting times using this technique.

Some traffic control systems move lifts to parking floors when they become idle. This feature may be useful during peak periods, but is wasteful out of hours or in light duty environments.

- *Operational aspects:* number of starts, travel distance, stopping floors, speed, load, duty.

In addition to the lift equipment aspects an important factor in energy consumption is the way the lift is used and operated. These factors are fundamental to providing the transportation service and cannot be changed and should be part of the specification.

13.5 Energy consumption of escalators and moving walks

13.5.1 Measuring the energy consumption of escalators and moving walks

The majority of escalators and moving walks operate continuously at a constant speed. However, some are programmed to operate at lower speeds, either when no demand is detected or by the use of time clocks. Escalators and moving walks can also be fitted with an 'auto-start' control, which detects the presence of potential passengers and starts the escalator or moving walks.

Escalator and moving walks energy consumption is dependent on:

- rise (if any)
- speed
- step/pallet width
- mechanical design
- direction of travel
- number of passengers
- whether passengers walk or not.

BS EN ISO 25745-1 (BSI, 2012) provides an agreed international method of energy measurement for escalators and moving walks. The measurements are practical to apply in the field and repeatable, when performed by a trained, competent person and they utilize commonly available measuring equipment.

BS EN ISO 25745-3 (BSI, 2015b) provides an internationally agreed method to estimate the energy consumption for escalators and moving walks.



Warning: what follows is a summary of the requirements of these standards and readers are advised to read and understand the standards in full before attempting to apply their provisions.

BS EN ISO 25745-1 defines a number of power measurements that should be made:

- main power measured when running at nominal speed

- power measured in standby mode
- power measured in auto-start condition (if fitted)
- power measured in slow speed condition (if fitted)
- power measured in no load condition
- power measured in ancillary equipment.

These measurements should be made:

- with no load
- ancillary equipment switched off
- a stable operating temperature has been reached
- without changing any system parameters.

The power consumed by ancillary equipment is measured separately.

BS EN ISO 2547-1 specifies a verification check, which is to measure the main power, when running at nominal speed.

13.5.2 Estimating the energy consumption of escalators and moving walks

It is often necessary to select the best performing escalator/moving walk installation in terms of energy efficiency, for example, to gain the first credit in the BREEAM classification system. Previous energy consumption calculation methods, such as that suggested in the 2010 edition of this Guide (CIBSE, 2010), have been inaccurate. A more accurate method has been developed by the International Standards Organisation and is given in detail in BS EN ISO 25745-3 (BSI, 2015b). A simplified form of the calculation method is given here.

The ISO method relies on knowledge of several data sets: known data, observed data, assumed data and derived data.

Known data for the target installation are the design data. These data are nominal speed, step width, inclination, rise/length, travel direction.

Observed data are obtained using the methods specified in BS EN ISO 25745-1, either from an actual target installation or a test facility set to emulate the target installation. These data are listed in the example calculations that follow.

Assumed data can be obtained from Tables 2.8, 13.11, 13.12.

13.5.2.1 Calculation method

The estimated daily energy of an escalator or moving walk is given by*:

$$E_{\text{tot}} = E_{\text{anc}} + E_{\text{main}} \quad (13.7)$$

The ancillary energy is given by:

$$E_{\text{anc}} = P_{\text{anc}} \times t_{\text{anc}} \quad (13.8)$$

The main energy consumption (E_{main}) is defined as the energy consumption of a unit without including the

ancillary energy. It thus adds the energy consumptions that occur during the conditions of: running under nominal speed, in standby (E_{stby}), in auto-start mode (E_{as}), in slow speed mode (E_{ss}), no-load (E_{nold}) and loaded (E_{ld}), as given by equation 13.9:

$$E_{\text{main}} = E_{\text{stby}} + E_{\text{as}} + E_{\text{ss}} + E_{\text{nold}} + E_{\text{ld}} \quad (13.9)$$

The following four equations define the first four parts of equation 13.9:

$$E_{\text{stby}} = P_{\text{stby}} \times t_{\text{stby}} \quad (13.10a)$$

$$E_{\text{as}} = P_{\text{as}} \times t_{\text{as}} \quad (13.10b)$$

$$E_{\text{ss}} = P_{\text{ss}} \times t_{\text{ss}} \quad (13.10c)$$

$$E_{\text{nold}} = P_{\text{nold}} \times t_{\text{nold}} \quad (13.10d)$$

This gives:

$$E_{\text{tot}} = P_{\text{anc}} \times t_{\text{anc}} + P_{\text{stby}} \times t_{\text{stby}} + P_{\text{as}} \times t_{\text{as}} + P_{\text{ss}} \times t_{\text{ss}} + P_{\text{nold}} \times t_{\text{nold}} + E_{\text{ld}} \quad (13.11)$$

The final term E_{ld} depends on the equipment type, i.e. escalator or moving walk, and inclination.

For escalators and inclined moving walks travelling in the up direction ($\alpha > 0^\circ$):

$$E_{\text{ld}} = \frac{N \times m \times g \times H}{(3.6 \times 10^6 \times \eta)} \times \left(1 + \frac{\mu}{\tan \alpha} \right) \quad (3.12)$$

For escalators and inclined moving walks travelling in the down direction ($\alpha > 0^\circ$):

$$E_{\text{ld}} = \frac{N \times m \times g \times H \times \text{CF}}{(3.6 \times 10^6 \times \eta)} \times \left(-1 + \frac{\mu}{\tan \alpha} \right) \quad (13.13)$$

For horizontal moving walks in both directions ($\alpha = 0^\circ$):

$$E_{\text{ld}} = \frac{N \times m \times g \times L \times \mu}{(3.6 \times 10^6 \times \eta)} \quad (13.14)$$

where:

- CF = 0 for $N/\text{day} \leq 10\,000$ (or non-regenerative)
- CF = 0.5 for $N/\text{day} > 10\,000$

13.5.2.2 Default values

Passenger usage varies according to location as given in chapter 2, Table 2.8 (reproduced below for convenience).

When a value for no load power is not available the default reference values given in Table 13.11 may be used.

When values for various power consumptions are not available the default values given in Table 13.12 may be used.

* Symbol definitions and units are given in section 13.2

Table 2.8 Escalator duty categories (reproduced from chapter 2)

Duty category	Typical usage (passengers per day)	Typical locations
Light	Up to 3000	Shops, museums, libraries and leisure facilities
Medium	Up to 10 000	Department stores, shopping centres, regional airports and regional railway stations
Heavy	Up to 20 000	Major railway and metro stations, major international airports and critical locations such as underground railway systems
Intensive	Over 20 000	Ditto

Table 13.11 Power in no load condition (P_{nold}) (default values) (source: BS EN ISO 25745-3, Table A.2 (reproduced by permission of BSI))

	Power in no-load condition (W) for stated speed (m/s)	
	$v = 0.50$ m/s	$v = 0.65$ m/s
(a) Escalator ($\alpha = 30^\circ$)		
Rise, H (m)		
3.0	2.243	3.222
4.5	2.505	3.602
6.0	2.766	3.983
8.0	3.114	4.490
(b) Horizontal moving walk ($\alpha = 0^\circ$)		
Length, L (m)		
30	3.326	4.204
45	4.352	5.538
60	5.378	6.871
(c) Inclined moving walk ($\alpha = 12^\circ$)		
Rise, H (m)		
3.0	2.788	—
4.5	3.333	—
6.0	3.878	—

Note: the power consumption includes control consumption.

Table 13.12 Typical default values (source: BS EN ISO 25745-3, Table A.1 (reproduced by permission of BSI))

Parameter	Value
P_{stby}	0.2 kW
P_{as}	0.3 kW
P_{nold}	According Table 13.11
P_{ss}	$P_{nold} \times 0.5$

- Period of standby on mode (t_{stby}): 12 h
- Period under nominal speed (t_{nom}): 10 h
- Period of slow speed condition (t_{ss}): 2 h
- Period of activated ancillary equipment (t_{anc}): 12 h
- Power in standby mode (P_{stby}): 0.15 kW
- Power in slow speed condition (P_{ss}): 0.80 kW
- Power in no load condition (P_{nold}): 1.80 kW
- Power of ancillary equipment (P_{anc}): 0.30 kW

Assumed data:

- Average weight of passengers (m): 75 kg
- Default values: $\eta = 0.75$, $\mu = 0.05$

Calculation

From equations 13.8, 13.12 and 13.13:

$$E_{anc} = 0.3 \times 12 = 3.6 \text{ kW}\cdot\text{h}$$

$$E_{ld}(\text{up}) = \frac{8000 \times 75 \times 9.81 \times 4.5}{3.6 \times 10^6 \times 0.75} \times \left(1 + \frac{0.05}{\tan 30}\right) = 10.7 \text{ kW}\cdot\text{h}$$

$$E_{ld}(\text{down}) = 0$$

From equation 13.9:

$$E_{main}(\text{up}) = (0.15 \times 12) + 0 + (0.80 \times 2) + (1.80 \times 10) + 10.7 = 32.1 \text{ kW}\cdot\text{h}$$

$$E_{main}(\text{down}) = (0.15 \times 12) + 0 + (0.80 \times 2) + (1.80 \times 10) = 21.4 \text{ kW}\cdot\text{h}$$

13.5.3 Example calculations

13.5.3.1 Example 13.5 (from measurements)

Calculation to estimate escalator and moving walk energy consumption for planning purposes based on measurements.

Known data:

- Escalator in an office building
- Rise: 4.5 m
- Angle of inclination: 30°
- Direction of travel: up
- Step width: 1000 mm
- Nominal speed: 0.5 m/s

Observed data:

- Observation period (day, week, month, year): 1 day
- Average number of passengers in observation period: 8000 person/day
- Period of energy consumption: 24 h

From equation 13.7:

$$E_{\text{tot}}(\text{up}) = 32.1 + 3.6 = 35.7 \text{ kW}\cdot\text{h}$$

$$E_{\text{tot}}(\text{down}) = 21.4 + 3.6 = 25 \text{ kW}\cdot\text{h}$$

13.5.3.2 Example 13.6 (from assumed data)

Calculation to estimate escalator and moving walk energy consumption for planning purposes from assumed data.

Known data:

- Escalator in an office building (assume medium duty)
- Rise: 4.5 m
- Angle of inclination: 30°
- Direction of travel: up
- Step width: 1000 mm
- Nominal speed: 0.5 m/s

Assumed data

- Period of energy consumption: 24 h
- Period of standby on mode (t_{stby}): 12 h
- Period of auto-start condition (t_{as}): 0 h
- Period under nominal speed (t_{nom}): 10 h
- Period of slow speed condition (t_{ss}): 2 h
- Average weight of passengers (m): 75 kg
- Default values: $\eta = 0.75$, $\mu = 0.05$

Derived data:

- Average number of passengers: 8000 person/day
- Power in standby mode (P_{stby}): 0.2 kW (Table 13.12)
- Power in auto start condition (P_{as}): 0.3 kW (Table 13.12)
- Power in slow speed condition (P_{ss}): 1.25 kW (Table 13.12)
- Power in no load condition (P_{nold}): 2.51 kW (Table 13.11)

Calculation

From equations 13.12 and 13.13:

$$E_{\text{ld}}(\text{up}) = \frac{8000 \times 75 \times 9.81 \times 4.5}{3.6 \times 10^6 \times 0.75} \times \left(1 + \frac{0.05}{\tan 30}\right)$$

$$= 10.7 \text{ kW}\cdot\text{h}$$

$$E_{\text{ld}}(\text{down}) = 0$$

From equation 13.9:

$$E_{\text{main}}(\text{up}) = (0.20 \times 12) + 0 + (1.25 \times 2) + (2.51 \times 10) + 10.7 = 40.7 \text{ kW}\cdot\text{h}$$

$$E_{\text{main}}(\text{down}) = (0.20 \times 12) + 0 + (1.25 \times 2) + 2.51 \times 10 = 30.0 \text{ kW}\cdot\text{h}$$



Note: according to equation 13.8, E_{anc} (power and period of ancillary equipment) is project specific and requires calculation on a project to project basis.

13.5.4 Determining a BREEAM rating for an escalator/moving walk

Many buildings, especially public and large buildings require an energy classification. Often an intending purchaser or tenant can be influenced in their occupancy decision by a building's rating. Tables 13.9 (above) and 13.13 (below) show extracts from BREEAM Technical Manual SD5076 (BRE, 2014), which should be referred to for full details.

If an escalator/moving walk(s) is installed in a building the number of credits available is three. Thus for an escalator or moving walk to contribute to a building's classification it must achieve three BREEAM credits.

13.5.4.1 BREEAM: Credit 1

See Table 13.9 above.

Criterion 1a requires an analysis to determine the optimum number, speed, step/pallet size, etc. This can be achieved by following and documenting the practice described in chapters 2 and 3 of this Guide. BREEAM allows 'the transport analysis can be in the form of a written statement justifying the selection'. An example might be that only an upwards travelling escalator is provided as stairs are provided for downwards travel.

Criterion 1b requires a calculation as described in section 13.5.2 for one of three situations and criterion 1d requires the selection of the system with the lowest energy consumption. Consideration of slow speed and auto start operation should be considered to meet these criteria.

Criterion 1c encourages the use of regenerative drives on condition: 'A regenerative drive should only be considered where it produces an energy saving greater than the additional standby energy used to support the drives.' There may be other reasons why a regenerative drive may be unsuitable.

13.5.4.2 BREEAM: Credits 2 & 3

See Table 13.13 below.

The specification by the customer of one or both energy saving features may increase the initial cost, which will have to set against the lift time cost of the installation, but will result in two credits being earned. It should be noted that either criterion 5 or 6 will earn two credits.

Table 13.13 Second BREEAM credit for escalators/moving walks

2.	Criterion 1 is achieved.
Each escalator and/or moving walk complies with at least one of the following:	
5.	It is fitted with a load-sensing device that synchronises motor output to passenger demand through a variable speed drive; OR
6.	It is fitted with a passenger-sensing device for automated operation (auto walk), so the escalator operates in standby mode when there is no passenger demand.

13.5.5 Factors affecting escalator/moving walk energy consumption

Unlike lifts, most escalators and passenger conveyors operate continuously once they have been started up. Measures that can be taken include:

- delay starting escalators and moving walks for as long as is practicable at the beginning of the working day.
- stop some escalators and moving walks, when convenient, after peak periods
- stop some escalators and moving walks, when convenient, after normal working hours.
- use auto start-up, or programme multiple escalators/moving walks, to ensure they operate only when there is a demand.

13.6 Classification according to ISO

13.6.1 Lifts

13.6.1.1 Combined classification

It is not possible to produce a definitive combined classification for lifts as the units for running are mW·h/kg·m and the units when standing are kW. Running energy and standing energy are mutually exclusive. However, BS EN ISO 25745-2 (BSI, 2015a) offers a colour coded classification for lifts similar to that used for white goods, see Table 13.14. This provides reference criteria to which a lift may be referred.

It will be noted that the energy efficiency class is related to a reference energy consumption, which is derived. For example:

$$\begin{aligned}\text{Class A} &= K_1 \times \text{performance level 1 (running)} \\ &\quad + t_{\text{nr}} \times \text{performance level 1 (standby)} \\ \text{Class B} &= K_1 \times \text{performance level 2 (running)} \\ &\quad + t_{\text{nr}} \times \text{performance level 2 (standby)} \\ \text{Class C} &= \text{etc...}\end{aligned}$$

Table 13.14 A colour coded classification according to BS EN ISO 25745-2, Table 7) (reproduced by permission of BSI)

Energy efficiency class	Energy consumption per day (W·h)
A	$E_d \leq 0.72 Q n_d s_{\text{av}}/1000 + 50 t_{\text{nr}}$
B	$E_d \leq 1.08 Q n_d s_{\text{av}}/1000 + 100 t_{\text{nr}}$
C	$E_d \leq 1.62 Q n_d s_{\text{av}}/1000 + 200 t_{\text{nr}}$
D	$E_d \leq 2.43 Q n_d s_{\text{av}}/1000 + 400 t_{\text{nr}}$
E	$E_d \leq 3.65 Q n_d s_{\text{av}}/1000 + 800 t_{\text{nr}}$
F	$E_d \leq 5.47 Q n_d s_{\text{av}}/1000 + 1600 t_{\text{nr}}$
G	$E_d > 5.47 Q n_d s_{\text{av}}/1000 + 1600 t_{\text{nr}}$

The factors K_1 and t_{nr} convert the two unmatched units of the performance levels to a specific energy consumption in W·h, where $K_1 = Q n_d s_{\text{av}}/1000$.

13.6.1.2 Example 13.7

(a) What ISO Class is the lift described in Example 13.3?

Evaluation of the threshold values:

- $t_{\text{av}} = 24.5$ (equation 13.6)
- $s_{\text{av}} = 33.0$ (Table 13.6)
- $t_{\text{nr}} = 18.9$ h (equation 13.5)

Using the formulae in Table 13.14:

$$\begin{aligned}\text{Class A: } E_d &\leq 0.72 \times 1500 \times 750 \times 33.0/1000 + 50 \times 18.9 \\ &= 27\,675 \text{ W·h}\end{aligned}$$

$$\begin{aligned}\text{Class B: } E_d &\leq 1.08 \times 1500 \times 750 \times 33.0/1000 + 100 \times 18.9 \\ &= 41\,985 \text{ W·h}\end{aligned}$$

Class C: $E_d \leq \text{etc...}$

Since $E_d = 31\,867$ W·h (reference cycle estimation) or $35\,815$ W·h (short run estimation), the lift in Example 13.3 is ISO Class B, operating in ISO Category 4.

(b) What is the ISO Class if the daily trips of the lift in Example 13.3 were to be only 125 (such as might occur at a weekend)?

The lift is now an ISO Category 2 lift.

The energy consumption (E_d) would become 9196 kW (reference) or 9854 kW (short run).

Evaluation of the threshold values:

- $t_{\text{av}} = 24.5$ (equation 13.6)
- $s_{\text{av}} = 33.0$ (Table 13.6)
- $t_{\text{nr}} = 23.15$ h (equation 13.5).

$$\begin{aligned}\text{Class A: } E_d &\leq 0.72 \times 1500 \times 125 \times 33.0/1000 + 50 \times 23.15 \\ &= 5612 \text{ W·h}\end{aligned}$$

Class B: $E_d \leq 1.08 \times 1500 \times 125 \times 33.0/1000 + 100 \times 23.15$
 $= 8997 \text{ W}\cdot\text{h}$

Class C: $E_d \leq 1.62 \times 1500 \times 125 \times 33.0/1000 + 200 \times 23.15$
 $= 14\,654 \text{ W}\cdot\text{h}$

Class D: $E_d \leq 1$ etc...

As $E_d = 9191 \text{ kW}$ (reference cycle estimation) or 9854 kW (short run estimation) the lift in Example 13.3 would be a ISO Class C lift, when operating in ISO Category 2.

Then the performance data for Example 13.3 is summarised in Table 13.15.

Table 13.15 Summary of performance for Example 13.3 at different starts per day

Item	Value for stated number of daily trips	
	750	125
ISO Category	4	2
Standby performance level	3	3
Specific running energy (mW·h/kg·m)	0.76	0.76
Running performance level	2	2
ISO Class	B	C



Warning: the ISO Class should be used very carefully when making comparisons as a lift can change class according to its duty. This can be due to changes in a buildings occupancy, or an incorrect estimation of the starts per day, or weekday/week end variations etc. However, running and standby performance levels, and specific running energy, are unchanged and are specific to the building in which the lift is installed. Using these latter parameters it is simple to compare different configurations of an installation independent of operational duty.



Caution: a classification obtained by calculation in a planning phase may vary by one class up or below when in operation.

13.6.2 Escalators/moving walks

A reference no load power consumption is determined as the sum of the no load power to drive the handrail plus the no load power to drive the step/pallet plus the no load power for the control.

The no load power for the hand rail (P_{nlhr}) is given by*:

$$P_{nlhr} = \frac{2 \cos \alpha (A Z + B) v}{1000 \eta} \quad (13.15)$$

where $Z = H/\tan \alpha$ for escalators/inclined moving walks and $Z = L$ for horizontal moving walks.

The no load power at the step/pallet (P_{nlsp}) is given by:

$$P_{nlsp} = \frac{v}{\eta_{nold}} \left(2 \frac{g_m}{1000} Z \mu_{sp} (2.47 m_{sp} + 2 m_c) + C \right) \quad (13.16)$$

The values for the various reference parameters are taken from Table 13.16. These reference values were derived by the ISO Committee TC178/WG10 from consideration of the worldwide installed stock of equipment.



Note: Table 13.11 was derived from Table 13.16.

BS EN ISO 25745-3 (BSI, 2015b) provides an energy performance class indicator as shown in Table 13.17 below. This based on the reference values centred on Class D (100%).

* Symbol definitions and units are given in section 13.2

Table 13.16 Escalator/moving walk reference value (BS EN ISO 25745-3, Table 1) (reproduced by permission of BSI)

Symbol	Escalator (all inclinations)		Moving walk		Unit
	$v < 0.65 \text{ m/s}$	$v \geq 0.65 \text{ m/s}$	Inclined ($\alpha > 3^\circ$ to 12°)	Horizontal ($\alpha = 0^\circ$ to 3°)	
A	9	5	4	5	N/m
B	400	400	400	300	N
C	0.1	0.1	0.1	0.1	kN
η_{nold}	0.3	0.25	0.34	0.4	—
μ_{sp}	0.05	0.05	0.05	0.05	—
m_{sp}	14	14	14	14	kg
m_c	5.5	7	5.5	5.5	g/m
P_{nold}	0.4	0.4	0.4	0.4	kW

Table 13.17 Escalator/moving walk energy performance class (BS EN ISO 25745-3, Table 4) (reproduced by permission of BSI)

Energy performance ratio	$\leq 55\%$	$\leq 60\%$	$\leq 65\%$	≤ 70	$\leq 80\%$	$\leq 90\%$	$\leq 100\%$	$> 100\%$
Energy performance class indicator	A+++	A++	A+	A	B	C	D	E

The energy performance ratio (EPR) is calculated as:

$$\text{EPR} = \frac{P_{\text{nold}}(\text{target})}{P_{\text{nold}}(\text{reference})} \quad (13.17)$$

The escalator in Example 13.5, had a measured no load power of 1800 W. Table 13.11 gives the reference no load power as 2505 W. Thus the value for EPR is 0.72 (i.e. 72%) and places it in Class B.



Note: the escalator classification system relies on the experts of WG10 making the determination of the reference values at the present time from the worldwide estate. The classification determined, however, is wholly independent of usage and is only dependent on the installed equipment. It does not address running at slow speed, standby power.

13.7 Conclusions

Traction lifts have always been energy efficient as a result of their counter-balanced design. Today, lifts with regenerative VVVF drives are even more so.

Hydraulic lifts have been less efficient, but recently they have been installed with energy accumulators to capture the down movement energy and some suppliers now use VVVF flow control systems.

The classification system for lifts using the performance levels for running and standby are robust and specific to each individual lift in a specific building. The ISO Class is less robust as it is uniquely linked to the number of operations per day. When these change so does the class.

Escalators and moving walks in the UK have traditionally been left running (if they are stationary UK passers-by think they are broken), even when there is no demand. However, auto-start control can considerably reduce, and slow speed operation can reduce, energy consumption.

The classification system for escalators and moving walks only addresses the no load condition against a set of reference installations. In time the reference values will change as technology and physical configurations progress.

If readers wish to understand the basis of the lift calculation tables they should consult Lorente (2013), who gives full details.

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Appendix 13.A1: Example format for calculation spreadsheet

Category data				
Measured number of trips/day			750	125
Category			4	2
Category range as Table 13.4a			500/1000	75/200
Median number of trips/day for category	<i>nd</i>		750	125
Installation data				
Rated load	<i>Q</i>	kg	1500	1500
Rated speed	<i>v</i>	m/s	2.5	2.5
Acceleration	<i>a</i>	m/s ²	1	1
Jerk	<i>j</i>	m/s ³	1.25	1.25
Door times	<i>td</i>	s	8	8
Total travel distance	<i>src</i>	m	75	75
Reference cycle energy	<i>Erc</i>	W·h	170	170
Short cycle distance	<i>ssc</i>	m	33	33
Short cycle energy	<i>Esc</i>	W·h	86	86
% Average travel as Table 13.5	<i>tr</i>	#	0.44	0.44
Measured idle power	<i>Pid</i>	W	500	500
Measured standby power St5+St30	<i>Pst</i>	W	120	120
Average travel	<i>sav</i>	m	33	33
Load Factor as formula 50% balance	<i>kl</i>	#	0.94	0.94
Idle percent as per Table 13.7	<i>Rid</i>	%	45	23
Standby percent as per Table 13.7	<i>Rst</i>	%	55	77
Energy calculation				
Specific energy	<i>Espc</i>	mW·h/kg·m	0.76	0.76
Standing time (h)	<i>tnr</i>	h	18.90	23.15
Running energy/day (W·h)	<i>Erd</i>	W·h	30315	5053
Standing energy/day (W·h)	<i>Enr</i>	W·h	5499	4801
Total energy/day (W·h)	<i>Ed</i>	W·h	35814	9854
Class		#	B	C
Class calculation				
Class A		W·h	27675	5612
Class B		W·h	41985	8997
Class C		W·h	63922	14654
Class D		W·h	97772	24295
Class E		W·h	150623	41104
Class F		W·h	233307	70885
Class G		W·h	233307	70885
Calculations				
tav		h	24.5	24.5
trd		h	5.10	0.85
tnr		h	18.90	23.15
Enr		W·h	5499	4801
Erm		W·h/m	1	1
Escc		W·h	10	10
Erav		W·h	86	86
Erd-sc		W·h	30315	5053
Ed-sc		W·h	35814	9854
Erd-rc		W·h	26367	4395
Ed-rc		W·h	31866	9196

14 Lift emergency alarms, data logging, monitoring and traffic surveys

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14 Lift emergency alarms, data logging, monitoring and traffic surveys

14.1 Reason for remote alarms and remote monitoring

This chapter offers some guidelines on remote alarms, lift monitoring and carrying out surveys. It suggests ways in which the resulting data can be used to improve the efficiency of vertical transportation systems, reduce their costs and allow them to be interfaced with other systems within the building and increase the safety of all users.

Section 14.2 considers the requirements for the provision of remote alarm systems to ensure the safety of all lift users, e.g. persons trapped within a lift car. These systems should connect to a fully attended rescue service.

The term 'lift monitoring' has been used to cover a wide variety of systems ranging from simple alarm pushes, through manually initiated voice calls to fully automated computerised systems. Section 14.3 addresses the need to manage a large volume of dispersed lifts of varying manufacture owned by local authorities, private housing associations, airports etc. The primary requirement being that of fault indication coupled with the gathering of extensive management information and the transfer of this detailed data back to a central computer system, or third party bureau application. Although lift and escalator/moving walk monitoring systems enable building owners to self-manage systems, not all building managers want or need this facility. Most major suppliers offer a monitoring service which simply reports the main facts.

Section 14.4 is concerned with gathering data by on-site surveys. This is often the only way to acquire authoritative data.

The first topic is a mandatory requirement to ensure compliance with the Lifts Regulations 1997 (TSO, 1997) for all lifts first put into service after 1 July 1999. The second topic also has some safety implications.

This chapter is principally concerned with lifts. However, some of the guidance can usefully be applied to escalator and moving walks, see section 14.5.

14.2 Remote lift alarms

14.2.1 BS EN 81-28: 2003: emergency alarms

The Lifts Directive (OJ, 1995, 2014), enacted in the UK as the Lifts Regulations 1997 (TSO, 1997), requires in Annex I ('Essential Health and Safety Requirements'), clause 4.5, that '*cars must be fitted with a two-way means of communication allowing permanent contact with a rescue service*'. This requirement is a health and safety matter to attempt to ensure the safe release of trapped passengers.

BS EN 81-1/2 (BSI, 1998a/b), clause 14.2.3, and BS EN 81-20 (BSI, 2014a), clause 5.12.3, provide a means to meet this requirement. Both standards call for an emergency alarm device and a remote alarm system to be installed.

The requirements in the 1998 standards were very short and gave rise to ambiguity. To clarify this difficulty BS EN 81-28 (BSI, 2003a) was published to elaborate clause 14.2.3. This standard provides the requirements for remote alarms as indicated in the boxed area in Figure 14.1. BS EN 81-28 remote alarms also apply to the later 2014 standard (BS EN 81-20).

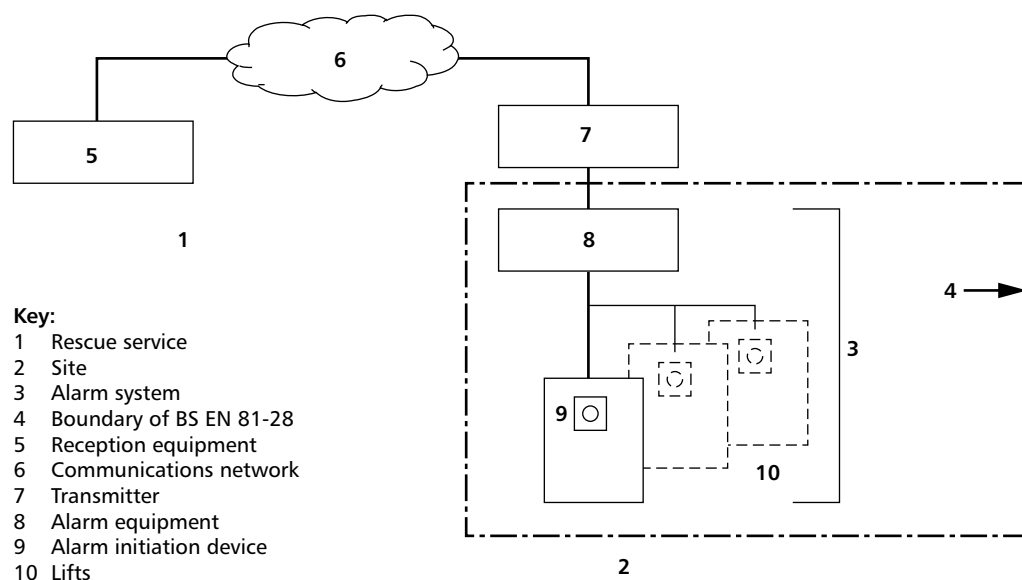


Figure 14.1 Diagram of a BS EN 81-28 lift remote alarm system (reproduced from BS EN 81-28 by permission of BSI)



Note: BS EN 81-28 has normative requirements for the remote alarm equipment only; the information regarding the call centre and the handling of alarm, response of rescue service etc. is informative.

14.2.2 Basic characteristics

BS EN 81-28 requires that an alarm system be provided at all times that a lift is in service, in order to ensure the rescue of trapped persons. The entrapment of passengers is regarded as a foreseeable event.

The alarm system is to be permanently connected to a permanently available rescue service, who must respond within five minutes (under normal circumstances) by a voice communication with the entrapped persons.

The rescue service is to intervene on site within one hour (under normal circumstances) of the alarm being raised.

The standard also states that trapped person is required to *'... be released within the shortest possible time.'*

An integrity check of the equipment by service interrogation or by remote initiation is required for *'the safety of the users ... at least every three days'*. The check is required to automatically simulate the input signal of an alarm (automatic test) and set-up the subsequent connection. The requirement means that a person could be trapped for three days before the system is checked. Then the trapped passengers would need to be discovered and released.



Caution: it is recommended that owners instigate an integrity check more frequently than this to ensure the complete alarm system is operational.

The alarm call can only be cancelled at the lift, where the call originated, by a competent person.

The alarm system should be powered by a battery. The alarm system should generate and transmit a warning if battery capacity is less than one hour of operation. At the present time there is no requirement to act on this warning local to the lift and lifts can continue to operate without the benefit of an alarm system. A daily check of the alarm system should be considered.



Note: some owner/operators set up an annual battery replacement as part of their preventative maintenance scheme.

The system is required to filter false calls, for example if the car doors are completely open.

Prior to the 1998 European harmonised standards, BS 5655-1 (BSI, 1986) and BS 5655-2 (BSI, 1988) required at clause 14.2.3 that an alarm device *'shall take the form of a bell, intercom system, external telephone or similar device'*. The requirement for a bell was not part of the 1998 standards.



Design tip: it is recommended that a local alarm bell sounding on each lift and at the main entrance is provided. This bell gives immediate feedback to a trapped passenger, reducing their stress levels and often ensures that local help and reassurance can be provided until a rescue service attends.

If no means of escape are provided for person(s) trapped in the well (lift industry personnel), which includes the lift pit and car top, then alarm initiation devices according to BS EN 81-28 must be installed at places where the risk of trapping exists, and they should be operable from the refuge space(s).

The alarm and test alarms must contain information that allows the rescue service to identify the location without the aid of the entrapped passenger.



Note: the BS EN 81-28 system may include intercom devices between the machine room and the lift car to allow contact with any trapped persons.

14.2.3 Operational flowchart

Figure 14.2 illustrates by means of a flowchart and accompanying text the sequence of operations, when an alarm is being processed. The numbers in parenthesis indicate clauses in BS EN 81-28 (BSI, 2003a).

There should be an exchange of information between the installer, the owner, the rescue service and the user.

After the completion of the lift installation, the following information should be given to the building owner:

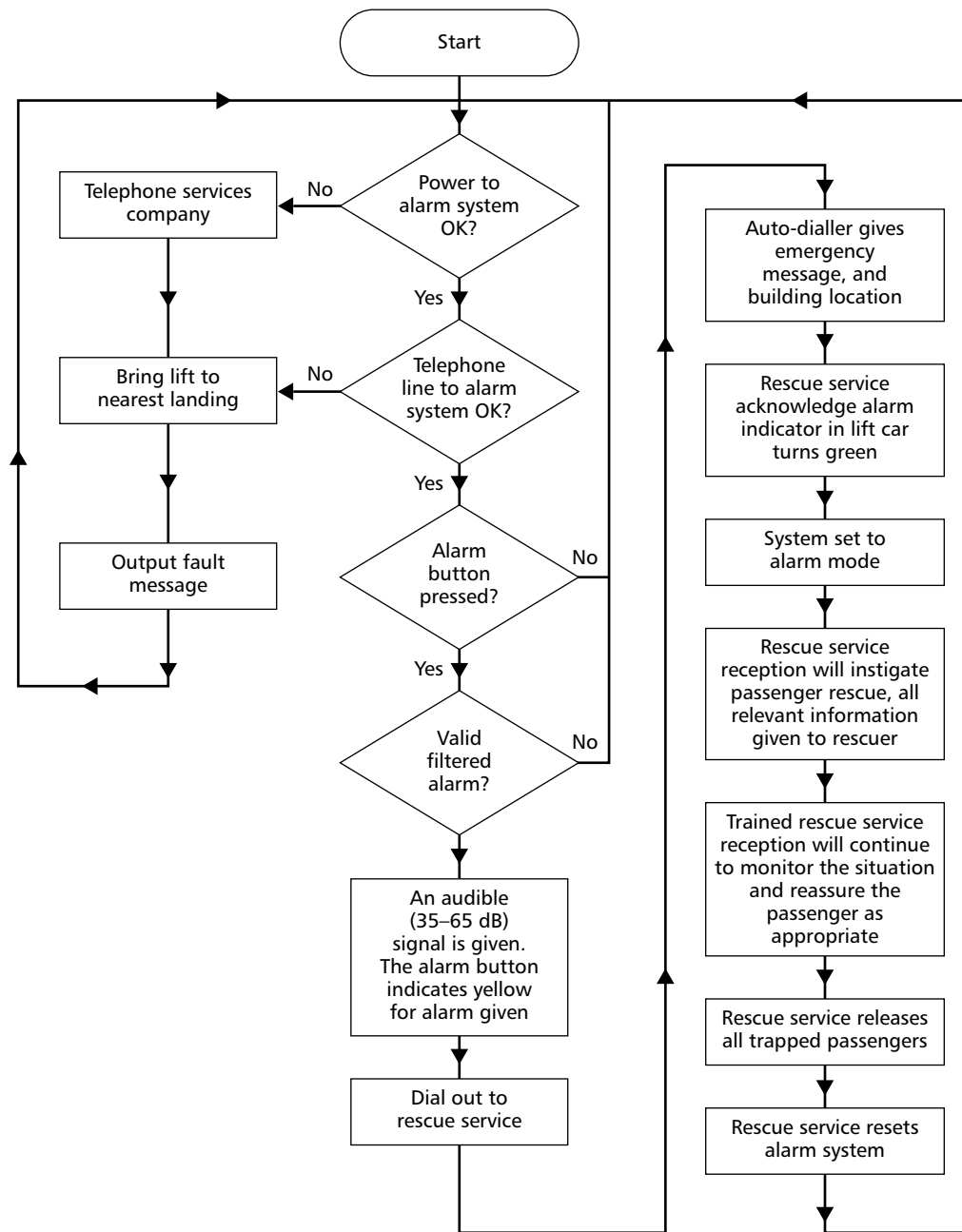
- that they must ensure that the lift is connected to a rescue service (5.2)
- all the site information is passed to the rescue service (5.2)
- the need to keep the equipment in working order, and to remove the lift from service when the equipment is out of order (5.2)
- minimum maintenance requirements of the alarm system (5.2)
- how to change dialling parameters, e.g. telephone numbers (5.2).

Information that should be provided by the owner to the rescue service:

- the general information of the system with reference to BS EN 81-28 (5.3)
- the need to establish a continuous 2-way communication with trapped users (5.3)
- the address and location of the lift (5.3)
- the building organisation and availability of on-site rescue service (5.3)
- access details for the building and lift (5.3)
- special risks for entering building and lift (5.3)
- compatibility between equipment (5.3)
- time limit of emergency power supply unit (5.3).

Sign to be displayed in the lift to provide passenger information (BSI, 2008):

'This lift is equipped with an alarm system and linked with a rescue service'.



To be read in conjunction with flowchart, Figure 14.2

- Alarm button pressed by passenger (once) to initiate an alarm call.
 - No further action is required by passenger.
 - The alarm equipment checks that it is a valid alarm before dialling rescue service. Note: the rescue service reception equipment must be compatible with site alarm equipment.
 - Filter alarm (4.1.5):
 - Is the lift in door zone, e.g. with the doors fully open?
 - Is the lift moving and will doors open at the next landing stop?
 - Alarm Call filtering inhibited during maintenance, repair and/or manual test. (4.1.1, 5.2)
 - Alarm Call filtering void when between acknowledgement and end of alarm. (4.1.1)
 - Once the alarm equipment verifies a valid alarm call (4.1.5) the unit immediately places itself into alarm mode.
 - The alarm equipment can then put out a message in the lift car to the passenger(s), e.g: 'Your call has been accepted please wait while we connect you'
 - Yellow indicator to illuminate (4.1.4 and BS EN 81-70: 2003, 5.4.4.3 (BSI, 2003b))
 - The alarm equipment dials the rescue service reception equipment. If the first number is unobtainable then alternative number(s) would immediately be called (4.2.1). Note: each of these numbers must be connect to the reception equipment, not only the telephone handset.
 - The rescue service will answer the call.
 - The reception equipment identifies and records the site and location of the lift.
 - Acknowledgement to the alarm equipment that the call has been received.
 - Green indicator to illuminate.
 - The rescue service will contact the rescuer and inform them of any relevant information (5.3).
 - Whilst the rescue service is travelling to site, the rescue service reception speak regularly with the trapped passenger(s) to inform them of the status of the rescue operation.
 - The rescue service arrives on site.
 - The rescue service promptly releases the trapped passenger(s).
 - After releasing all the passengers, the rescue service reception is informed using the voice unit in the lift car.
 - The alarm system is reset. Note: the reset button/switch/key is located on the lift installation, inaccessible to unauthorised persons.
 - The button/switch/key will generate an end of alarm message before hanging up (4.1.2).
- Automatic checks to be made by alarm unit**
- Where a rechargeable emergency electrical power supply is used, the reception equipment will be informed automatically that the alarm system has less than one hour of function remaining (4.1.3).
 - The alarm equipment must check the system automatically with a simulated input signal at least every 3 days (4.2.1).
- Manual checks**
- Manual tests should be carried out periodically by the maintenance company or building owner.

Figure 14.2 Operation of remote alarm: flowchart and description (figures in parenthesis refer to BS EN 81-28 (BSI, 2003a))

14.2.4 Testing BS EN 81-28 emergency alarms at installation

When a lift is installed in accordance with the Lifts Regulations 1997 (TSO, 1997) and is first placed into service, a verification of the operation of the alarm device is required to BS EN 81-1/2 (Annex D, D.2m) (BSI, 1998a/b) and BS EN 81-20, Table 18 (BSI, 2014a).

The flowchart in Figure 14.2 indicates that the operation of a BS EN 81-28 alarm system is complex. BS 8486-1 (BSI, 2007a) provides a pro forma test sheet, which is partially filled in at the manufacturer's test rig and partially filled in at the installation. The tests include:

- alarm transmissions (4.1.1)
- end of alarm (4.1.2)
- emergency electrical power supply (4.1.3)
- alarm filtering (4.1.5)
- alarm equipment identification
- communication
- technical characteristics.

The pro forma provides a record of the results of the tests and can also be used whenever an alarm device is replaced or repaired.

14.2.5 Communication protocol for BS EN 81-28 remote alarms

The scope of BS EN 81-28 (BSI, 2003a) does not include the communications network for remote alarms. The lack of a standard communications protocol allowed manufacturers to develop proprietary systems, which did not interface with each other. This often led to the complete replacement of a working alarm system when maintenance contracts changed. It also led to large number of 'silent' calls being made and the associated costs to attend to them.

This situation led to a BSI draft for development, DD 265 (BSI, 2008) in response to requests from purchasers and users of lift alarm systems for the establishment of common signalling protocols to ensure that lift alarm systems from different manufacturers exchange essential information and controls in a compatible manner.

At that time most remote alarms used multi-frequency tone (MFT) signalling over copper pairs to the local exchange.



Note: the connection system is often called the 'auto dialler'.

DD 265 followed this practice and is based on the social alarm protocol, BS 7369: *Multi-frequency tone signalling protocol for social alarm systems* (BSI, 1991).

This draft for development had the support of, and was implemented by, some UK suppliers but was withdrawn as it was not adopted as a standard in the time frame required by BSI.

Some emergency call centres have now implemented systems that recognise the protocols of all the major proprietary alarm systems. This delivers a universal service,

but adds complexity, which is ultimately reflected in the cost of these services.

14.2.6 Advances in communications technology

Multi-frequency tone signalling, as used for the vast majority of lift remote alarms, pre-dates advances in communication technology. The UK's PSTN (public switched telephone network) telephone service was based on copper twisted pairs. The backbone of the UK's telephone service is now based on an internet protocol (IP)* that will carry all types of traffic including voice, data, video, web surfing and television. The migration from copper cables to fibre, where practical and economic, has provided faster and more reliable network services. However, the final 'mile' from a lift is often still copper.

Within some organisations telephone exchanges have also been replaced with 'voice over IP' (VoIP), which removes the need for separate data and telephone networks. Meanwhile the cost of fixed lines has helped drive the rapid expansion in the application of 'global system for mobile communications' (GSM) technologies, which deliver mobile telephone and mobile broadband services.



Note: GSM gateways can be installed onto private exchanges to allow integration within an organisation.

These changes in technology have not been significantly reflected in lift alarm products, as at the current time about 90% still use analogue MFT signalling. Some lift alarms suppliers offer the option to replace fixed telephone lines with a GSM option or a network connection for VoIP. Although GSM may be the only solution to some problems, e.g. where digging up a road is impractical, the problem is one of reliability.



Caution: network disturbances can lock out lift alarms and if the GSM is requisitioned to deal with a major emergency, lift alarms are disconnected at a time when they are most needed.

14.2.7 Owner/operator duties

The trapping of passengers in a lift is a serious health and safety issue as mandated in the Lift Directive (Essential Health and Safety Requirement 4.5). The owner/operator should ensure that their lifts comply with BS EN 81-28 (BSI, 2003a).



Warning: should the emergency alarm system become inoperable then the lift should be removed from service until a repair has taken place.

It may be possible for an owner to allow temporary service provided additional surveillance systems are put in place, e.g. by patrol staff on a hospital or university campus.

The reliability of the connection to the rescue service is of prime importance. Generally all BS EN 81-28 alarm systems are based on an auto-dialler with the ability to make a sequence of first, second and third calls. How these calls are managed depends on the environment in which the lift is

* Part of the ISO 7-layer OSI model

installed. For example, on a hospital or university campus the first call may be made to a local control room, the second to the maintenance service provider and the third to a fully attended off-site rescue centre. In a smaller enterprise, say a heritage centre, the first call might be made to the manager, the second to the service provider and the third to the local Fire and Rescue Service (FRS). If a call is to be made to the local FRS then this should be by arrangement.



Note: many fire and rescue services consider that the owner should make adequate rescue arrangements (e.g. having trained rescue staff on site) and they will make a substantial charge if called out.

The most vulnerable link in the remote alarm system is the connection between the lift and the rescue point(s). The most reliable connection is a dedicated (wired) land line. If the alarm call is routed through a private automatic branch exchange (PABX) then it must have the highest priority and not have to compete for an outside line. Systems routed through computer based networks are generally not satisfactory owing to the lack of back-up equipment and down times associated with computer system maintenance. Mobile telephone services sometimes are employed but should only be used on a temporary basis, for example at commissioning, or where no other fixed line is possible.

14.3 Lift monitoring

14.3.1 Data logging

In the UK the Building Research Establishment commissioned the data logging of a number of lifts based on a transportable mini-computer in the mid-1970s (Malet et al., 1980; McKay, 1980). This work was mainly concerned with the performance of lifts in meeting passenger demands. As digital computer technology advanced manufacturers included data logging into their products. Today most lift traffic controllers include comprehensive data logging (see section 9.5.3).

There are usually several levels of data logging with access restricted to persons possessing different skill sets. For example the front line service staff should be able to access operational data, technicians able to interrogate and alter system parameters and owners/operators should have access to performance data to allow analysis.

Lift data logging permits the functioning of the lift to be recorded allowing improved fault diagnosis and maintenance provision. Access to this data should be restricted to maintenance service staff. They can then review the operation of the lift and check any irregular behaviour. If attending a call back to restore a lift to service the maintenance staff should be able to interrogate the data logger to establish the reason for lift failure. Such data would include: indications of the safety circuit being interrupted prematurely, doors failing to open, journey timer time-out, excessive re-levelling operations, door lock failures, etc.



Design tip: it is essential this information is backed-up and is not lost should the lift be switched off, e.g. to carry out a rescue. It should not be possible to delete these data.

The importance of comprehensive operational data can be used to provide advance indication of fault situations, which might affect the health and safety of passengers. For example, the recording of safety circuit interruptions (known colloquially as 'lock tipping') may eventually lead to a trapping or a lift stopping out of level and harm to passengers.

Most lift controllers incorporate the ability to alter parameters such as speed, acceleration, door timings, enabling/disabling access to landings, etc. The data recorded will enable informed adjustments to be made.



Caution: access to these data and the opportunity to adjust the parameters should not be available to first responding staff, but to persons at technician level.

Other data should be recorded indicating how well the lift installation is managing the passenger demands. Some systems provide a traffic analysis. The information available will vary according to the traffic control algorithm (see chapter 9). Conventional systems will normally provide: number of stops, number of landing calls, their origin, car calls, system response times and an analysis of landing and hall calls. Systems utilising hall call allocation control can provide more detailed information, including an estimation of passenger waiting and transit times based on a map of destination calls to passengers. If data collection is fully comprehensive, it is possible to replay lift operation into a traffic simulation program, closing the loop between traffic simulation for planning and what is happening in the actual installation (Smith and Peters, 2008).



Design tip: the owner/operator of a lift should have access to these data in co-operation with engineering staff of the installer company/maintenance provider.

14.3.2 Remote monitoring

Unlike remote alarms, remote monitoring requires more complex communications. BS EN 627 (BSI, 1996) provided a specification for data logging and monitoring of lifts, escalators and passenger conveyors. It was already out of date at the time of its publication and thus was never used. Lift manufacturers developed their own systems of remote monitoring, none of which would (and still will not) allow interoperability.

Remote monitoring provides a number of functions, including:

- *Fault monitoring:* Fault monitoring can provide the service company with immediate notification that a lift has gone out of service. This enables a faster call back response and thus less down time. The fault monitoring can indicate a specific fault code, e.g. identifying a door lock failure. This might assist in the correct replacement part being brought to site.
- *Condition monitoring:* Condition based monitoring can monitor the number of starts, hours of service and other operational statistics allowing data to be analysed to help deliver efficient and selective planned maintenance. The system may store historical information on faults, which may be used to assess reliability on a unit by unit basis.

- *Status indication*: ‘Lift in service’ status is important. Some systems provide a real time display of lift activity. This can act a reassurance that the lifts are operating; conversely unusual behaviour is sometimes first noticed on graphical displays. These displays are often provided locally to the owner/operator.
- *Performance monitoring*: As discussed in section 14.3.1, some systems provide a traffic analysis.
- *Remote control*: Remote control can be used by a service provider to initiate actions by a lift. For instance a hall call may be entered to check that a lift is in service. Only actions that a passenger may carry out should be permitted, e.g. landing/car calls, operation of door control buttons. No attempt remotely should be permitted to alter vital parameters such as speed, door timings, etc. These should only be carried out in ‘sight’ of the installation for safety reasons.
- *Alarms*: Alarms to BS EN 81-28 (BSI, 2003a) are discussed in section 14.2 and should be provided independently. Remote monitoring of unauthorised entry to the machine room, car top, etc. Alarms may also be provided to monitor site personal safety; after logging-in during attendance, service personnel must periodically reset a ‘watchdog’ alarm.
- *Video monitoring*: The availability of inexpensive internet connected cameras makes it practical to make provision for live video to be streamed to a rescue centre or other monitoring point.
- *Nuisance operation of emergency alarm buttons*: A check can be made that the lift is still in service or has its doors open at a landing reducing unnecessary rescue call outs. A lift alarm integrity check can be made remotely to establish a complete communication path is operational, i.e. the integrity of the landline.
- *Other features*: There are many other features that can be considered such as the ability to conduct ‘on-line’ investigations and analysis of lift activity; optional measurement of levelling performance.

14.3.3 Building automation systems (BAS) and building management systems (BMS)



Note: it is not the purpose of this section to detail BAS/BMS and only an overview is presented here.

Building automation systems (BAS) or building management systems (BMS) are computer-based control systems installed to monitor and control equipment including CCTV fire, lighting, security, power and ventilation systems. Generally a BAS consists of one or more networked controllers (or outstations). Controllers are equipped with input and output points that control and monitor the operation of the building systems. Controllers are distributed throughout the building in close proximity to the items of plant under control. They can work independently and are usually supplied from uninterruptible power supplies (UPS) to ensure they can operate during a power failure.

Controllers interface with individual system components, for example, to monitor temperature from a thermostat and

respond by turning on a fan. At a high level, a standalone fire alarm system may issue signals to the lift control systems to behave as BS EN 81-73 (BSI, 2005) requires.

Most BAS manufacturers promote themselves as supporters of the philosophy of open architecture and interoperability. However, there are many competing standards, including:

- BACnet is a data communication protocol for building automation and control networks and is a non-proprietary, open protocol communications standard specifically for building automation and control equipment. It became an international standard in 2003; the current implementation is recorded in BS EN ISO 16484-5 (BSI, 2014b).
- LonWorks (local operating network) is a networking platform specifically created to address the needs of control applications. The platform is built on a protocol created by Echelon Corporation. It is used for the automation of various functions within buildings such as lighting and HVAC. Lonworks has been adopted by international standards organisations as BS EN 14908-1 (BSI, 2014c).
- Modbus was developed by Modicon (now Schneider Electric), but is managed by an independent group, The Modbus Organisation. Modbus is not industry specific, and is a commonly used means of connecting industrial devices.
- KNX is a standardized (EN 50090, ISO/IEC 1454316), OSI-based network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus).
- CANopen is a communication protocol and device profile specification for embedded systems used in automation. In terms of the OSI model, CANopen implements the layers above and including the network layer.

A proposed addendum to BACnet (BSR/ASHRAE, 2012) includes proposals for standard objects to represent the status of lifts and escalators, and standardized services to convey this status, so that standardized remote condition-based monitoring and maintenance becomes possible using BACnet. KNX has a simple application for lifts.

The possibilities for the lift data to reach the end user (e.g. the building owner) is very limited. The lift and escalator industry could take advantage of the considerable success and widespread application of building management systems, which are now almost a standard item of equipment within the heating, ventilation, refrigeration and air conditioning industry.

Co-ordination between the BAS and lift manufacturers often takes place after contracts have been awarded. Thus, the possibilities of linking into a BAS are frequently considered too late in the design process. Adoption of standard communications or open communications protocols is a contentious issue within the lift industry. Standard systems give the customer a choice of suppliers for the same components, ranging from push buttons to control systems. Some consultants see standard protocols as the means by which they can provide an integrated system without restricting their clients to a single supplier.

Understandably, many lift manufacturers are wary of standard protocols, apart from commercial considerations, the integrity of systems may fall outside their control.

14.3.4 Future possibilities

The emergence of ‘cloud’ computing with the hosting of services on remote server farms is becoming increasingly common. This approach removes the need for on-site server maintenance, and takes advantage of economies of scale through grouping and sharing of computing resources. It is also attractive to vendors as it provides a more secure income stream than an outright sale supported by maintenance contracts. This trend is reflected throughout the software sector, e.g. Microsoft Office 365, Adobe Creative Cloud.

A BAS can take advantage of these trends. The BAS may be accessed via any internet enabled computer, reducing the space requirements for dedicated BAS terminals. Figure 14.3 shows the basic structure of a cloud based BAS. The system may be available to authorised users through an internet enabled device.

Readers of this section will have noted a common theme, the inevitable convergence towards open protocols, IP networks and cloud based technologies. The lift industry is rarely at the leading edge in implementing new technologies. However, client demands and cost considerations will inevitably drive the industry along this path.



Design tip: all parties should not forget to extend the building network to the lift motor room and ensure that any special requirements, e.g. the need for fixed IP addresses, are allowed for, if required.



Warning: company networks may block internet communications with firewalls, so it is essential that network security considerations are addressed when specifying the internet connection required for the lift monitoring system.

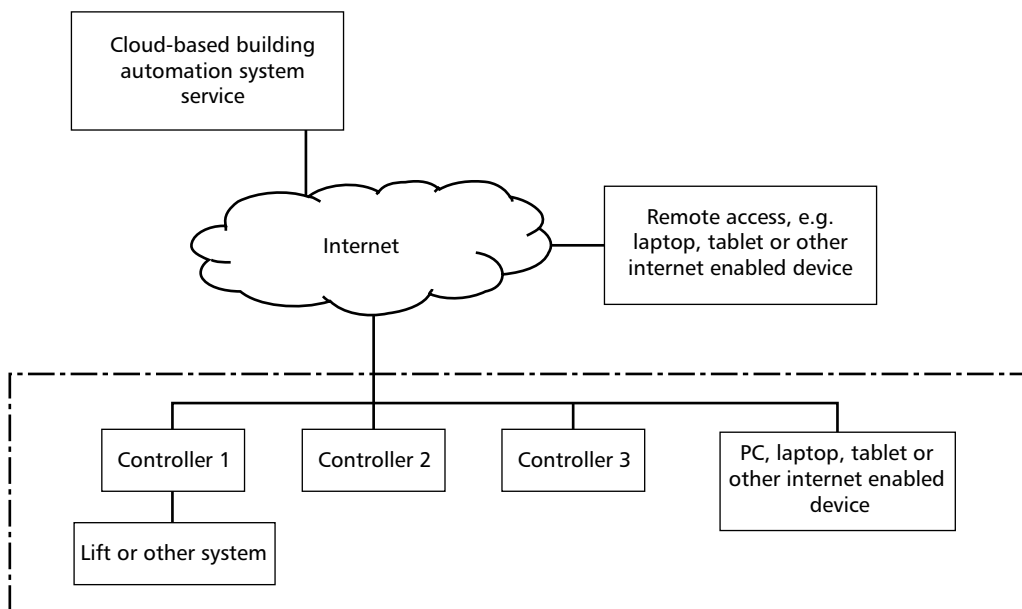


Figure 14.3 Cloud-based BAS system

14.4 Traffic surveys

14.4.1 The importance of traffic surveys

Traffic surveys are integral to lift traffic analysis (chapters 3 and 4) and the design process.

Traffic surveys are an important tool in the lift traffic designer’s armoury. They allow the designer or the user to assess demand in a building in order to use this value in future designs; or to verify the performance of an existing building in order to confirm the adequacy of a lift traffic design or to carry out remedial action if necessary. Research involving extensive surveys of different buildings (Peters et al, 2011) has shown that traffic patterns in buildings are repeatable over different days, despite small variations. The traffic pattern in a building can be thought of as a signature of that building.



Note: this section examines the types of traffic surveys that can be carried out in a building and describes the methodology of carrying them out and lists the reasons for doing them. It is brief and readers may wish consult other publications for detailed guidance (Barney and Al-Sharif, 2015).

Section 4.5 of this Guide gives details of survey practice.

14.4.2 Types of traffic surveys

14.4.2.1 Passenger related surveys

Three types are described below.

Assessing the passenger demand (e.g. the arrival rate) in an existing building

This type of survey aims to assess the passenger demand in a building. In addition to attempting to quantify the magnitude of the demand, it is also necessary in some cases

to understand the split of traffic into different modes (i.e. incoming traffic, out-going traffic and inter-floor traffic). Assessing the passenger demand in a building is necessary in two cases. The first case is carried out once a building has been commissioned and occupied to confirm whether the actual passenger demand is equal to that used in the design. The second case is where the lift system will be refurbished or upgraded and a survey is carried out in order to ensure that the new design will meet the existing passenger demand.

Measuring the performance of a lift traffic system in an existing building

This type of survey is more complicated and involved. Not only does it assess the demand, it also measures the lift system performance under the passenger demand. Such a survey could be carried out, for example, following the commissioning of a new lift system in order to verify the adequacy of a traffic system design, or to understand the reason for the poor performance of a lift system (Malet et al., 1980; McKay, 1980). The data this type of survey captures includes actual round trip times, actual intervals, system response times, maximum car load and average car load (Peters and Evans, 2008), number of door re-openings, stair usage (Green and Stafford Smith, 1977).

Understanding and modelling the nature of passenger arrival process

An improved understanding of the nature and the model for the passenger arrival process can be used to run more representative simulations for lift traffic. Process examples include Poisson arrival process (Alexandris and Barney, 1976), the process of batch arrival (Kuusinen et al., 2012) to understand relationships between various lift traffic

variables. Examples include trying to confirm the formula describing the relationship between the number of up-peak passengers boarding the lift car and the number of stops generated by the calls that they register, or trying to reconcile the values of the round trip time found by calculation and by simulation with the actual values recorded in practice.

14.4.2.1 Lift related surveys

Two types are described below.

Extracting the lift kinematic parameters (distance, velocity, acceleration and jerk)

These parameters allow a simulation to be carried out of an existing installation. The processing of the raw data signal extracted must be carried out in accordance with BS ISO 18738 (BSI, 2012).

Automated measurement of door timing performance

This includes door opening time, door closing time, door advance opening and door-start delay.

14.4.3 Survey methods

Manual paper-based surveys are carried out by human observers that locate themselves in the lobbies (for lobby surveys), or in the lift cars (for in-car surveys), see section 4.5. Filling-in paper forms is tedious and requires synchronizing the form data to a watch. An example of a lobby survey form is shown in Table 14.1.

Table 14.1 Form for a lobby survey

Time doors closed to depart from main lobby	Lift number	Number of people leaving that lift upon arrival	Number of people boarding the lift	Comments
08:03:42	4	1	1	
08:04:18	1	0	4	
08:05:21	2	0	3	r/o
08:05:35	1	0	1	
08:06:14	4	0	1	
08:06:41	1	0	1	
08:07:05	6	0	5	
08:07:34	3	0	3	
08:08:16	5	0	4	
08:08:16	4	1	0	r/o
08:08:47	2	0	1	
08:09:44	4	0	2	
08:10:47	5	0	2	
08:11:46	3	0	2	
08:12:18	2	0	2	
08:12:25	5	0	1	
08:13:06	3	0	2	
08:13:20	1	0	2	r/o
08:13:34	2	0	1	
08:13:52	5	0	3	
08:14:14	3	0	2	r/o
08:14:44	2	0	2	

Although manual surveys are usually based on filling-in paper forms, the use of laptops and tablets is becoming more prevalent in order to automate the process (Barney and Al-Sharif, 2015). Using a laptop/tablet provides important advantages, such as allowing immediate input to spreadsheets, time synchronism and improved accuracy.

It is also possible to place one or more cameras in the lobby in order to record the detailed passenger arrival and departures. The video can then be later analysed and survey data extracted by human observers. Using video recording to obtain survey data has advantages such as greater detail, repetitive replay opportunities, no human observers to affect the behaviour of passengers and image processing.

14.5 Escalators and moving walks

There are no remote alarms prescribed for escalators/moving walks. Many owners of large estates of escalators, e.g. underground railway systems, have set up comprehensive monitoring systems. A remote monitoring system for an escalator/moving walk is similar to that used for lifts and comprises monitoring units, communication systems and management systems. The overall system may be designed to monitor one or more data sources, e.g. alarms, faults, events and information.

Many escalators and moving walks suffer from being out of service as a result of not being reset after a nuisance operation of the emergency stop button. Such a delay accumulates downtime. Remote monitoring brings many advantages to all operators of such equipment, e.g. railways, underground railways, retail shops etc. Much of the lift guidance above is applicable.

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15 Commissioning, preventative maintenance, thorough examination and testing of lifts, escalators and moving walks

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15 Commissioning, preventative maintenance, thorough examination and testing of lifts, escalators and moving walks

15.1 Introduction

The proper commissioning, preventive maintenance, thorough examination and testing of lifts, escalators and moving walks is critical to ensure that they are correctly installed and are then inspected and maintained in order to achieve longevity, reliability and safety and comply with relevant legislation. The capital cost of such equipment is high so ensuring that it gives the maximum service life possible is essential.

The purchaser of any installation should bear in mind that quality differs from manufacturer to manufacturer. The life expectancy of any installation is, however, directly linked to quality and also to its correct maintenance and inspection. Lift expectancy is also linked to the user setting, e.g. in a social housing environment prone to vandalism versus a high quality office environment.

This chapter outlines the concepts behind the commissioning of new and modernised, or upgraded, equipment and details the subsequent preventive maintenance requirements during their operational life. It identifies the various regulatory requirements with regard to thorough examination/inspection and explains their role in the safe operation of lift, escalator and moving walk systems.

It should be understood that the roles of commissioning, thorough examination, inspection and maintenance are often undertaken by different persons. Many people are confused by the meaning of these different aspects. The free Health and Safety Executive publication *Thorough examination and testing of lifts — Simple guidance for lift owners* (HSE, 2008) gives a layperson's interpretation of these aspects and valuable guidance to duty holders.

The meanings used here are:

- *commissioning*: final work on an installation prior to putting into service (of a new or upgraded installation)
- *thorough examination*: systematic and detailed examination to detect any defects which are or might become dangerous
- *inspection*: visual and functional checks to determine that the equipment is operating correctly. *Note*: the extent of the inspection is dependent on the potential risk that could arise from the equipment.
- *preventive maintenance*: making of routine adjustments, cleaning, replacing worn or damaged parts, topping up fluids etc., to ensure the equipment is in an efficient and safe working condition.

All these aspects include some element of 'testing', which includes checking the correct operation of various components, often to their maximum ratings.

It is important to note that all the operations discussed in this chapter require persons to work on equipment. At all times they should work safely. Attention is therefore drawn to the requirements of the Provision and Use of Work Equipment Regulations 1998 (PUWER) (TSO, 1998a) and the Management of Health and Safety at Work Regulations 1999 (TSO, 1999), and the guidance given in BS 7255: *Safe working on lifts* (BSI, 2012a), BS 7801: *Safe working on escalators and moving walks in use* (BSI, 2011a) and BS 9102: *Code of practice for safe working on lifting platforms* (BSI, 2014a).

15.2 Commissioning

15.2.1 General conditions

Commissioning is the process of testing an installation to ensure that it meets its specification and complies with recognised standards and legislation. Various types of building services require to be commissioned to simulate the conditions which they will meet when they enter service, this includes any safety related items which only operate when and if they are needed to. Lifts, escalators and moving walks are no different and the early detection of possible defects can be critical to ensuring that the design life expectancy is achieved. Guidance to achieve a successful installation can be found in two British Standard Codes of Practice: BS 5655-6: *Selection, installation and location of new lifts* (BSI, 2011b) and BS 5656-2: *Selection, installation and location of new escalators and moving walks* (BSI, 2004).

Commissioning covers those activities undertaken to ensure compliance with the specified requirements. Within the framework of the Health and Safety at Work etc. Act 1974 (HMSO, 1974), the Lifts Regulations 1997 (TSO, 1997) and the Supply of Machinery (Safety) Regulations 2008 (TSO, 2008), a supplier has a responsibility to ensure that supplied goods are suitable for the stated intended purpose and in compliance with the relevant 'essential health and safety requirements' (EHSRs) as endorsed by the CE marking of a complete system or safety components.

This is in addition to the contractual responsibility to ensure that the goods are in accordance with the contract specification. Therefore lift and escalator manufacturers normally undertake their own systems of checks at various stages within the contract. The relevant design standard for the equipment, e.g. the BS EN 81 series of standards for lifts or BS EN 115 series for escalators and moving walks, may also recommend certain site tests to be undertaken on completion of the installation work.

The client may also supplement these systems with inspections by their personnel or by a third party. Such third parties may be insurance companies, inspection

organisations or consultancies that specialise in lift and/or escalator/moving walk systems. The intention to carry out such inspections should be specified in the early stages of the contract negotiation so that adequate provisions can be incorporated.



Design tip: when specifying, it is rare that a third party will want to witness all of the tests undertaken whilst the lift, escalator or moving walk is being set-up for service as this can be a lengthy process. Very often consultants specify the need to attend after it has been set-up and when it is expected to be a formality that everything is functioning correctly. They may choose to witness only a selected number of tests. If this is the case time should be allowed in the programme and the contractor should be asked to give sufficient notice for when witness testing can take place.

A prerequisite to commissioning is the possession of the relevant contract documents including dimensioned drawings and specifications, together with details of all agreed changes effected since origination, together with access to the technical file required by the Lifts Regulations 1997 (TSO, 1997) and Supply of Machinery (Safety) Regulations 2008 (TSO, 2008). In practice, even final installation drawings are commonly amended on site by agreement with those present at the time.



Caution: insist that documentation is provided prior to issuing practical completion (PC) otherwise the documents may never be received, which would cause difficulties later in the life of the lift, escalator or moving walk as well as not complying with the requirements of statutory instruments.

Specifications provide the contractual means by which specific requirements are recorded by the parties involved. In their most basic form, they may be based on a manufacturer's catalogue or a standard such as the BS EN 81 series or BS EN 115 series. Specifications are also used to define particular requirements such as the desired performance or the handling characteristics. In addition client requirements with respect to aesthetics and/or finishes may be specified. In some cases it may be necessary to define the environmental standards required, which are described in chapter 12 of this Guide.

The documentation prepared by the supplier should be checked to ensure compliance with the purchaser's requirements. Often this stage reveals oversights of detail known only to the client, or the innocent inclusion of minor variations by the supplier in order to match a standard product item.

The preliminaries having been duly agreed, the manufacture of the lift, escalator or moving walk unit commences in the knowledge of the client's requirements. There are a number of intermediate checks that can be undertaken during manufacture, including manufacturing base visits and site inspections. However, the main check is generally the commissioning test undertaken upon completion of the installation. Broadly the sequence is:

- off-site checks, during manufacture
- on-site checks, during installation
- on-site commissioning
- on-site checks on completion.

15.2.2 Off-site checks during manufacture

For all supply organisations, the manufacture of a lift, escalator or moving walk involves a combination of buying in manufactured components and producing components from raw materials. Reputable manufacturers will have systems of tests and controls, within the production cycle, to ensure compliance with specified requirements. These may relate to the purchase of materials, components or subassemblies, machining or fabricating processes, packaging, storage, transportation, installation etc. The systems are tailored to the organisation's general production requirements but may be supplemented by special conditions to meet the purchaser's requirements.



Note: off-site checks may be required to speed up the installation programme but very often they are only undertaken when there is a bespoke element to the design (such as lift car finishes).

For standard lift units, the benefits of imposing additional or special tests during this stage of supply rarely justifies the expenditure involved. Such tests are normally recommended only where the unit is beyond the manufacturer's normal range, e.g. some special configuration, or where significant development risks are involved.

Many manufacturers have quality management systems. Where these are in place, it is common to find 'manufacturing quality plans', which cover materials, drawings, processes, equipment etc. and the manufacturing interfaces during production. Such systems, if developed within a quality conscious manufacturing environment, afford increased assurance to the purchaser.

15.2.3 On-site checks during installation

After factory testing, pre-assembled lift components and escalator/moving walk units will be transported, perhaps over long distances, transferred across a building site or through a building and hauled into position, all of which may result in the need for adjustment or realignment. Pre-assembled components will then be connected to other components, structures and a power supply to produce the final installation.

Lifts are generally supplied to the site as consignments of components for assembly/reassembly in the lift well. Prior to the commencement of the installation, the manufacturer should carry out checks on the lift well within which the equipment is to be installed to verify its general alignment, finish, dimensions, location of fixings etc. Additionally, manufacturers normally undertake intermediate tests and checks at various stages during installation.

Alignment tolerances for lifts are becoming increasingly critical due to the increased emphasis on quality of ride, the tendency towards higher running speeds, and the development of steel framed buildings and 'fast-track' building techniques. This is particularly true for car and counterweight guide rails and the relative positions of the machine. Manufacturers have developed schedules for

checking these items since errors left undetected until completion are expensive and time consuming to correct. Similarly, alignment and fixing of landing door equipment, door locks, fixings for lift well switches and other internal equipment will be checked at appropriate stages during installation when the respective items are easily accessible. It is normal practice to document these checks, together with the relevant documentation (i.e. drawings, specification, procedures, etc.).

The majority of escalators and moving walks are supplied to site pre-assembled. Accordingly, checks on standard units during the installation process are generally confined to structural alignment and positional accuracy of fixings. Usually it is only special units that require extensive site assembly, such as the unusually long units required in transportation facilities such as airports and underground railway systems. In this case the installer will carry out various checks and tests prior to final commissioning.

15.2.4 Commissioning of lifts

15.2.4.1 New electric traction lifts

For new traction lifts specified to either the BS EN 81-1 (BSI, 1998a) or BS EN 81-20 (BSI, 2014b), there is a requirement under Annex D of BS EN 81-1 or Table 18 of BS EN 81-20 (as relevant) for examinations and tests before putting into service and the CE marking applied. In the documents, a number of tests are defined that need to be undertaken to ensure that the lift is functioning properly and has been installed to a satisfactory standard that complies with the specification and meets the requirements of current standards and legislation. These tests include:

- landing door locking devices
- electrical safety devices/systems
- suspension elements
- braking system
- measurement of speed and current (or power)
- insulation resistance and earth continuity
- limit switches
- traction and balance
- overspeed governor
- car safety gear
- counterweight safety gear (if fitted)
- buffers
- alarm devices
- functional tests
- ascending car over speed protection device
- ‘hand’ winding device/manual movement system.

The tests can be reported using the pro-forma BS 8486-1 (BSI, 2007a). There may be additional tests applied by the installer. The client may also require supplementary tests, which should be agreed at the time the contract is awarded as these may involve extra time and expense to carry out. These tests are often termed ‘witness tests’, when carried out and witnessed by the client or their representative.



Design tip: if a new electric traction lift is being installed in an existing building the requirements of BS EN 81-21 (BSI, 2009) may be applicable for issues where full compliance with BS EN 81-1 (BSI, 1998a) or BS EN 81-20 (BSI, 2014b) (as relevant) cannot be achieved such as pit depths or head rooms. Notified Body approval may be required.

15.2.4.2 New hydraulic lifts

For new hydraulic lifts specified to either BS EN 81-2 (BSI, 1998b) or BS EN 81-20 (BSI, 2014b) there is a requirement under Annex D of BS EN 81-2 or Table 18 of BS EN 81-20 (as relevant) for examinations and tests before putting into service and the CE marking is applied. In these documents, a number of tests are defined that need to be undertaken to ensure that the lift is functioning properly and has been installed to a satisfactory standard that complies with the specification and meets the requirements of current standards and legislation. These tests include the same requirements as the traction tests above, except the braking system, traction and balance, but additionally including the following:

- limitation of piston stroke
- measurement of full load pressure
- relief valve
- rupture valve
- restrictor device
- system pressure test
- creeping and anti-creep devices
- emergency lowering systems
- motor run time limiter
- fluid temperature detecting device.

The tests can be reported using the pro-forma BS 8486-2 (BSI, 2007b). There may be additional tests applied by the installer. The client may also require supplementary tests, which should be agreed at the time the contract is awarded as these may involve extra time and expense to carry out. These tests are often termed ‘witness tests’, when carried out and witnessed by the client or their representative.



Design tip: if the new hydraulic lift is being installed in an existing building the requirements of BS EN 81-21 (BSI, 2009) may be applicable for issues where full compliance with BS EN 81-2 (BSI, 1998b) or BS EN 81-20 (BSI, 2014b) (as relevant) cannot be achieved, such as pit depths or head rooms. Notified Body approval may be required.

15.2.4.3 Lifts subject to important modifications (modernised lifts)

During the lifetime of any lift there may be modifications to the equipment, or it may be modernised (see chapter 16).

For lifts installed before 1 July 1999 earlier versions of BS EN 81, BS 5655 and even BS 2655 may apply. Any modernisation should attempt to comply to the latest standards. However, in some instances this is not possible. BS 5655-11: *Code of Practice for the undertaking of modifications to existing electric lifts* (BSI, 2005a), BS 5655-12: *Code of*

Practice for the undertaking of modifications to existing hydraulic lifts (BSI, 2005b) and *BS EN 81-80: Rules for the improvement of safety of existing passenger and goods passenger lifts* (BSI, 2003) give guidance.

For lifts installed after 1 July 1999 they should continue to be in full compliance with the EHSRs of the Lifts Regulations 1997 (TSO, 1997) or the current version of the relevant harmonised BS EN 81 standard. Any commissioning and testing should therefore be to those parts of BS 8486-1 (BSI, 2007a) or BS 8486-2 (BSI, 2007b) that apply to the changed equipment.

No test documents have been published by BSI specifically for modernised lifts installed before 1 July 1999. BS 5655: Part 10.1.1 (BSI, 1995a) and BS 5655: Part 10.2.1 (BSI, 1995b) are available, but apply to the commissioning tests for new traction and new hydraulic lifts, respectively. These documents can be used as a basis for the testing of modernised lifts supplemented by sections from the BS 8486 standards previously mentioned. The testing documents mentioned apply only for lifts installed when those documents were current.

15.2.5 Commissioning of escalators and moving walks

There are two generic types of escalators and moving walks: those that are built on site and those that leave the factory as a pre-constructed package. The type that are pre-constructed are generally commissioned prior to leaving the factory. This allows any defects found to be rectified before the unit reaches the site, especially if the unit is manufactured and assembled abroad. Clearly, units that are built on site need to be commissioned on site. New escalators should be built to conform to BS EN 115-1 (BSI, 2008) and are generally commissioned to the manufacturer's specification. Clause 7.3 of BS EN 115-1 requires a constructional inspection and acceptance inspection and test, before placing in service, that comprises:

- an overall visual inspection
- a functional test
- a test of electrical safety devices with regard to their effective operation
- brake tests
- insulation resistance tests.

For escalators, these tests can be documented using BS 5656-1: *Examination and test of new escalators before putting into service. Specification for means of determining compliance with BS EN 115-1:2008+A1:2010* (BSI, 2013) or, for moving walks, BS 5656-3: *Examination and test of new moving walks before putting into service. Specification for means of determining compliance with BS EN 115-1: 2008+A1: 2010* (BSI, 2014c).

15.2.6 On-site checks after completion

Following testing of the installed units, the applicable standards recommend inspection as an integral part of the test procedure. This inspection usually involves examining the completed installation for conformity with the specification and with regard to proper workmanship. Although usually carried out by the manufacturer, third

party inspection is often specified at this crucial stage of the client acceptance process.

This inspection generally results in a report, commonly known as a 'snagging list', which identifies items requiring attention by either the manufacturer or other parties involved in final installation (e.g. electrical supply contractor, builder etc.). These items may be minor and rectifiable immediately or if of a more serious nature may involve protracted contractual negotiations and/or delay to the programme.

There are no specific documents for the testing of escalators that have been modernised. Particular attention is drawn to BS EN 115-2: *Rules for the improvement of the safety of existing escalators and moving walks* (BSI, 2010). Following a modernisation the tests can be documented using BS 5656-1 (BSI, 2013) as previously mentioned for new escalators and BS 5656-3 (BSI, 2014c) for moving walk installations.

15.3 Preventative maintenance

15.3.1 Why maintain?

Lifts, escalators and moving walks are expensive items of equipment. It would be foolish to think that a piece of equipment could operate for long without adequate maintenance being undertaken. In this context, preventive maintenance refers to adjustment, cleaning, lubrication, replacement of worn components etc. Maintenance should not be regarded as an optional extra, nor should a 'breakdown only' approach be adopted. Statutory provisions in Regulation 5 of PUWER (TSO, 1998a) mention the requirement that the equipment be properly maintained. Failure to maintain equipment would lead to its safety and reliability being compromised and would be in contravention of the statutory provisions.



Caution: when specifying new lifts, escalators or moving walks it is recommended that a cost for maintenance is sought prior to placing a contract with a contractor. Costs sought should be for long, medium and short term periods. This is particularly important where closed protocol equipment is installed and it is not possible to have the unit maintained by anyone other than the original installer, who may charge premium rates.

BS EN 13015: *Maintenance for lifts and escalators. Rules for maintenance instructions* (BSI, 2001) sets out the basic rules for maintenance and its provisions should be used to form the basis of a maintenance contract. Annex A (informative) of this standard provides checklists of typical maintenance operations. Table 15.1 provides a summary of these checklists for escalators and moving walks.

An important requirement of the standard is the provision of a maintenance instruction handbook to be supplied by the installer to the owner of each installation.

The Lift and Escalator Industry Association (LEIA) has published a freely available Code of Practice, LM01: *Maintenance requirements for lifts, lifting platforms, escalators*

Table 15.1 Maintenance check list for electric lifts from BS EN 13015: 2001 (BSI, 2001)

Area	Equipment	Check:
(a) Electric lifts		
General	Housekeeping	All components are clean; free from dust and corrosion
	Electric wiring	Insulation
Pit	Pit area	For excess oil/grease at bottom of guides; area is clean, dry and free from debris
	Anti-rebound device and switch	For free movement and operation; for equal tension of ropes; switch (where fitted); lubrication.
	Buffers	Oil level; lubrication; switch (where fitted); fixings; operation.
	Electric safety devices	Operation
Machine room	Drive motor/generator	Bearings for wear; lubrication; commutator condition
	Gear box	Gear for wear; lubrication
	Traction sheave	Condition and grooves for wear
	Brake	Braking system; parts for wear; stopping accuracy
	Controller	Cabinet is clean, dry and free from dust
	Overspeed governor and tension pulley	Moving parts for free movement and wear; operation; switch
	Main rope diverter pulley(s)	Condition and grooves for wear; bearings for abnormal noise and/or vibrations; guarding; lubrication
	Suspension ropes/chains	For wear, elongation and tension; lubrication only where intended
	Rope/chains terminations	For deterioration and wear; fixings
	Safety gear(s)/ascending car overspeed protection means	Moving parts for free movement and wear; lubrication; fixings; operation; switch
	Motor run time limiter	Operation
	Electric safety devices	Operation; electric safety chain; correct fuses are fitted
Well	Car/counterweight guides	For film of oil where required on all guide surfaces; fixings
	Car/counterweight guide shoes	Guide shoes/rollers for wear; fixings; lubrication where necessary
	Suspension ropes/chains	For wear, elongation and tension; lubrication only where intended
	Rope/chains terminations	For deterioration and wear; fixings
	Final limit switches	Operation
	Well lighting	Operation
	Electric safety devices	Operation; electric safety chain
External	Lift car	Emergency lighting, car buttons, key switches; fixings of panels and ceiling
	Landing entrances	Operation of landing locks; doors for free running; door guiding; door gaps; wire rope, chain or belt when used, for integrity; emergency unlocking device; lubrication
	Car door	Door closed contact or lock; doors for free running; door guiding; door gaps; wire rope or chain when used for integrity; passenger door protective device; lubrication
	Floor level	Stopping accuracy at landing
	Emergency alarm device	Operation
	Landing controls and indicators	Operation
(b) Hydraulic lifts		
General	Housekeeping	All components are clean; free from dust and corrosion.
	Electric wiring	Insulation
Pit	Pit area	For excess oil/grease at bottom of guides; pit area is clean, dry and free from debris
	Buffers	Oil level; lubrication; switch where fitted; fixings
	Electric safety devices	Operation
Machine room	Tank unit	Hydraulic fluid level; tank and valve unit for leakage
	Controller	Cabinet is clean, dry and free from dust
	Pressure relief valve	Operation
	Manual lowering valve	Operation
	Hand pump	Operation
	Motor run time limiter	Operation
	Electric safety devices	Operation; electric safety chain; correct fuses are fitted
	Hose/pipe work	For damage and leakage

Table continues

Table 15.1 Maintenance check list for electric lifts from BS EN 13015: 2001 (BSI, 2001) — *continued*

Area	Equipment	Check:
(b) Hydraulic lifts (<i>continued</i>)		
Well	Jack	For oil leakage
	Telescopic jack	For synchronisation
	Overspeed governor and tension pulley	Moving parts for free movement and wear; operation; switch
	Main rope pulley(s)	Condition and grooves for wear; bearings for abnormal noise and/or vibrations; guarding; lubrication
	Car/balancing weight/jack guides	For film of oil where required on all guide surfaces; fixings
	Car/balancing weight/jack shoes	Guide shoes/rollers for wear; fixings
	Safety gear/pawl/clamping devices	Moving parts for free movement and wear; fixings; operation; switch
	Suspension ropes/chains	For wear, elongation and tension; lubrication only where intended
	Ropes/chains terminations	For deterioration and wear; fixings
	Well lighting	Operation
	Final limit switch	Operation
	Electric safety devices	Operation; electric safety chain
	Anti-creep device	Operation
	Rupture valve/One way restrictor	Operation
	Hose/Pipe work	For damage and leakage
External	Lift car	Emergency lighting, car buttons, key switches; fixing of panels and ceiling
	Landing entrances	Operation of landing locks; doors for free running; door guiding; door gaps; wire rope, chain or belt when used, for integrity; emergency unlocking device; lubrication
	Car door	Door closed contact or lock; doors for free running; door guiding; door gaps; wire rope or chain when used for integrity; passenger door protective device; lubrication
	Floor level	Stopping accuracy at landing
	Emergency alarm device	Operation
	Landing controls and indicators	Operation
(c) Escalators and moving walks		
Machine space	Controller	Cabinet is clean, dry and free from dust
	Gear box	Gear and associated parts; lubrication
	Drive motor	Bearings for wear; lubrication
	Brake	Braking system; parts for wear
	Auxiliary brake	Braking system; parts for wear
	Intermediate gear box	Gear and associated parts; lubrication
	Main drive chain	For tension and wear; lubrication
	Step/pallet chain	For tension and wear; lubrication
	Step/pallet	Step/pallet and step/pallet wheels for integrity
	Conveyor belt	For condition and tension
	Drive belt	For condition and tension
	Track system	For condition and wear; fixings
	Safety devices	Operation
EXTERNAL	Clearances	Step to step and step to skirting clearances
	Combs	Condition; meshing with steps, pallets or belt.
	Comb plate	Clearances and operation.
	Handrails	For free running and condition; tension; synchronisation between step/pallet band and the handrail.
	Safety devices	Operation
	Deflector devices	Condition
	Lighting	Operation
	Display	Operation
	Signs/pictograms	Condition
	Balustrade	Condition of panels; fixings of interior claddings
	Controls	Operation
	Unobstructed access	Availability

and moving walks (LEIA, 2013), which may be referred to for guidance.



Note: many large buildings with numerous lifts and/or escalators/moving walks negotiate an on-site maintenance team who are permanently based in a building.

15.3.2 Maintenance contracts or agreements

Maintenance contracts or agreements vary from contractor to contractor, but in general there are three types of contract within the lift and escalator industry:

- Contracts that provide for checking and lubrication only, repairs being subject to agreed further costs. These are more aptly called ‘oil and grease’ or basic contracts.
- Contracts that provide for fully comprehensive preventive maintenance cover all parts, labour and call-out fees.
- Contracts that provide premium services beyond a simple comprehensive contract, such as condition monitoring, remote monitoring, performance guaranteed service, etc.

LEIA Code of Practice LM01 (LEIA, 2013) cites some but not all contract possibilities.

With the ‘oil and grease’ contract, an operative from the lift maintenance company will attend and check lubrication levels, adjust anything that requires attention and clean the unit. Any further labour attendances or component replacement(s) etc. will normally attract an additional cost.

The fully comprehensive preventive maintenance contract usually includes for all activity described in the ‘oil and grease’ contract, but the labour and component costs in the event of a breakdown are met by the maintenance contractor. The small print of such contracts needs to be read carefully to avoid misunderstandings regarding exclusions. It is normal to exclude vandalism and misuse but, in addition, some companies will exclude major items such as hydraulic ram seals, gearbox repairs, etc.

Fully comprehensive maintenance contracts allow for a regular budgeted cost and should secure a predetermined performance level throughout the life of the installation. The on-going maintenance costs of lift/escalator/moving walk systems must be considered an integral part of the operating costs of the building. In most cases, they are negotiable with the equipment manufacturer in the form of a long-term agreement. The longer the agreement period, the greater is the incentive for the contractor to develop effective programmes for maintenance work. Contracting the equipment manufacturer to provide the maintenance beyond the initial warranty period has inherent advantages in respect of product familiarity, particularly in terms of design, development and training.

The overall costs of both forms of contract over the life cycle of the equipment should be similar. Unfortunately, the low initial cost of the ‘oil and grease’ contract is often a deciding factor in their selection. The total budget for lift/escalator maintenance is then sometimes determined solely on the cost of the ‘oil and grease’ contract and non-essential

preventive works are regarded as unnecessary expenditure. This inevitably leads to poor performance, accelerated deterioration of equipment and premature failure.

The level of activity undertaken by the maintenance contractor varies according to the age and complexity of each installation, the equipment usage and the performance requirements. These factors determine not only the number of visits per year (which may range from two to twenty) but also the scope of work undertaken at each visit over, say, a five- or eight-year programme.

The installation of performance data loggers, to either new, or existing lift control systems, makes it feasible to specify maintenance requirements in terms of quantitative performance criteria. With such equipment, it is now comparatively simple to record and analyse performance data such as service and usage characteristics, number of failures over a specified period, mean time between failures, average/maximum service response time and system downtime/percentage system availability.

It should be borne in mind that the quality of the maintenance undertaken will vary with time allowed per unit on site and with the skill level of the operative appointed to maintain the equipment.



Caution: attention is drawn to the fact that some manufacturer’s products are supplied under an arrangement known as ‘closed protocol’. This sometimes means that the equipment can only be maintained by the manufacturer as specialist equipment may be required to interrogate or adjust the system.



Caution: ensure that the contractor appointed to install and/or maintain equipment has a local presence. A London-based contractor may not have sufficient resources to undertake work in Edinburgh, for example.

15.4 Thorough examination and tests

15.4.1 Competent persons

A thorough examination of an installation is a systematic and detailed examination, performed by a competent person. The purpose is to determine the condition of the installation and report on its suitability for its continued safe use. It could be likened to the ‘MoT’ test applied to motor vehicles.

Thorough examinations are generally required to be carried out so that the duty holder complies with the legislation. The principal applicable legislation is the Health and Safety at Work etc. Act 1974 (HMSO, 1974), specifically:

- Section 3: the duty of employers and self-employed persons to conduct their undertakings in such a way that people they do not employ are not put at risk.
- Section 4: the duty of owners of premises to maintain safe conditions for persons other than

employees who may use or come into contact with equipment within premises.

- Section 6: the duty of suppliers, importers and/or manufacturers to ensure equipment is safe for its intended use (including incorporation of safe means of cleaning, maintenance, setting and inspection) and is supplied with adequate information regarding safe use.

All these provisions must be complied with in so far as is reasonably practicable.

According to BS 7255: *Code of practice for safe working on lifts* (BSI, 2012a), a competent person is:

‘[a] person, suitably trained and qualified by knowledge and practical experience, and provided with the necessary instructions, to enable the required work to be safely carried out.’

It is important that the competent person is independent and impartial so that an objective assessment can be made. For example, it is not appropriate to engage someone employed by the maintainer of the equipment to be examined, as they could be responsible for assessing their company’s work. Few organisations have such competencies in-house and must use an external third party. An inspection body accredited by the United Kingdom Accreditation Service (UKAS) to BS EN ISO/IEC 17020 (ISO, 2012b) would be a suitable organisation to carry out thorough examinations. Some insurance companies do not carry out thorough examinations themselves. The Safety Assessment Federation (SAFed), a trade organisation, can recommend inspection bodies or details can be found at the UKAS website (<http://www.ukas.com/about-accreditation/accredited-bodies/inspection-body-schedules.asp>).

15.4.2 Thorough examination of lifts

The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) (TSO, 1998b) introduced requirements for the safe provision and use of lifting equipment and applies to lifts and hoists used to lift people and loads. Regulation 9 of LOLER requires that in-service thorough examinations take place to ensure the continued safe use of the equipment. These examinations are required to take place every six months for passenger lifts and annually for goods only (non-passenger carrying) lifts, unless a risk assessment shows the frequency should be reduced or increased in accordance with an examination scheme drawn up by a competent person. The thorough examination should include as a minimum:

- landing door locking devices
- door equipment
- main drive system components
- worm and other gearing
- electrical safety devices/systems
- suspension elements
- braking system
- governors
- safety gear
- overload detection devices
- control equipment
- supporting structure, guides and fixings
- clearances and tolerances
- hydraulics
- check of Part 28 alarm device
- operation of any Part 73 recall devices.

To avoid ‘equipment not available’ reports, it is advisable to contract the inspection body carrying out thorough examinations to make fixed diary appointments. This avoids the disruption of lift service in a building as lifts have to be taken out of service in order to carry out the inspection. It may also be advisable to ensure a service visit has been made shortly before the thorough examination.

Following a thorough examination a report should be issued by the competent person (see Figure 15.1). The requirements of such a report are detailed in Schedule 1 of LOLER. Many people still refer to such a report as an ‘insurance inspection’. This is incorrect as it is a statutory thorough examination. A LOLER thorough examination must also be carried out after substantial or significant changes have occurred, e.g. modernisation, major repair, or after an exceptional circumstance such as an accident. LOLER applies to workplaces and not to domestic dwellings, although a similar examination regime is recommended as it is seen as best practice.



Caution: for owners or managers of equipment falling under LOLER it is recommended that a robust system for managing any defects found be in place, such that an audit trail demonstrating rectification can be provided if necessary. If a competent person undertaking the LOLER thorough examination recommends that a piece of equipment be taken out of service this should be done until the defect is rectified. If there is a reason to doubt the opinion of the competent person it is recommended that professional advice be sought before putting the equipment back into service.



Caution: LOLER does not specifically mandate that a competent person returns to site to verify that a defect has been rectified. If it were an MoT test carried out on a motor vehicle it would need to be taken back to an MoT centre if it failed its first examination. LOLER is not so robust, but it would be considered good practice to ask the competent person to re-examine the equipment and issue a new certificate.



Note: at the time of publication of this Guide (September 2015) some inspection bodies have agreed with the Managing Agents Property H&S Forum (<http://www.propertyforum.org.uk>) to try and create a form having a standard appearance as they differ from company to company. Under earlier regulations ‘Form 54’ was used, which presented a standard appearance and created consistency that has been lost since the introduction of LOLER.

15.4.3 Periodic testing of lifts

Generally thorough examinations are visual checks and functional tests and do not involve any extensive testing.

Type: (P) — periodic; (PS) — periodic, following a scheme of examination;
(O) — examination after the occurrence of exceptional circumstances

Address: Town Hall
Bishop's Place
Anytown
GC4 6PO

Location of lift: Town Hall fover

(C) The following recommendations are made:

1. That an approved type rubber mat, to BS 921, be provided at the control panel.
2. That emergency lighting be installed within the machine room.
3. That ventilation be provided within the machine room.
4. That a safety barrier be provided in accordance with BS 7255

Lift Guidelines (LG1) Tests/
Examinations. Internal lock examination (PSL): 19/09/15.
Levels 1 to 3 internally examined.
Observation: the shaft-top lifting beam (S.W.L. 1 tonne) was included within the scope of this examination.

M Jones

Date of issue of report: 19/09/2015

However examinations and tests are detailed under section 16.3.3 of BS EN 81-1 (BSI, 1998a) and BS EN 81-2 (1998b) and Table 18 of BS EN 81-20 (BSI, 2014b). To meet these requirements in the UK, guidelines have been issued by the Safety Assessment Federation in consultation with the HSE, suppliers, installers, consultants and users. These guidelines were known as the Lift Guidelines (LG1) (SAFed, 1998).

LG1 (1998) was updated in March 2006 by SAFed in consultation with a wide spectrum of organisations and published as *Guidelines on the supplementary tests of in-service lifts* (SAFed, 2009). These guidelines recommend supplementary examinations, which are undertaken when the competent person carrying out the periodic thorough examination calls for them, subject to a risk assessment. These supplementary tests are generally to be completed before the next thorough examination. Prior to 2006 these tests were recommended at specified time intervals which some owners and/or operators of lifts continue to adopt. The supplementary tests can include the following.

Both electric and hydraulic lifts:

- earth continuity
- electrical safety devices
- terminal speed reduction systems
- landing door interlocks
- shafts and plain bearings
- roller, ball and needle bearings
- overspeed governors
- safety gear
- overspeeding of ascending car
- car overload detection devices.

Traction lifts only:

- traction, brake and levelling:
- geared machines
- energy dissipation buffers.

Hydraulic lifts only:

- hydraulic systems
- hydraulic rupture/ restrictor valves
- hydraulic cylinders
- electrical anti-creep systems
- mechanical anti-creep device
- low pressure detection devices.

These tests are required to be no more severe than those carried out at commissioning. They should be undertaken by a competent person, who may be employed by the maintenance company or by a third party. It is again important that the competent person is independent and impartial so that an objective assessment can be made. It may not be appropriate for the maintainer of the equipment to use one of their staff and many maintenance companies chose to sub contract these inspections to a body specialising in their provision.



Warning: it is not acceptable to simply operate a safety switch by hand as all this proves is that the switch is free to operate and it is wired correctly into the control circuit. The mechanism that operates the switch should be verified as operational and that any movement of that mechanism will, in fact, operate the switch.

Certificates are issued following each test with details of a pass or fail. There are 21 different certificates covering a range of tests in Annex A of the current SAFed Lift Guidelines (SAFed, 2009) available from the SAFed website (<http://safed.co.uk>) in Microsoft Word® format.

15.4.4 Thorough examination of escalators and moving walks

There is no specific legislation requiring the thorough examination of escalators and moving walks. However, The Health and Safety at Work etc. Act 1974 (HMSO, 1974) applies generally, together with the Management of Health and Safety at Work Regulation 1999 (MHSWR) (TSO, 1999). Section 19 of the Workplace (Health, Safety and Welfare) Regulations 1992 (TSO, 1992) makes reference to escalators and that regular inspections should be made. Previous Health and Safety Executive Guidance Note PM45 (HSE, 1984) (now withdrawn) recommended a basic six-monthly examination by a competent person. Clause 7.4.1(f) of BS EN 115-1 (BSI, 2008) recommends that the documentation provided with a new escalator or moving walk includes a periodic inspection and test that should ascertain whether the escalator or moving walk is safe in operation.

In 2006 under the auspices of the HSE, a SAFed working group was formed comprising owners, user groups, escalator manufacturers, installers, suppliers, maintenance companies, inspection bodies, the enforcement authorities, consultants and other professional bodies to provide guidance for the thorough examination of escalators and moving walks. This object of this working group was to fill the void created by the withdrawal of PM45 and, in May 2011, SAFed's *Guidelines for the safe operation of escalators and moving walks* (EMW) were published, the latest version of which is dated December 2012 (SAFed, 2012).

The EMW guidelines (SAFed, 2012) do not define the scope of a thorough examination as that is the responsibility of the competent person undertaking the thorough examination. It does however give recommendations. As a minimum the examination should be carried out every six months and include the following:

- check on general operation
- electrical safety devices
- earthing continuity
- braking system
- treadway (steps and pallets) and check on running clearances
- comb plate condition
- balustrades, decking and skirts
- handrails
- escalator skirt deflector devices

- visual examination of exterior of the complete unit
 - surrounds, lighting and warning/advisory signs
 - drive system
 - controller.
- A report should be issued following the thorough examination of an escalator or moving walk to the duty holder. The SAFed working group include as Annex D of the EMW guidelines (SAFed, 2012) a generally agreed template for a report of a thorough examination. This is reproduced here as Figure 15.2.

Guidelines for the safe operation of escalators and moving walks — Issue 02.1 — Dated 20 Dec 2012			
ANNEX D— Example report of thorough examination of an escalator or moving walk Inspection Companies are free to use other formats containing the minimum required information similar to that in LOLER 1998 — Schedule 1.			
Owner/Duty Holder		Address	
Date of this examination		Type of Examination	
Type: (P) - Periodic; (O) - Examination after the Occurrence of Exceptional Circumstances.			
Distinguishing No. and Description			
Manufacturer and date			
Location			
Details of defects found. Defects noted should be consistent with the rejection criteria listed in Annex C			
Access and guarding			
Running condition			
Electrical Safety devices			
Earthing continuity			
Braking system			
Treadway (steps and pallets)			
Comb plate/comb			
Balustrades, decking, skirt			
Handrails			
Skirt Deflector devices			
Surrounds, lighting and warning/advisory signs			
Drive system			
Controller			
Other (specify)			
Parts inaccessible?			
Defects found which affect continued safety and repairs required immediately or in a specified time. If none state "none".			
Other defects and repairs required. If none state "none".			
Other observations. If none state "none".			
Date of last thorough examination		Due date of next thorough examination	
I confirm that the equipment was thoroughly examined on: and that subject to any remedial action(s) noted above being completed, is safe to operate. Details of person making the report (name, address, qualifications and employer/self employed) Details of person authenticating report on behalf of the author (if different) Date of Issue of Report:			

Figure 15.2 Suggested format for a report of a thorough examination of an escalator or moving walk (reproduced from *Guidelines for the safe operation of escalators and moving walks* (SAFed, 2012) by permission of the Safety Assessment Federation)

15.5 Documentation

Owners of lift, escalator and moving walk equipment should maintain documentation detailing their commissioning, preventive maintenance, testing and thorough examination. Besides the requirements to keep the statutory thorough examination documents, it is recommended that copies of the following information should be retained:

- the commissioning certificate and declaration of conformity (signed and dated)
- the test documents
- past and current maintenance contract documentation
- maintenance attendances (machine room log cards)
- break down attendances
- supplementary reports (lifts only).

These documents will provide a valuable source of information in the event of the equipment becoming unreliable, upgraded, involved in an accident, etc.

References

- BSI (1995a) BS 5655-10.1.1: 1995: *Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Electric lifts. Commissioning tests for new lifts* (London: British Standards Institution)
- BSI (1995b) BS 5655-10.2.1: 1995: *Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Hydraulic lifts. Commissioning tests for new lifts* (London: British Standards Institution)
- BSI (1998a) BS EN 81-1: 1998 + A3: 2009: *Safety rules for the construction and installation of lifts. Electric lifts* (London: British Standards Institution) (consolidated BS EN 81-1: 1998 + A1: 2005 + A2: 2004 + A3: 2009 + corrigendum September 1999)
- BSI (1998b) BS EN 81-2: 1998 + A3: 2009: *Safety rules for the construction and installation of lifts. Hydraulic lifts* (London: British Standards Institution) (consolidated BS EN 81-2: 1998 + A1: 2005 + A2: 2004 + A3: 2009 + corrigendum September 1999)
- BSI (2001) BS EN 13015: 2001 + A1: 2008: *Maintenance for lifts and escalators. Rules for maintenance instructions* (London: British Standards Institution)
- BSI (2003) BS EN 81-80: 2003: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of safety of existing passenger and goods passenger lifts* (London: British Standards Institution)
- BSI (2004) BS 5656-2: 2004: *Escalator and moving walks. Safety rules for the construction and installation of escalators and moving walks. Code of practice for the selection, installation and location of new escalators and moving walks* (London: British Standards Institution)
- BSI (2005a) BS 5655-11: 2005: *Lifts and service lifts. Code of practice for the undertaking of modifications to existing electric lifts* (London: British Standards Institution)
- BSI (2005b) BS 5655-12: 2005: *Lifts and service lifts. Code of practice for the undertaking of modifications to existing hydraulic lifts* (London: British Standards Institution)
- BSI (2007a) BS 8486-1: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Electric lifts* (London: British Standards Institution)
- BSI (2007b) BS 8486-2: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Hydraulic lifts* (London: British Standards Institution)
- BSI (2008) BS EN 115-1: 2008 + A1: 2010: *Safety of escalators and moving walks. Construction and installation* (London: British Standards Institution)
- BSI (2009) BS EN 81-21: 2009 + A1: 2012: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. New passenger and goods passenger lifts in existing building* (London: British Standards Institution)
- BSI (2010) BS EN 115-2: 2010: *Safety of escalators and moving walks. Rules for the improvement of safety of existing escalators and moving walks* (London: British Standards Institution)
- BSI (2011a) BS 7801: 2011: *Escalators and moving walks. Code of practice for safe working on escalators and moving walks* (London: British Standards Institution)
- BSI (2011b) BS 5655-6: 2011: *Lifts and service lifts. Code of practice for the selection, installation and location of new lifts* (London: British Standards Institution)
- BSI (2012a) BS 7255: 2012: *Code of practice for safe working on lifts* (London: British Standards Institution)
- BSI (2012b) BS EN ISO/IEC 17020: 2012: *Conformity assessment. Requirements for the operation of various types of bodies performing inspection* (London: British Standards Institution)
- BSI (2013) BS 5656-1: 2013: *Safety rules for the construction and installation of escalators and moving walks. Examination and test of new escalators before putting into service. Specification for means of determining compliance with BS EN 115-1:2008+A1:2010* (London: British Standards Institution)
- BSI (2014a) BS 9102: 2014: *Code of practice for safe working on lifting platforms* (London: British Standards Institution)
- BSI (2014b) BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts* (London: British Standards Institution)
- BSI (2014c) BS 5656-3: 2014: *Safety rules for the construction and installation of escalators and moving walks. Examination and test of new moving walks before putting into service. Specification for means of determining compliance with BS EN 115-1:2008+A1:2010* (London: British Standards Institution)
- HMSO (1974) Health and Safety at Work, etc. Act 1974 Elizabeth II. Chapter 37 (London: Her Majesty's Stationery Office) (available at <http://www.legislation.gov.uk/ukpga/1974/37>) (accessed July 2015)
- HSE (1984) *Thorough examination of escalators and passenger conveyors* HSE PM45 (Bootle: Health and Safety Executive) (obsolete)
- HSE (2008) *Thorough examination and testing of lift. Simple guidance for lift owners* INDG 339 (rev1) (Bootle: Health and Safety Executive) (available at <http://www.hse.gov.uk/pubns/indg339.pdf>) (accessed July 2015)
- LEIA (2013) *Maintenance requirements for lifts, lifting platforms, escalators and moving walks* LM01 (London: Lift and Escalator Industry Association) available at http://www.leia.co.uk/upload_image/file/LM01%202013.pdf (accessed July 2015)
- TSO (1992) Workplace (Health, Safety and Welfare) Regulations 1992 Statutory Instruments 1992 No. 3004 (London: Her Majesty's Stationery Office) (available at <http://www.legislation.gov.uk/ukSI/1992/3004>) (accessed July 2015)
- TSO (1997) The Lifts Regulations 1997 Statutory Instruments 1997 No. 831 (London: The Stationery Office) (available at <http://www.legislation.gov.uk/ukSI/1997/831>) (accessed July 2015)

SAFed (1998) *Guidelines on the thorough examination and testing of lifts* Lift Guidelines LG1 (volumes 1 and 2) (London: Safety Assessment Federation) (superseded by SAFed (2009))

SAFed (2009) *Guidelines on the supplementary tests of in-service lifts* LG1 issue 03 (London: Safety Assessment Federation)

SAFed (2012) *Guidelines for the safe operation of escalators and moving walks* (EMW) (London: Safety Assessment Federation) (available at <http://safed.co.uk/technical-guides/machinery-lift-and-crane>) (accessed July 2015)

TSO (1998a) Provision and Use of Work Equipment Regulations 1998 Statutory Instruments 1998 No. 2306 (London: The Stationery Office) (available at <http://www.legislation.gov.uk/ukSI/1998/2306>) (accessed July 2015)

TSO (1998b) Lifting Operations and Lifting Equipment Regulations 1998 Statutory Instrument 1998 No. 2307 (London: The Stationery Office) (available at <http://www.legislation.gov.uk/ukSI/1998/2307>) (accessed July 2015)

TSO (1999) Management of Health and Safety at Work Regulations 1999 Statutory Instruments 1999 No. 3242 (London: The Stationery Office) (available at <http://www.legislation.gov.uk/ukSI/1999/3242>) (accessed July 2015)

TSO (2008) The Supply of Machinery (Safety) Regulations 2008 Statutory Instruments No. 1597 2008 (London, The Stationery Office) (available at <http://www.legislation.gov.uk/ukSI/2008/1597>) (accessed July 2015)

16 Upgrading of safety, performance and equipment for existing lifts

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16 Upgrading of safety, performance and equipment for existing lifts

16.1 Introduction

In the UK there are about 200 000 passenger and passenger/goods lifts in service, 50% of which were installed before 1979. These are all candidates for some level of upgrading (see Figure 16.1).

16.1.1 Life cycle considerations

Some reasons for upgrading a lift are that, as time progresses, it becomes less reliable, probably less aesthetically pleasing and technologically backward. A more important reason for upgrading is to ensure that the owners fulfil their duty to provide a safe environment, since some old lifts would have unacceptable levels of safety when compared against today's state of the art.

Upgrading may be undertaken to improve the performance in terms of its traffic handling, ride quality or energy consumption or to improve the equipment. Often this type of upgrading is termed 'modernisation'.

A lift is often refurbished to restore it to a 'good as new condition'. Then the worn out equipment and components are simply replaced. A like-for-like replacement of any equipment or any component is not considered to be upgrading. Some replacements can occur during routine maintenance operations, e.g. the replacement of a burnt out motor. The status quo of the installation is unchanged and the level of safety is maintained.

Owners of lifts are conscious of the life cycle of their equipment with regard to the capital expenditure and recurrent costs. Most are concerned with the economic life cycle defined as the estimated number of years until an item no longer represents the least expensive method of performing its function. However, some owners may consider the technological life of their equipment important, i.e. when it becomes obsolete. These owners may choose to upgrade their equipment in order that their building is attractive to its tenants or prospective tenants. Other owners consider the useful life of their equipment, i.e. when it no longer performs its function to some established performance standard. For example, passengers now expect the lift ride quality to be better than that provided a decade ago.

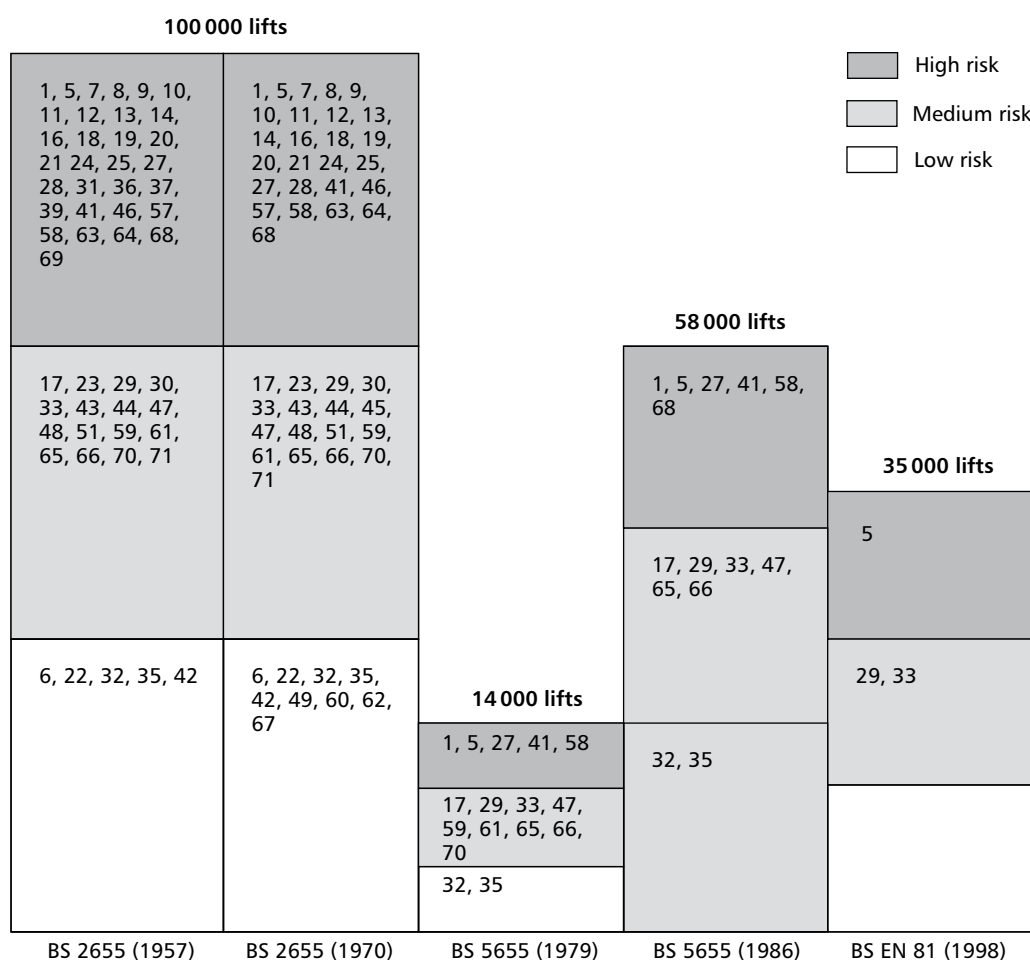


Figure 16.1 Approximate number of UK lift installations; the numbers refer to significant hazards identified in BS EN 81-80 (BSI, 2003) and give guidance on those hazards likely to require consideration

16.1.2 Influencing factors to upgrading

The formulation of a lift upgrading scheme should be undertaken by a competent person in conjunction with the client in order to ensure the client's needs are fully satisfied, both from an aesthetic and safety point of view. During the lifetime of a lift, taken as 20–25 years for an electric lift and 15 years for an hydraulic lift, it may have two changes of car interior and landing doors, one change of drive system and one change of traffic control panel. Each upgrading scheme will vary from one lift installation to another.

The type of installation often dictates whether an upgrading scheme is practicable and/or economic. A low-budget lift installed ten years ago may not be a viable proposition for upgrading as the equipment was not designed for a prolonged life. Conversely, a high quality lift installed 25 years ago may be further upgraded for a further decade of useful life. Upgrading can be undertaken as a step-by-step process in order to spread the financial costs.

A refurbishment is usually less expensive than a full upgrading, but may not extend the life of the lift by more than a few years. In the long term it could be more expensive.

Future plans for the building in which the lift is installed may influence the decision regarding the type of upgrading. A building purchased as an investment may only be prepared for re-sale. A building situated in an area selected for re-development would warrant little expenditure unless considered to be unsafe.

Compliance to the latest safety standards is an important factor. It would be unwise for a building owner to ignore changes in legislation and safety standards. In the event of an incident ignorance of such subjects would be no defence.

16.2 Relevant legislation, standards and codes of practice

The following will be referred to in the subsequent sections. An owner contemplating the upgrading of a lift should be familiar with, or engage someone who is, with the following minimum legislation, standards and codes of practice.

The main legislation applying to lifts is the Lifts Regulations 1997 (TSO, 1997), which enact European Lifts Directive 95/16/EC (OJ, 1995). It gives requirements for new lifts to be designed, manufactured and installed either to a harmonised European standard or to have design certification from a notified body, to ensure that the Essential Health and Safety Requirements (EHSRs) are met.

The Lifts Directive has been amended by EU Directive 2014/33/EU (OJ, 2014), which takes effect from April 2016.

The two main harmonised standards for the construction and installation of lifts have been BS EN 81-1 (BSI, 1998a) for electric lifts and BS EN 81-2 (BSI, 1998b) for hydraulic lifts. These two safety standards were applied to all lifts installed after 1 July 1999, unless otherwise approved by a notified body. Other standards in the BS EN 81 series may

be applicable to meet some of the Lift Directive's EHSRs, e.g. alarm systems, accessibility etc, see section 16.6.

In August 2014, BS EN 81-1/2 were superseded by BS EN 81-20 (BSI, 2014a).

BS EN 81-1/2 can continue to be used until August 2017, when they will become obsolescent and only BS EN 81-20 will be able to be used for presumption of conformity to the Lifts Regulations 1997.

It can be expected that manufacturers will start to deliver products according to the requirements of the new standard sometime after 2015, and so obviously these will not be a target for modernisation. However, BS EN 81-20 introduces many new technical requirements improving the 'state of the art' with regard to lift safety and so it can be anticipated that BS EN 81-80 (BSI, 2003a) will be modified in the future to give guidance on the adaptation of these new features to existing lifts.

From time to time there are queries raised against these standards submitted to CEN from national standards committees such as BSI. These queries relate to the interpretation of a clause within the standard. Once CEN confirms or rejects the interpretations, they are published in DD CEN TS 81-11 (BSI, 2011a).



Note: prior to publication interpretations may be found at the CEN/TC10 interpretations website*.

BS EN 81-80 provides guidance for progressive improvement to the safety of existing lifts. This standard is not a harmonised standard, but represents the considered thinking of a number of European experts and it has been approved by all the standards institutions (including BSI) in Europe.

BS EN 81-82 (BSI, 2013a) follows on from BS EN 81-80, but gives guidance on the improvement in accessibility and use of controls by persons with disabilities based on the requirements of BS EN 81-70 (BSI, 2003b).

DD CEN/TS 81-83 (BSI, 2009a) is a guide for the improvement of existing lifts with regard to their vulnerability to vandalism. It is a technical specification rather than a full standard due to having a review on its successful application after three years from date of publication. It should not be treated with less regard than a full EN standard.

Recommendations for the modernisation of lifts in existing buildings are given in BS 5655-11 (BSI, 2005a) for electric lifts and BS 5655-12 (BSI, 2005b) for hydraulic lifts. These standards do not state what to modify, but instead give rules for the upgrading of the lift once the choice of what to modify has been made; i.e. once the decision to make the lift operate at a faster speed has been made the standard will give guidance on the consequences of this action and what other equipment might need to be considered. See Table 16.3.

BS 5655-6 (BSI, 2011b) is a code of practice for the selection, installation and location of new lifts. It does suggest, however, that its recommendations may be used as guidance when making alterations to existing lift installations.

* http://portailgroupe.afnor.fr/public_espacenormalisation/CENTC10/index.html

Code of practice BS 7255 (BSI, 2012) indicates the environment for safe working on lifts. It is divided into two main sections: section 4 deals with the responsibilities of the owner and section 5 deals with the responsibilities of the worker towards safe working on lifts. Annex B offers suggested improvements for consideration by an owner to improve safe working relating to car top controls.

16.3 Undertaking modifications to existing lift installations

16.3.1 Lifts installed before 1 July 1999

A lift installed before 1 July 1999, when the Lifts Regulations 1997 (TSO, 1997) came into force, should have been installed to the safety rules for the construction and installation current at the time it was put into service. The relevant standards could have been the BS 2655 (BSI, 1959–1972) series dating back to 1958, or the BS 5655 (BSI, 1979–1995) series dating back to 1979. Some lifts may have been upgraded from, for example, a BS 2655 standard, to a BS 5655 standard over a period of time.

The technology and subsequent level of safety will therefore vary depending on the age of the lift. For example, some features commonly expected to be found on today's lifts in order to ensure the safety of the engineer, such as counter weight and pit division screens, may not have been required when the lift was first installed. Figure 16.2 below shows those hazards described in BS EN 81-80 (BSI, 2003a) and the probability of finding them on any given lift depending on the standard prevalent at that time.

When upgrading an existing lift it does not have to comply with the latest standards, but only to the standard applying at the time of the original installation. However the opportunity should be taken to upgrade it to the latest 'state of the art' for technology and safety to maximise the improvements.

There is no compulsion on an owner, or operator, to bring a lift up to the latest level of safety — this is voluntary. However, in the event of an incident it is likely that their attention will be drawn to the best practice contained in the latest safety standards. This situation can be avoided by carrying out a safety audit from time to time and upgrading all lifts to the latest safety standard in order to ensure the highest currently perceived level of safety is obtained. It is not always reasonable and practicable to carry out all the recommendations resulting from an audit. In deciding what is practicable the seriousness of a risk to injury should be weighed against the difficulty and cost of removing or reducing that risk. In considering the cost no allowance should be made for the size, nature or profitability of the business concerned. Where the difficulty and costs are high and a careful assessment of the risk shows it to be comparatively small, action may not need to be taken. However, where the risk is high, action should be taken at whatever cost. BS ISO 14798 (BSI, 2013b) is a suitable document to use for such assessments.

An owner contemplating the complete removal* of an existing lift may not be able to install a lift to fully meet the EHSRs of the Lift Regulations 1997 (TSO, 1997). For example, it may not be possible to provide refuge spaces at the extremes of travel to EHSR 2.2. However, if the existing lift is completely removed, or only the existing guide rails and their fixings remain, then the upgrading becomes the installation of a new lift in an existing building and the EHSRs of the Lifts Regulations 1997 apply.

Note that whilst BS EN 81-21 (BSI, 2009b) gives some relaxation with regard to pit and headroom requirements for lifts installed into existing buildings according to special provisions to create refuge spaces by mechanical means, after taking legal advice the UK government has stated that this standard can have only partial applicability in the UK.

Therefore any design of new lift, even if compliant with BS EN 81-21, must have individual approval from the UK government to be installed where the refuge spaces are less than those described in BS EN 81-1/2 (BSI, 1998a/b) (which will be changed to those in BS EN 81-20 (BSI, 2014a) from August 2017).

Therefore any design using BS EN 81-21 to provide means of refuge for modernized lifts should be assessed with great care to these considerations.

16.3.2 Lifts installed after 1 July 1999

When a lift installed after 1 July 1999 is upgraded, it must continue to comply with the EHSRs of the Lifts Regulations 1997 (TSO, 1997). The upgrading should also take note of any revisions to BS EN 81-1/2: 1998 + A3: 2009 (BSI, 1998a/b) since installation, e.g. the Corrigenda dated March 2000 (and any subsequent amendments), and any interpretations in DD CEN/TS 81-11 (BSI, 2011a). In addition other amendments that may apply include the following:

- BS EN 81-1/2: 1998 plus A1 (Amendment 1) with regard to electronic safety systems.
- BS EN 81-1/2: 1998 plus A2 (Amendment 2)† with regard to machine room-less lifts.
- BS EN 81-1/2: 1998 plus A3 (Amendment 3) with regard to uncontrolled movement.
- BS EN 81-1/2: 1998 plus BS EN 81-28: 2003 (BSI, 2003c) with regard to remote alarms.
- BS EN 81-1/2: 1998 plus BS EN 81-70 (BSI, 2003b) with regard to provision of lifts for the use of persons with disabilities.
- BS EN 81-1/2: 1998 plus BS EN 81-71 (BSI, 2005c) with regard to vandal resistant lifts.
- BS EN 81-1/2: 1998 plus BS EN 81-72 (BSI, 2003d) with regard to firefighting lifts.

* Complete removal is considered to have occurred if only the guide rails and their fixings remain.

† Published by BSI in conjunction with Amendment 1 and therefore only A1 is referenced in the published document title.

Risk level	Item	Building Council CoP	BS 2655-1	BS 2655 (major rev.)	BS 2655 (major rev.)	BS 5655-1	BS 5655-2	BS 5655 (major rev.)	BS EN 81-1/2	Present day	Notes
		1935>	1957>	1970>	1974>	1979>	1983>	1986/8>	1998>	2009>	
H	1 Harmful materials										Introduced by Building Regs. 1992 Introduced by BS 2655 then BS 5655-6 Introduced by BS 5566-13 Introduced by BS 2655 then BS 5588
N/A	2 Disabled										
H	3 Levelling										
N/A	4 Vandal resistance										
N/A	5 Controls for fire										By national deviation to BS 5655
H	6 Perforate enclosures										
H	7 Partially enclosed wells										
H	8 Access door lock										
H	9 Landing apron										Partial requirement in CoP
L	10 Spaces under pit										
L	11 Counterweight screen										
H	12 Pit division screens										
H	13 Full height screens										Partial requirement in CoP and BS 2655
H	14 Safety spaces for pit and headroom										
H	15 Unsafe pit access										
H	16 Stop switches in machine and pulley room										
H	17 Well lighting										Partial requirement in CoP
M	18 Alarm for pit and car roof										
H	19 Machine room access										
L	20 Machine room floor										
H	21 Machine room working spaces										Partial requirement in CoP onwards
H	22 Machine room levels										
H	23 Machine room lighting										
M	24 Lifting beams										
H	25 Perforate car and landing doors										Partial requirement in BS 2655
H	26 Door fixing strength										
H	27 Unsafe glass in doors										
L	28 Glass door protection										
M	29 Lighting on landings										Partial requirement in CoP
H	30 Landing door forces										
H	31 Landing door locks										
H	32 Unlocking key										
H	33 Perforated well near locks										National Regulation
H	34 Self closing landing doors										
M	35 Inadequate door linkage										
M	36 Fire resistance of doors										
M	37 Swing landing door — powered car door										Not in any standard
L	38 Car area/load ratio										
H	39 Car apron										
H	40 Car without doors										
M	41 Trap door interlock										Partial requirement in CoP and BS 2655
L	42 Car roof strength										
H	43 Car roof balustrade										
M	44 Car ventilation										
M	45 Car lighting										Partial requirement in CoP
M	46 Car emergency lights										
M	47 Pulley guards										
L	48 Pulley protection — ejection										
L	49 Pulley protection — objects										Partial requirement in CoP and BS 2655
H	50 Car safety gear										
M	51 Governor slack rope switch										
H	52 Speed governor										
H	53 Electro-mechanical brake										Partial requirement in BS 2655
H	54 Overspeed, creeping, freefall										
L	55 Rope guided counterweight										
H	56 Buffers										
M	57 Final limits										Partial requirement in CoP and BS 2655
H	58 Car to front wall gap										
H	59 Car door to landing door space										
H	60 Emergency operation										
L	61 Hand shut off valve										Partial requirement in BS 5655
H	62 Machine stopping										
H	63 Slack rope switch										
H	64 Run time limiter										
M	65 Low pressure device										Partial requirement in CoP and BS 2655
H	66 Protection and marking of elec. equipment										
M	67 Over-temperature protection										
M	68 Lockable main switch										
L	69 Phase reversal protection										Partial requirement in CoP
H	70 Inspection control										
H	71 Alarm system										
M	72 Car to machine room comm's system										
L	73 Overload in car										Partial requirement in CoP
M	74 Notices and instructions										

Key

	Partially compliant
	Compliant
	Mandatory
	Non-compliant
	Not required by Standards

Figure 16.2 Comparison of lift safety standards and hazards identified in BS EN 81-80 (BSI, 2003)

- BS EN 81-1/2: 1998 plus BS EN 81-73: 2005 (BSI, 2005d) with regard to the behaviour of lifts in the event of a fire.

All of the above BS EN 81-1/2 standards (with their amendments) have been amalgamated into BS EN 81-1: 1998 + A3: 2009 (BSI, 1998a) and BS EN 81-2: 1998 + A3: 2009 (BSI, 1998b).

These in turn are now amalgamated into the newly published BS EN 81-20 (BSI, 2014a), which contains technical requirements for both electric traction and hydraulic lifts.

It is important to emphasise that an owner, or operator, of a lift be vigilant, or engages a competent person who is, to any changes to the standards and codes of practice.

16.4 Important considerations when undertaking modifications to existing lifts

Owners and operators of lifts have duties under various regulations to ensure the safety of persons transported in a lift, persons working on it and persons in its vicinity. To show due diligence it would be wise to periodically carry out, or have carried out, by a technically competent and sufficiently trained person, a safety audit to determine the level of safety of the installation.

The improvement of the safety of lifts is a continual process. It results from expert considerations of any risk assessments carried out, experience of serious events occurring to lifts in service and the adoption of various directives, acts, regulations, standards, codes, etc. that are issued from time to time. Lifts installed to the latest published British, European and International safety standards reflect the state-of-the-art for safety that can be achieved today according to the experts who have developed these standards and to the technology available. This is not to say that lifts cannot be made safer.

When installed, a lift will provide levels of safety deemed sufficient by the safety standard current at that time. As a lift ages it moves further and further from the currently applicable safety standards and thus its level of safety is likely to be lower than that provided by a newly installed lift. For example, consider a pair of lifts operating as a duplex, one installed in 1998 and the other in 2000. The younger lift will be provided with an emergency alarm permanently connected to a rescue service, which the slightly older lift may not have.

It is important for an owner, or operator, of a lift to be aware of the changes in safety requirements. This is illustrated by three examples from BS EN 81-1/2: 1998 + A3: 2009 (BSI, 1998a/b), which have been improved in BS EN 81-20 (BSI, 2014a), but were much less stringent in earlier standards.

- (1) To protect passengers, clause 14.2.3 requires an emergency alarm device to be permanently connected to a rescue service, to enable trapped passengers to be released.

- (2) To protect workers, clause 5.9 requires that adequate lighting be provided in the well, to enable work activities to be conducted safely.
- (3) To protect passers-by, clause 5.2.1.2 requires that partially enclosed wells be provided with a sufficiently high enclosure, to prevent human contact or interference.

The UK has adopted BS EN 81-80: 2003: *Safety rules for the construction and the installation of lifts. Existing lifts. Rules for the improvement of safety of existing passenger and goods passenger lifts* (BSI, 2003a). This safety standard does not have the status of a harmonised standard under the European Directives and in the UK will not be enacted in law. The BS EN 81-80 safety standard does, however, provide the rules for the upgrading of existing lifts with the aim of providing an equivalent level of safety to that of a newly installed lift. This not always possible, but measures should be put in place to reduce all hazards to the smallest residual risk.

There is no duty on an owner (or operator) to bring a lift up to the latest level of safety — it is voluntary. However, in the event of an incident it is likely that their attention will be drawn to the best practice contained in the latest safety standards. This situation can be avoided by carrying out a safety audit from time to time and upgrading all lifts to the recommendations of BS EN 81-80, in order to ensure the highest currently perceived level of safety is obtained.

Due to the publication of BS EN 81-20 (BSI, 2014a), which has improved the safety of newly installed lifts above that found in BS EN 81-1/2 (BSI, 1998a/b), it is only a matter of time before the European Committee for Standardization (CEN) decides to update the content of EN 81-80 to include these new safety provisions. However, at time of publication of this Guide the content of these future amendments is not known.

16.5 Step-by-step approach to improving the safety of existing lifts

One way in which to improve the safety and service of the lifts over time is to apply a step-by-step approach. In this way hazards can be identified and those which represent the greatest threat can be eliminated first. Later those hazards that are considered as minor might be attended to. Thus the improvement in safety of existing lifts by tracking the changes required as the standards develop can be made over a period of time, allowing owners to budget for them. This is illustrated in Figure 16.3 below.

BS EN 81-80 (BSI, 2003a) is a European standard written to address the hazards that may be present on existing installations due to the differences in levels of safety between what was thought permissible at the time of installation and what would be considered as acceptable today.

Through risk assessment it has identified 74 significant hazards. These are listed in Table 16.1. In the examples found in 16.4 above, (1) is No. 71, (2) is No. 17 and (3) is No. 7. Table 16.1 can be used as an aide-memoire to determine the number and basic requirements for each hazard present.

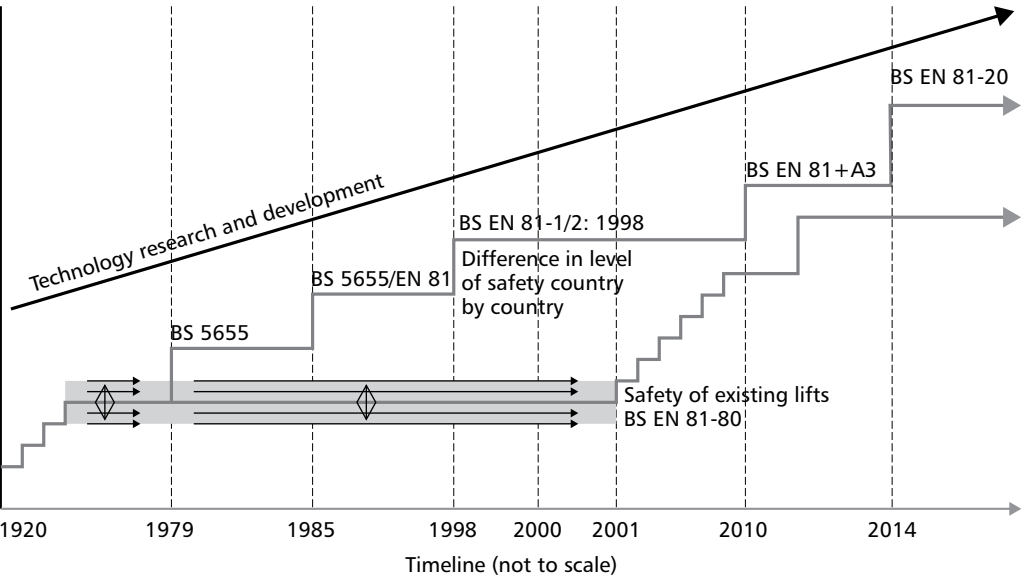


Figure 16.3 Step by step improvement of the safety of existing lifts

The ‘remedial action’ column indicates the requirements for modification to be undertaken by reference to a current safety standard. These are mostly taken from BS EN 81-1: 1998 + A3: 2009 (BSI, 1998a) (electric lifts) and BS EN 81-2: 1998 + A3: 2009 (BSI, 1998b) (hydraulic lifts). Some remedial actions are specific to electric lifts and are shown (indicated by (1)) and others are specific to hydraulic lifts and are shown (indicated by (2)). Some hazards have a number of options that can be applied, i.e. (a), (b), (c), etc. Table 16.1 is necessarily succinct and should only be applied with appropriate reference to BS EN 81-1: 1998 + A3: 2009 (BSI, 1998a), BS EN 81-2: 1998 + A3: 2009 (BSI, 1998b), BS EN 81-28 (BSI, 2003c), BS EN 81-70 (BSI, 2003b) and BS EN 81-80 (BSI, 2003a).

BS EN 81-80 was written as a European safety standard and as such has had to allow for the wide range of situations in all the CEN member states. To accommodate this range, the standard proposed a filtering method to identify the priority of each risk. This procedure is particularly useful in the UK as it permits each installation to be accessed individually. What is a high priority hazard in one installation may

be low priority in another. Considering example 2, a lift with no well lighting would be at a higher priority than a lift installed to BS 5655-1/EN 81-1 (BSI, 1986a), which had some well lighting.

Applying the filtering process in the UK results in the 74 significant hazards being allocated high, medium or low priority, as shown by the numbers in the boxes of Figure 16.1 or the left hand column in Figure 16.2. This priority allocation is for guidance only as each installation must be examined individually (by a competent person) in order to determine its particular risks. It will be noted that there are three significant hazards that require attention on post-1st July 1999 installations.

Table 16.2 also includes a remark ‘Checks to BS EN 81-80’ in the second column. This remark refers to the significant hazards listed in BS EN 81-80 (BSI, 2003a) and summarised in Table 16.1.

Table 16.3 may be used in conjunction with Table 16.1 to anticipate the future requirements of BS EN 81-80.

Table 16.1 Summary of significant hazards from BS EN 81-80: 2003 that might be encountered while undertaking modifications to existing lifts; column 1 is hazard number, column 2 is a summary, column 3 refers to the relevant clause number in BS EN 81-80: 2003 and column 4 offers remedial action (references are to BS EN 81-1/2: 1998 unless indicated otherwise, see sections 16.8 and 16.9)

No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*	No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*
General				Lift well			
1	Presence of harmful materials	5.1.4	0.3.1	(Section 5 of BS EN 81-1: 1998, BS EN 81-2: 1998)			
Accessibility				6	Well enclosures with perforate walls	5.5.1.1	(a) fit imperforate well enclosure, or (b) fit perforate enclosure to BS EN 294: 1992, 4.5.2
2	No or limited accessibility for disabled persons	5.2.1	Measures to BS EN 81-70	7	Partially enclosed well with too low enclosure	5.5.1.2	5.2.1.2
3	Drive system with bad stopping/leveling accuracy	5.2.2	BS EN 81-70, 5.3.3	8	(a) Inadequate locking devices on access doors to well and pit	5.5.2	5.2.2.2.1
Vandalism					(b) Car does not stop when access doors to well and pit are opened	5.5.2	5.2.2.2.2
4	No or inadequate vandal resistance	5.3	Measures to EN 81-71				
Behavior in the event of fire							
5	No or inadequate control functions in case of fire	5.4	Measures to BS EN 81-73				

* (1) indicates BS EN 81-1 only; (2) indicates BS EN 81-2 only

Table continues

Table 16.1 Summary of significant hazards from BS EN 81-80: 2003 — *continued*

No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*	No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*
Lift well (continued)				Landing doors and car doors (continued)			
9	Inadequate vertical surface below landing door sills	5.5.3	5.4.3	28	No or inadequate protection against dragging of a child's hands on a horizontal sliding car or a landing doors with glass	5.7.4	7.2.3.6, 8.6.7.5
10	Counterweight/balancing weight without safety gear in case of accessible spaces below well	5.5.4	(a) provide solid pier, or (b) fit safety gear to counterweight/balance weight	29	No or inadequate lighting on landing	5.7.5	7.6.1
11	No or inadequate partition of counterweight/balancing weight travel path	5.5.5	5.6.1	30a	No or inadequate protective devices on power operated car and landing doors (not intended for disabled use)	5.7.6	(a) 7.5.2.1.1, 8.7.2.1.1, or (b) BS EN 81-70, 5.2.3–5.2.4
12	No or inadequate pit screen for several lifts in the same well	5.5.6.1	5.6.2.1	30b	No or inadequate protective devices on power operated car and landing doors (intended for disabled use)	5.7.6	BS EN 81-70, 5.2.3–5.2.4
13	No or inadequate partition for several lifts in the same well	5.5.6.2	5.6.2.2	31	Unsafe or inadequate locking device of landing door	5.7.7	7.7.3.1
14	Insufficient safety spaces in headroom and pit	5.5.7	(1) 5.7.1–5.7.3 (2) 5.7.1–5.7.2	32	Unlocking of landing door without using a special tool	5.7.8.1	7.7.3.2
15	Unsafe pit access	5.5.8	(1) 5.7.3.2 (2) 5.7.2.2	33	Access to door locks through perforate well enclosure	5.7.8.2	(a) fit imperforate well enclosure, or (b) fit protection around door locks
16	No or inadequate stopping devices in the pit or in the pulley room	5.5.9	(1) 5.7.3.4, 6.4.5 (2) 5.7.2.5, 6.4.5	34	No automatic closing device on horizontal sliding doors	5.7.9	7.7.3.2
17	No or inadequate lighting of the well	5.5.10	5.9	35	Inadequate link between panels of landing doors	5.7.10	7.7.6
18	No alarm system in pit and on car top	5.5.11	5.10 (14.2.3, BS EN 81-28)	36	Inadequate fire resistance of landing doors	5.7.11	Fit doors to specified fire regulations
Machine and pulley rooms (Section 6 of BS EN 81-1: 1998, BS EN 81-2: 1998)				37	Power operated car door moving with open hinged landing door	5.7.12	Ensure: the landing door is not unlocked until the car door is fully open and the car door cannot close until the landing door is fully closed
19	No or unsafe means of access to machine and pulley room	5.6.1	6.2	Car, counterweight and balancing weight (Section 8 of BS EN 81-1: 1998, BS EN 81-2: 1998)			
20	Slippery floor in machine or pulley room	5.6.2	6.3.1.2, 6.4.1.2	38	Large car area in relation to rated load	5.8.1	(a) reduce the available car floor area, or (b) restrict use of lift to instructed users only, or (c) verify the intended use
21	Insufficient clearances in machine room	5.6.3	Guard to BS EN 294: 1992, Table 4	39	Inadequate length of car apron	5.8.2	8.4
22	No or inadequate protection on different levels in machine pulley room	5.6.3	6.3.2.4–6.3.2.5	40	No car doors	5.8.3	(a) fit power operated car doors to 8.6-8.10, or (b) fit manual car doors to 8.6-8.7.1, 8.9-8.10
23	Inadequate lighting in machine or pulley room	5.6.5	6.3.6, 6.4.7	41	Unsafe locking of car top emergency trap door	5.8.4	8.12.4.2
24	Inadequate lifting means for handling equipment	5.6.6	Test and display SWL of lifting means and check suitability of position	42	Insufficient strength of car top and emergency trap door	5.8.5	8.13.1
Landing doors and car doors (Section 7 of BS EN 81-1: 1998, BS EN 81-2: 1998)							
25	Perforate landing doors and car doors	5.7.1	7.1, 8.6.1				
26	Inadequate strength of landing door fixings	5.7.2	7.2.3.1, 7.4.2.1				
27	Inadequate provision of glass in doors	5.7.3	(a) 7.2.3.2–7.2.3.4, 8.6.7.2–8.6.7.4, or (b) Annex J, or (c) 7.6.2, or (d) remove, add signal				

* (1) indicates BS EN 81-1 only; (2) indicates BS EN 81-2 only

Table continues

Table 16.1 Summary of significant hazards from BS EN 81-80: 2003 — *continued*

No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*	No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*
43	No or inadequate balustrade on car to protect against falling	5.8.6	(a) reduce free distance to less than 0.3 m, or (b) fit balustrade to 8.1.3.3, or (c) fit full height partition to reduce free distance to less than 0.3 m	Distances car/landing doors (Section 11 of BS EN 81-1: 1998, BS EN 81-2: 1998)			
44	Insufficient ventilation in car	5.8.7	8.16	58	Large horizontal gap between car and wall facing the car entrance	5.11.1	(a) reduce distance to 11.2.1, or (b) fit car door locking device to 8.9.3
45	Inadequate lighting in car	5.8.8.1	8.17.1–8.17.3	59	Excessive horizontal distance between car door and landing door	5.11.2	11.2.3
46	No or inadequate emergency lighting in car	5.8.8.2	8.17.4 and illuminate alarm button	Lift machine (Section 12 of BS EN 81-1: 1998, BS EN 81-2: 1998)			
Suspension, compensation, overspeed (Section 9 of BS EN 81-1: 1998, BS EN 81-2: 1998)				60a	No or inadequate emergency operation system (electric lifts)	5.12.2	(1) 12.5, 16.3.1
47	No or inadequate protection against injury on sheaves, pulleys and sprockets	5.9.1	(1) 9.7 (2) 9.4	60b	No or inadequate emergency operation system (hydraulic lifts)	5.12.2	(2) 12.9, 16.3.1
48	No or inadequate protection against rope/chains leaving the sheaves, pulleys or sprockets	5.9.1	(1) 9.7 (2) 9.4	Lift machine (continued)			
Suspension, compensation, overspeed (continued)				61	No shut-off valve (hydraulic lifts)	5.12.3	(2) 12.5.1
49	No or inadequate protection against introduction of objects on sheaves, pulleys or sprockets	5.9.1	(1) 9.7 (2) 9.4	62	No or inadequate means of stopping the machine and checking its position	5.12.4	(1) 12.7 (2) 12.4
50a	No safety gear and/or overspeed governor (electric lifts)	5.9.2	(1) 9.8–9.9	63	No or inadequate slack rope/chain device	5.12.5	(1) 9.5.3, 12.9 (2) 12.13
50b	Incorrect functioning of safety gear (electric lifts)	5.9.2	(1) (a) adjust system, and/or overspeed governor (b) 9.8–9.9	64	No run-time limiter	5.12.6	(1) 12.10 (2) 12.12
51	No or inadequate slack rope switch for governor rope	5.9.3	(1) 9.9.11.3 (2) 9.10.2.10.3	65a	No or inadequate low pressure device (indirect hydraulic lifts)	5.12.7	(2) 12.9.1.5
52	No protection means against ascending car overspeed on electric lifts with counter-weight (electric lifts)	5.9.4	(1) 9.10	65b	No or inadequate low pressure device, jack not rigidly fastened to the car (direct acting hydraulic lifts)	5.12.7	(2) 12.9.1.5
53	Inadequate design of lift machine to prevent uncontrolled movement with open doors {electric lifts}	5.9.4, 5.12.1	(1) (a) change to BS EN 81-1: 1998 machine, or (b) install protective mean to BS EN 81-80, 5.9.4, Note 2, and/or (c) fit double acting brake to 12.4.2	Electric installation/appliances (Section 13 of BS EN 81-1: 1998, BS EN 81-2: 1998)			
54a	No or inadequate protection against free fall, overspeed and creeping (hydraulic lifts)	5.9.5	(2) 9.5 and Table 3	66	Insufficient protection against electric shock and/or marking of electrical equipment; missing notices	5.13.1	(a) 13.1.2 and (b) 13.5.3.3 and (c) fit warning notice to group controllers
54b	Automatic return to lowest floor when anti-creep used (hydraulic lifts)	5.9.5	(2) 14.2.1.5	67	No or inadequate protection on lift machine motor	5.13.2	13.3.1–13.3.3
Guide rails, buffers, final limit switches (Section 10 of BS EN 81-1: 1998, BS EN 81-2: 1998)				68	No lockable main switch	5.13.3	13.4.2
55	Counterweight or balancing weight guided by 2-wire ropes (electric lifts)	5.10.1	(1) (a) 10.2.1, or (b) fit 4-wire ropes	Protection against electric faults, etc. (Section 14 of BS EN 81-1: 1998, BS EN 81-2: 1998)			
56	No or inadequate buffers	5.10.2	10.3	69	No protection against phase reversal	5.14.1	14.1.1.1(j)
57	No or inadequate final limit switches	5.10.3	10.5	70a	No or inadequate inspection control station on car top	5.14.2	14.2.1.3
				70b	No or inadequate stopping device on car top	5.14.2	14.2.2
				71	No or inadequate emergency alarm device	5.14.3	14.2.3, measures to BS EN 81-28

* (1) indicates BS EN 81-1 only; (2) indicates BS EN 81-2 only

Table continues

Table 16.1 Summary of significant hazards from BS EN 81-80: 2003 — *continued*

No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*	No.	Description	BS EN 81-80 clause	Remedial action to BS EN 81-1/2*
72	No or inadequate communication system between machine room and car (travel height ≥ 30 m)	5.14.4	14.2.3.4	Notices, markings, operating instructions (Section 15 of BS EN 81-1: 1998, BS EN 81-2: 1998)			
73	No or inadequate load control on car	5.14.5	14.2.5	74	Missing notices, markings and operating instructions for safe use and maintenance	5.15	(1) 15.2.1, 15.3, 15.4, 15.5.1, 15.5.3, 15.7, 15.11, 15.15 (2) 15.2.1, 15.2.5, 15.3, 15.4, 15.5.1, 15.5.3, 15.7, 15.11, 15.15, 15.17, 15.18

* (1) indicates BS EN 81-1 only; (2) indicates BS EN 81-2 only

Table 16.2 Undertaking modifications to existing lifts (users of this table should note that it provides guidance only and they must carefully consider each cross reference in order to identify any other relevant clauses and then to determine if any consequential alterations are required or if other factors need to be checked together with appropriate reference to BS 5655-11, BS 5655-12, BS EN 81-1, BS EN 81-2, BS EN 81-28, BS EN 81-70 and BS EN 81-80)

1 Change in rated speed	Major modification — full tests and records required
Definition For electric lifts a change in rated speed is any increase greater than 5% or decrease greater than 8% (see BS EN 81-1, Section 12.6). For hydraulic lifts a change in rated speed is any increase in rated speed greater than 8% (see BS EN 81-2, Section 12.8). Motivation An increase in rated speed can occur, for example, where it is desired to improve performance. A decrease in rated speed can occur, for example, as the result of change of use from passenger to goods service.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Dimensions at the well ceiling and pit (5) Safety gear (9.8) Buffers (10.3-10.4) Guide system (10.2) The limits of the unlocking zone (7.7.1) Power supply and switchgear (13) Inspection speed (14.2.1.3) Security of the counterweight/balancing weights (8.18) The safe working spaces and equipment clearances (6) Electric only: Suspension (9.1) and traction (9.3) Tripping means for safety gears (9.9) Overspeed governor, ascending car overspeed protection device (9.10) Hydraulic only: Suspension (9.1-9.3) The tripping means for safety gears and clamping devices (9.10) Rupture/restrictor valves (12.5) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 3, 6-18, 19-24, 40, 47-53, 60, 62-64, 66-72, 74 Hydraulic: 3, 6-18, 19-24, 40, 47-49, 51, 54, 60-72, 74
2 Change in rated load	Major modification — full tests and records required
Definition A change in rated load is a change greater than 5%, or 75 kg (whichever is the greater). Motivation A change in rated load can occur as the result of a need to transport heavier loads or can result from changes to the available size of the platform area of the car.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Verification of the well structure (5) Drive supports, guide rail fixings, buffer supports (10) Safety gear (9.8) Overspeed governor (9.9) Guidance system (10.2) Buffers (10.3-10.4) Drive system (12) The available car area and the new rated load (8, Table 1) Load weighing detection system (14.2.5) The load plate (15) The safe working spaces and equipment clearances (6) Electric only: Suspension (9.1-9.3) and traction (9.3) Ascending car overspeed protection device (9.10) Hydraulic only: Suspension (9.1, 9.3) Compatibility of the pressure relief valve (12.5.3)

Table continues

Table 16.2 Undertaking modifications to existing lifts — (continued)

2 Change in rated load (continued)	Major modification — full tests and records required
	Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 38–46, 50–53, 55–57, 60, 66, 70, 73, 74 Hydraulic: 38–46, 51, 54–57, 60–66, 70, 73, 74
3 Change in travel	Increase in travel is a major modification — full tests and records required
	Decrease in travel is a modification — appropriate tests and records required
Definition A change of travel is any increase or decrease of the travel distance between the highest and lowest finished floor levels. <i>Note:</i> a small change may cause refuge spaces and over-travel distances to be insufficient. Motivation A change in travel can occur where a lowest, or highest, finished floor level is raised, e.g. to accommodate a suspended floor, or lowered, e.g. to accommodate access for persons with disabilities. A change in travel can also occur where higher or lower floors are no longer served, e.g. service to a basement level is no longer required or higher floors are removed from a traffic zone. <i>Note:</i> the provision of additional entrances may be required.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Dimensions at the well ceiling and pit (5) System of guiding (10.2) Final limit switches (10.5) Changes to the wiring (13) should be checked Access (5.2.2, 5.5, 5.7.3.2) and rescue (5.10) Machine room/pulley room requirements (6) Structural and fire integrity (5.3) Pit depth (5.7.2.2) Stopping devices (5.7.2.5) Buffering characteristics (10.4) Top/bottom clearances (5.7) Electric only: Suspension system and traction (9.1–9.6) Hydraulic only: Suspension system (9.1–9.3) Hydraulic jack (12.2) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 6–18, 19–37, 40, 66 Hydraulic: 6–18, 19–37, 40, 66
4 Change of mass	Major modification — full tests and records required
Definition A change of suspended or driven mass of either empty car, or suspended mass, or mass of a jack is any increase, or decrease, greater than 5%. Motivation A change in mass can occur as the result of a larger or smaller car being installed, changes to the linings (car refurbishment), changes to the car doors/operators (manual to power doors, adding car doors, change of operator type), addition or changes of other equipment; and attachments carried on the car (car top balustrades, guarding, canopies, traps, etc.). <i>Note:</i> changes to the mass has similar effects to changing the rated load.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Verification of well structure (5) Guidance system (10.2) Suspension (9.1–9.3) Buffers (10.3–10.4) Safety gear (9.8) Electric only: Drive system (12) Traction (9.3) Governor (9.9) Ascending car overspeed protection (9.10) Hydraulic only: Tripping means (9.10) Balancing weight (8.18) Compatibility of the pressure relief valve (12.5.3) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 38–46, 50–53, 55–57, 60, 66, 70, 73, 74 Hydraulic: 38–46, 54–57, 60, 66, 70, 73, 74
5 Change of complete controller including door operation	Appropriate tests and records required
Definition A change of all or part of a controller. <i>Note:</i> a complete controller comprises the drive control system, the traffic controller and the door operator.	For details see drive control system (change 6); traffic controller (change 7); door operator (see change 14).

Table continues

Table 16.2 Undertaking modifications to existing lifts — (continued)

6 Change of drive control system	Appropriate tests and records required
Definition A change in the drive control system, which is the system controlling and monitoring the running of the lift machine (but not door operations), sometimes called motion control (see BS 5655-6: 2002, 9.2, and chapter 8 of this Guide). <i>Note:</i> for electric lifts the drive system comprises the hoist motor, any gear (if installed), brake, sheave, bearing, bedplate, drive controller and signal interface. For hydraulic lifts the drive system comprises the pump unit, control valves, jack, piping, drive controller and signal interface. Motivation A change in the drive system might be required to improve the ride comfort to passengers, improve passenger handling, the accuracy of floor levelling, reduce the number of breakdowns, reduce energy consumption, or provide a greater level of safety to the operation of the lift. <i>Note:</i> a new electric motor (see BS 5655-6:2002, 9.2) or pump motor (see BS 5655-6:2002, 9.2.2) might be required to match the drive technology employed (see change 12).	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Earthing (13) Wiring (13) Safe working spaces and equipment clearances (6.3.2) Rated voltage, current, power (13) Electromagnetic compatibility (EMC) (BS EN 12015/12016) Inspection control (14.2.1.3) Ventilation (6.3.5) Auxiliary supplies (13.4.1) Hydraulic only: Anti-creep devices (9.12) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 53, 60, 62–64, 66–69, 74 Hydraulic: 54, 60–69, 74
7 Change of traffic control system	Appropriate tests and records required
Definition A change of the traffic control system, which supervises and distributes landing and car calls to specific lift car(s) in order to handle the calls in an efficient manner (see BS 5655-6: 2002, clause 7; chapter 9 of this Guide, Barney and Al-Sharif (2015)). Motivation A change of traffic control system might be required to reduce passenger waiting and journey times, increase the number of passengers served, provide special features to increase accessibility for disabled persons, reduce lift group failures by the replacement of relays with solid state technology, improve the behaviour of the lift in the event of fire, reduce any risks owing to the poor condition of wiring, etc.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Earthing (13) Wiring (13) Safe working spaces and equipment clearances (6.3.2) Rated voltage, current, power (13) Electromagnetic compatibility (EMC) (BS EN 12015/12016) Ventilation (6.3.5) Auxiliary supplies (13.4.1) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 23, 66, 68, 74
8 Change from manual to power operated doors	Appropriate tests and records required
Definition This change involves the addition of powered devices to drive (operate) the car and/or the landing doors. Motivation A change from manual to power-operated doors might be required to improve the service to the passengers (traffic handling) or to reduce the burden on passengers to open and close the doors by hand, e.g. to assist persons with disabilities.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Verification of the well structure (5) Adequate clearances (11) Hazards on the car roof (5.7.1.1) Change the mass of the car (see change 4) Capability of the drive system (see change 6) Child hand protection (7.2.3.6) Protection against electric shock (13.5.3.2 and 13.5.3.5) Dynamic requirements (8.7.2.1.1) Fire integrity of the landing entrance (7.2.2) Electric only: traction (9) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 4, 6–18, 25–44, 58, 59, 66, 68, 70
9 Change of entrances	
9.1 Alterations to existing landing entrances	Appropriate tests and records required
Definition This change involves alterations to the landing entrances that can occur when they are refurbished by the addition of new panel skins or when they are completely replaced by different components not of the same specification as the original, e.g. heavier. <i>Note:</i> the type of operation, manual or powered, is not changed (see change 8). Motivation To replace damaged or distressed door panels or complete doors.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (7) Fire integrity (7.2.2) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 6–18, 25–37, 58, 59, 66, 74

Table continues

Table 16.2 Undertaking modifications to existing lifts — (continued)

9 Change of entrances (continued)	
9.2 Change in number of landing entrance	Appropriate tests and records required
Definition This change involves the provision of additional entrances or the reduction in the number of entrances. <i>Note:</i> see change 3 for change of travel. Motivation Additional landing entrances might be required where an existing lift does not serve all floors throughout its existing travel, e.g. skip/stop arrangements, or where a mezzanine floor is introduced. There might also be occasions when entrances are to be removed, e.g. at the extremes of travel.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Structural integrity (5.3) Fire integrity (7.2.2) Clearances (11) Safe working spaces (5.7.1) Compatibility with door operator (7) <i>Note:</i> new locks to be a 'CE' type-tested design. Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 6–18, 25–37, 50–53, 58, 59, 66, 73, 74
9.3 Addition of car entrance	Appropriate tests and records required
Definition This change involves the provision of additional car entrances. Motivation An additional car entrance may be added to service landings at the rear or side of the well.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Hazards on the car top (8.15) Car structural integrity (8.3) Refuge spaces (5.7.1, 5.7.2) Clear working areas (8.13.2) <i>Note:</i> if floor area changes, see change 2; if suspended mass changes see change 4. Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 25, 27, 28, 30, 33, 37, 58, 59
10 Change of a safety component	
10.1 Landing door locking devices	Appropriate tests and records required
Definition This change involves the changing or replacement of a landing door locking device. Motivation Landing door locking devices can be changed or replaced by a more modern device, as the result of the unavailability of an identical equipment. New landing door locking devices might be fitted as the result of the change in the number of entrances (see change 9).	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (7.7) Fire integrity of landing door (7.2.2) Fire integrity of locking device <i>Note:</i> new locks to be a 'CE' type-tested design. Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 1, 4, 29–37, 40, 58, 59
10.2 Safety gear	Appropriate tests and records required
Definition Safety gear can be of an instantaneous or progressive type. Motivation A change can occur when a replacement is required or another change requires a different device.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (9.8) Energy absorption (F 3.2.4.1) Compatibility with associated safety system (see change 10.3) Soundness of the mountings. Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 1, 10, 50a or 50b
10.3 Overspeed governors	Appropriate tests and records required
Definition This change involves the changing or replacement of an overspeed governor. Motivation A change can occur when a replacement is required or another change requires a different device.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (9.9) Calibration Compatibility with associated safety system (see change 10.2) Clear working space (6.3.2) Checks to BS EN 81-80 (see Table 16.2 and BS EN 81-80 for details), include: Electric/hydraulic: 1, 50a or 50b

Table continues

Table 16.2 Undertaking modifications to existing lifts — (continued)

10 Change of a safety component (continued)	
10.4 Buffers	Appropriate tests and records required
Definition Buffers can be of energy accumulation or energy dissipation types.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (10.3–10.4) Safe working spaces (5.7.3) and equipment clearances Pit strength (5.3.2)
Motivation A change can occur when a replacement is required or another change requires a different device.	Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 14–18, 56–57
10.5 Electronic safety devices	Appropriate tests and records required
Definition Electronic safety devices, replacing the functions of devices listed in BS EN 81-1/2: 1998, Annex A.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (14, F.6, Annex H)
Motivation A change can occur when a replacement is required or another change requires a different device.	
E10.6 (Electric) Ascending car overspeed protection	Appropriate tests and records required
Definition Ascending car overspeed protection comprises speed monitoring and speed reducing elements.	Checks to clauses of BS EN 81-1 (detailed in BS 5655-11), include: Conformity (9.10) Integration with other equipment Integration with building structure
Motivation A change can occur when a replacement is required or another change requires a different device. Ascending car overspeed protection may be added, as it was first required by the Lift Regulations 1997.	Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 10, 50a or 50b, 52
H10.6 (Hydraulic) Rupture valves and one-way restrictors	Appropriate tests and records required
Definition A rupture valve is a device that is capable of stopping a downward moving car and holding it stationary. A restrictor is a device that is capable of restricting the downward speed of a car in the case of a major leakage.	Checks to clauses of BS EN 81-2 (detailed in BS 5655-12), include: Conformity (12.5.5, 12.5.6)
Motivation A change can occur when a replacement is required or another change requires a different device.	Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Hydraulic: 54, 65
H10.7 (Hydraulic) Clamping and pawl devices	Appropriate tests and records required
Definition A clamping device is a device that is capable of stopping a downward moving car and holding it stationary, and can be of a progressive or instantaneous type.	Checks to clauses of BS EN 81-2 (detailed in BS 5655-12), include: Well structure (5) Conformity (9.9, 9.11) Compatibility with tripping system (9.10)
Motivation A change can occur when a replacement is required or another change requires a different device.	Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Hydraulic: 54, 56
11 Change of electric safety devices	
11.1 Electric safety devices — manually operated	Appropriate tests and records required
Definition ‘Electric safety devices — manually operated’ are one of the seven manually operated stopping devices listed in Annex A of BS EN 81-1/2 (incorporating A2), e.g. pit switch stopping device.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (14.1.2, 14.2.2) Location (Annex A) Prevent involuntary release (14.2.2.2)
Motivation A change can occur when a replacement is required or another change requires a different device.	Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 16, 70a, 70b

Table continues

Table 16.2 Undertaking modifications to existing lifts — (continued)

11 Change of electric safety devices (continued)	
11.2 Electric safety devices — non-manually operated	Appropriate tests and records required
Definition 'Electric safety devices — non-manually operated' are one of the 37 non-manual devices listed in Annex A of BS EN 81-1 (incorporating A2) and 30 non-manual devices listed in Annex A of BS EN 81-2 (incorporating A2), e.g. buffer switch.	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Conformity (14.1.2) Location (Annex A) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric/hydraulic: 8, 31, 41, 51, 57, 6
Motivation A change can occur when a replacement is required or another change requires a different device.	
E12 (Electric) Change of the drive components	
E12.1 Lift machine	Appropriate tests and records required
Definition The lift machine comprises the hoist motor, gear (if installed), sheave, pulley, bearing and bedplate are changed.	Checks to clauses of BS EN 81-1 (detailed in BS 5655-11), include: Safe working spaces and equipment clearances (6.3.2) Integration with other equipment Rated voltage, current, power (13) Electromagnetic compatibility (EMC) (BS EN 12015/12016) Ventilation (6.3.5) Rated voltage, current, power (13) Guarding (9.7) Traction (9.3). Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 21–24, 47–49, 53, 60, 62–64, 66–68, 69, 74
Motivation This change can occur for many reasons, including where excessive wear has taken place, fatigue of the main components is suspected, change of speed, change of levelling accuracy etc. A traction sheave might be changed as the result of wear or other damage.	
E12.2 Brake	Appropriate tests and records required
Definition Device which can operate automatically and hold a car stationary.	Checks to clauses of BS EN 81-1 (detailed in BS 5655-11), include: Conformity (12.4.2.1) Safe working spaces and equipment clearances (6.3.2) Integration with other equipment Rated voltage, current, power (13) Electromagnetic compatibility (emc) (BS EN 12015/12016) Ventilation (6.3.5) Rated voltage, current, power (13) Guarding (9.7) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 1, 21, 47, 60, 66, 74
Motivation A change can occur when a replacement is required or another change requires a different device.	
H12 (Hydraulic) Change of jack and lift machine	
H12.1 Change of jack	Appropriate tests and records required
Definition A jack comprises a cylinder and ram (piston) and its connecting pipework.	Checks to clauses of BS EN 81-2 (detailed in BS 5655-12), include: Compatibility of hydraulic fluid Potential fire hazards Well structure (5) Pressure and buckling calculations (12.2.1–12.2.2) Compatibility with building structure Guarding (9.4) Safe working spaces and equipment clearances (6.3.2) Top/bottom clearances (5.7) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Hydraulic: 3, 6–18, 54, 61, 65
Motivation A change of jack might be required as the result of damage or wear or as the result of another modification, such as a change in travel or rated load.	

Table continues

Table 16.2 Undertaking modifications to existing lifts — (continued)

H12 (Hydraulic) Change of jack and lift machine (continued)	
H12.2 Pump and pump motor	Appropriate tests and records required
Definition Unit comprising an electric motor and attached pump which circulates the hydraulic fluid. Motivation A change in the pump/pump motor can occur when the capacity and/or the control characteristics of the system has been changed, or a like-for-like replacement cannot be found.	Checks to clauses of BS EN 81-2 (detailed in BS 5655-12), include: Compatibility of hydraulic fluid Potential fire hazards Integration with other equipment Rated voltage, current, power (13) Electromagnetic compatibility (EMC) (BS EN 12015/12016) Ventilation (6.3.5) Rated voltage, current, power (13) Guarding (9.4) Safe working spaces and equipment clearances (6) Cooling (12.14) Wiring (13) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Hydraulic: 19–24, 61, 62, and 64–69
H12.3 Hydraulic control block	Appropriate tests and records required
Definition A hydraulic control block controls the hydraulic fluid in and out of the jack and provides control of rated, inspection and emergency lowering speeds. Motivation A change might be required as the result of damage or wear or as the result of another modification, such as a change in travel or rated load.	Checks to clauses of BS EN 81-2 (detailed in BS 5655-12), include: Compatibility of hydraulic fluid Potential fire hazards Integration with other equipment Rated voltage, current, power (13) Electromagnetic compatibility (EMC) (BS EN 12015/12016) Ventilation (6.3.5) Rated voltage, current, power (13) Inspection speed (14.2.1.3d) Emergency lowering (12.9.1.2) Non-return valve (12.9) Wiring (13) Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Hydraulic: 3, 5, 19–24, 54, 60, 61, 65
H12.4 Change of pressure relief valve	Appropriate tests and records required
Definition A pressure relief valve is needed to limit the system pressure to 1.4 times the full load pressure (exceptionally to 1.7 times). Motivation A change might be required as the result of damage or wear or as the result of another modification, such as a change in travel or rated load.	Checks to clauses of BS EN 81-2 (detailed in BS 5655-12), include: Compatibility of hydraulic fluid Potential fire hazards Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Hydraulic: 54, 61, 65
13 Change of a car enclosure and/or interior finishes	Appropriate tests and records required
Definition The car enclosure is the passenger/goods carrying unit, including the car frame, car interior and fit out. Motivation From time to time the car interiors begin to look tired and dated and require a new fit out. Sometimes the car enclosure requires change to accommodate a change in landing doors or change of rated load. At this time consideration should be given to increasing the platform area to include the floor area of any extensions or recesses (BS EN 81-1: 1998, 8.2.1), e.g. stretcher extensions, or they should be removed. (<i>Note:</i> a car with a stretcher extension (see BS 5655-6: 2002, 9.1.4) is one where the extension is available for the transport of stretchers under controlled conditions.)	Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include: Disability access (BS EN 81-70) Platform area, see change 2(15) Load change, see change 4 Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include: Electric: 38–40, 44 to 46, 58, 59, 73 Hydraulic: 38–40, 44 to 46, 58, 59, 73

Table continues

Table 16.2 Undertaking modifications to existing lifts — (continued)

14 Change of door operator		Appropriate tests and records required
Definition		Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include:
Mechanism for opening and closing the landing and car doors.		Structural compatibility with car/car frame
Motivation		Compatibility with locking devices
The door operator is changed to one with a different specification. A change in positional performance might be desired from open loop to closed loop control, or the dynamic performance might require improvement.		Unlocking zone (7.7.1)
		Apron (8.4)
		Adequate clearances (5.7,11)
		Hazards on the car roof (5.7.1.1)
		Change the mass of the car (see change 4)
		Protection against electric shock (13.5.3.2 and 13.5.3.5).
		Dynamic requirements (8.7.2.1.1)
		Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include:
		Electric: 34, 35, 66, 74
		Hydraulic: 34, 35, 66, 74
15 Change from gates to doors		Appropriate tests and records required
Definition		Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include:
Gates are used to protect the access to a lift car and are perforate.		Conformity (7, 8)
Motivation		Well structure (5)
In order to improve safety the gates can be replaced by doors. The change might retain manual operation or the opportunity might be taken to fit power-operated doors.		Clearances (11)
		Change the mass of the car (see change 4)
		Electric only: traction (9.3)
		Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include:
		Electric/hydraulic: 25–37, 40, 58, 59, 66, 74
16 Change of guide rails or type of guide rails		Appropriate tests and records required
Definition		Checks to clauses of BS EN 81-1/2 (detailed in BS 5655-11/12), include:
Guidance system for the lift car and counterweight/balancing weight.		Guidance system (10, Annex G)
Motivation		Well structure (5)
A change of guide rails or type of guide rails can occur when an installation is upgraded or modified.		Clearances (5.7)
		Compatibility with fixings
		Compatibility with safety gear (9.8)
		Compatibility with governor (9.9)
		Checks to BS EN 81-80 (see Table 16.1 and BS EN 81-80 for details), include:
		Electric: 11–13, 50, 55
		Hydraulic: 11–13, 50, 55

Table 16.3 Comparison of requirements between BS EN 81-1, BS EN 81-2, BS EN 81-20 and BS EN 81-50 (this table can be used in conjunction with Table 16.1 to anticipate the future requirements of BS EN 81-80 as it becomes amended to meet the requirements of BS EN 81-20 and BS EN 81-50)

BS EN 81-1 +A3	BS EN 81-2 +A3	BS EN 81-20	BS EN 81-50	BS EN 81-1 +A3	BS EN 81-2 +A3	BS EN 81-20	BS EN 81-50
—	—	0		2	2	2	2
0.1	0.1	0.1		3	3	3	3
—	—	0.2		4	4	4	—
0.2	0.2	0.3		4.1	4.1	—	—
0.3	0.3	0.4		4.2	4.2	—	—
1	1	1		5	5	5.2.5	
1.1	1.1	1.1		5.1	5.1	5.2.5.1	
1.2	1.2	1.2		5.2	5.2	5.2.5.2	
1.3	1.3	1.3		5.3	5.3	5.2.1.8.1	
1.4	1.4	1.4		5.4	5.4	5.2.5.3	

Table continues

Table 16.3 Comparison of requirements between BS EN 81-1, BS EN 81-2, BS EN 81-20 and BS EN 81-50 — *continued*

BS EN 81-1 +A3	BS EN 81-2 +A3	BS EN 81-20	BS EN 81-50	BS EN 81-1 +A3	BS EN 81-2 +A3	BS EN 81-20	BS EN 81-50
5.5	5.5	5.2.5.4		9.2	9.2	5.5.2	
5.6	5.6	5.2.5.5		9.3	9.3	5.5.3	
5.7	5.7	5.2.5.7, 5.2.5.8		9.4	9.4	5.5.4	
5.8	5.8	5.2.1.2, 5.2.1.2.1, 5.2.1.5.3		9.5	9.5	5.5.5	
5.9	5.9	5.2.1.4, 5.2.1.4.1		9.6	9.6	5.5.6	
5.10	5.10	5.2.1.6		9.7	Not used	5.5.7	
6	6	5.2.6		9.8	9.8	5.6.2.1	
6.1	6.1	5.2.2.1, 5.2.6.1		9.9		5.6.2.2.1	
6.2	6.2	5.2.2			9.9	—	—
6.3	6.3	5.2.6.3		9.10		5.6.6	
6.4	6.4	5.2.6.4			9.10	5.6.2.2	
6.5	6.5	5.2.6.5		9.11		5.6.7	
6.6	6.6	5.2.6.6			9.11	5.6.5	
6.7	6.7	5.2.6.7		—	9.12	5.12.1.10	
7	7	5.3		—	9.13	5.6.7	
7.1	7.1	5.3.1, 5.3.1.1, 5.3.1.2, 5.3.1.3, 5.3.1.4, 5.3.1.5		10	10	5.7, 5.8, 5.12.2	
7.2	7.2	5.3.5, 5.3.5.1		10.1	10.1	5.7.2.1	
7.3	7.3	5.3.2		10.2	10.2	5.7.1	
7.4	7.4	5.3.3		10.3	10.3	5.8.1	
7.5	7.5	5.3.6		10.4	10.4	5.8.2	
7.6	7.6	5.3.7		10.5	10.5	5.12.2	
7.7	7.7	5.3.8		11	11	5.2.5.3	
7.8	7.8	5.3.12		11.1	11.1	0.4.4	
8	8	5.4		11.2	11.2	5.2.5.3.1	
8.1	8.1	5.4.1		11.3	11.3	5.2.5.5.1	
8.2	8.2	5.4.2		12	12	5.9	
8.3	8.3	5.4.3		12.1	12.1	5.9.1, 5.9.1.1	
8.4	8.4	5.4.5		12.2		5.9.2	
8.5	8.5	5.3.1.1			12.2	5.9.3.2	
8.6	8.6	5.3		12.3		—	
8.7	8.7	5.3.6			12.3	5.9.3.3	
8.8	8.8	5.3.6.3		12.4	12.4	5.9.2.2	
8.9	8.9	5.3.13				5.9.2.5	
8.10	8.10	5.3.14		12.5		5.9.2.3	
8.11	8.11	5.3.15			12.5	5.9.3.5	
8.12	8.12	5.4.6		12.6		5.9.2.4	
8.13	8.13	5.4.7			12.6	5.9.3.6	
8.14	8.14	—	—	12.7		5.9.2.5	
8.15	8.15	5.4.8			12.7	5.9.3.7	
8.16	8.16	5.4.9		12.8		5.12.1.3	
8.17	8.17	5.4.10			12.8	5.9.2.4	
8.18	8.18	5.4.11, 5.4.11.1		12.9		5.5.5.3	
9	9	5.5			12.9	5.9.2.3	
9.1	9.1	5.5.1		12.10		5.9.2.7	
					12.10	5.5.7	
				12.11	12.11	5.9.1.2	
				12.12		5.12.1.1.4	
					12.12	5.9.3.10	
				—	12.13	5.5.5.3	
				—	12.14	5.9.3.11	
				—	12.15	5.12.1.1.4	

Table continues

Table 16.3 Comparison of requirements between BS EN 81-1, BS EN 81-2, BS EN 81-20 and BS EN 81-50 — *continued*

BS EN 81-1 +A3	BS EN 81-2 +A3	BS EN 81-20	BS EN 81-50	BS EN 81-1 +A3	BS EN 81-2 +A3	BS EN 81-20	BS EN 81-50
13	13	5.10		16.1	16.1	6.1	
13.1	13.1	5.10.1		16.2	16.2	7.2, 7.3.1, 7.3.2	
13.2	13.2	5.10.3		16.3	16.3	7, 7.1, 7.2, 7.2.1	
13.3	13.3	5.10.4		Annex A	Annex A	Annex A	
13.4	13.4	5.10.5		Annex B	Annex B	5.3.9.3.1	
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16.5.1 Improvement in accessibility

BS EN 81-82 (BSI, 2013a) addresses the issues of improvement in access and use of lifts by disabled persons. This is of particular importance since the coming in to full force of the Disability Discrimination Acts 1995 (HMSO, 1995) and 2005 (TSO, 2005) and the removal of any time based exceptions for equipment in compliance with Building Regulations (TSO, 2010) at the time of installation.

Now all premises should be made accessible to persons with disabilities, where practical, including the removal of any physical barriers, which may include aspects of the lift installations.

To achieve this improvement BS EN 81-82 considers the individual technical requirements of BS EN 81-70 (BSI, 2003b) and the effect of each item on different levels of disability. A value is then given to each as a way to avoid subjective decisions for the selection of the most effective solutions.

In addition to trying to make the process less subjective by adding quantitative values, it can be of help to map out the decisions to be made with regard to possible lift modification, and deciding how effective various solutions are in removing physical access barriers. Figure 16.4 illustrates a typical decision tree for replacement of lift car and landing doors.

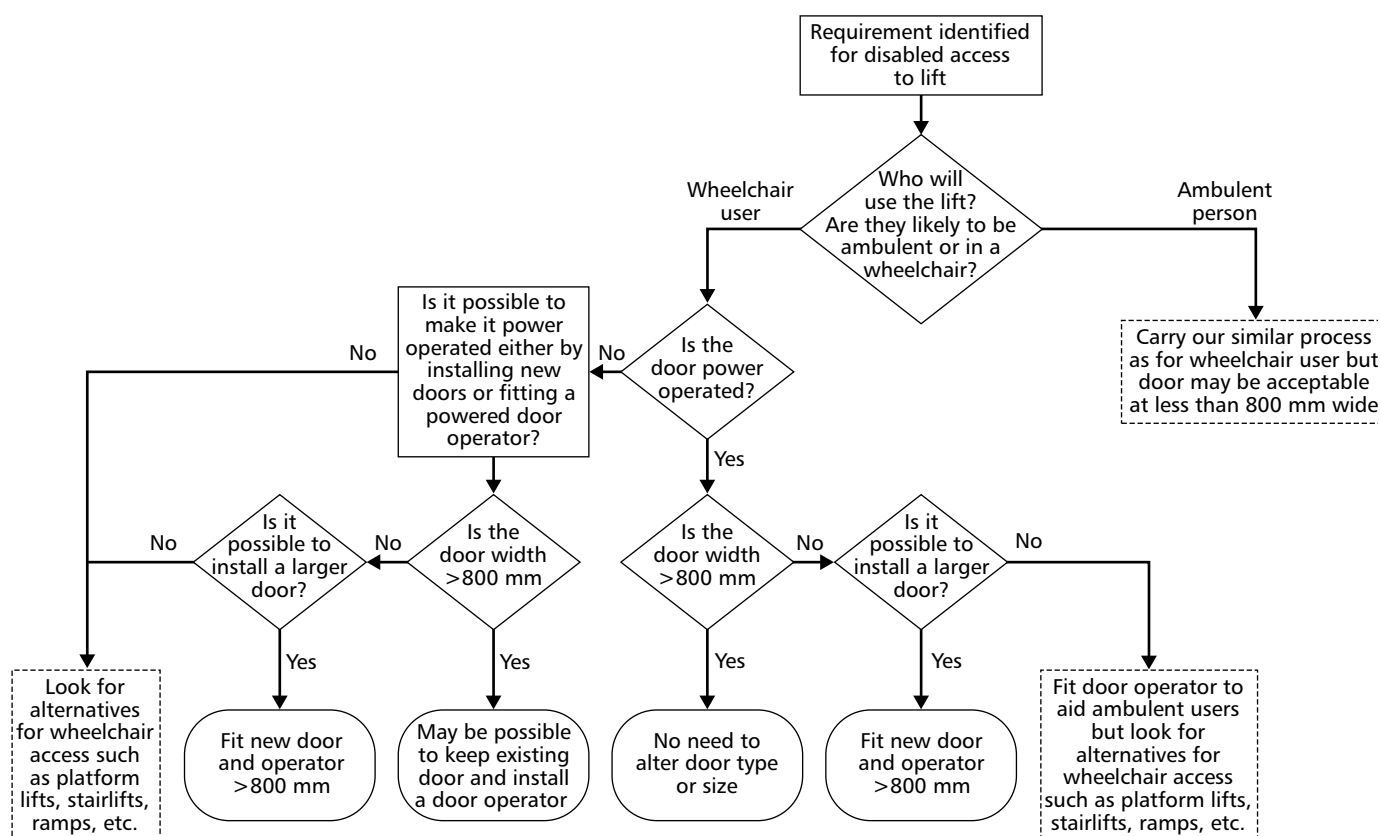


Figure 16.4 Typical example of a decision tree for replacement of lift car and landing doors

Decisions can be taken as a similar three stage process to that used for risk assessment.

- (1) Can the lift be modified to completely remove the barrier?
- (2) If (1) above is not possible, what other alternatives may be available to make the lift accessible to most categories of disabled persons?
- (3) If the lift cannot be modified to remove the physical barriers are there alternative procedures, such as the provision of helpers, that may be put into place?

The first stage must consider the present equipment and what is required to make the lifts accessible to disabled users, within the bounds of what is possible and practical.

For example, if the lift is only suitable for four persons then it is unlikely that an 8-person lift, suitable for use by unaided persons in wheelchairs, will be able to be accommodated in the existing lift well without extensive building alteration. Where in some public buildings this might be fully justified in other less diversely populated buildings it might not.

The second stage, having recognised that it may not be possible to make the lift entirely free from barriers to use by disabled persons, should consider if the existing lift may be modified to make it suitable for use by persons with less severe disabilities. In this case the incorporation of power doors, accessible controls, audible and visual signals etc. will help in removing accessibility barriers for those persons whose disabilities do not restrict the user to a wheelchair.

Finally, where no practical solutions present itself for the vertical transport of disabled persons using lifts, or where

their use is restricted by the physical constraints of the lift equipment, the only solution may be to consider alternative means of transportation.

In this case stairlifts, ramps, the provision of helpers etc. may aid accessibility in the building to disabled persons.

These options should always be taken as the last resort. In adopting these solutions it is accepting that the needs of disabled persons may not have been fully met.

BS EN 81-80 (BSI, 2003a) and BS EN 81-82 (BSI, 2013a) also provide an audit checklist to enable an existing installation to be examined against the requirements of BS EN 81-70 (BSI, 2003b) and determine the most applicable solution.

16.5.2 Improvement in protection from vandalism

Continuing in the BS EN 81-80 series of standards, technical specification DD CEN TS 81-83 (BSI, 2009a) gives recommendations for the improvement of existing lifts with regard to resistance to vandalism.

Again, it recommends that a survey is carried out by a competent person to identify requirements based on those found in BS EN 81-71 (BSI, 2005c).

This divides lifts into three categories:

- Category 0: those without special protection against vandalism
- Category 1: those prone to vandalism in an observed area

— Category 2: those in an unobserved area.

The level of protection required increases proportionally.

Care should be taken in the application of this standard. Whilst its recommendations are clearly warranted the level of protection varies greatly between Categories 1 and 2.

Lifts in observed areas such as shopping centres and other public areas, whilst subject to minor acts of vandalism, may be easily modified to incorporate the aims of the document.

However, those installed in social housing, car parks etc. where high levels of vandalism might be predicted would constitute a major refurbishment project, with high cost levels, in order to achieve the necessary improvements.

As with all BS EN 81-80 (BSI, 2003a) series standards a check list is provided giving details of each individual opportunity for improvement, categorised by level of risk, along with the suggested protective measure.

16.5.3 Improvement in use for evacuation and firefighting

BSI has recently committed to producing a new standard that will examine existing lifts and suggest ways in which they might be improved in accordance with the requirements of BS 9999: 2008: *Code of practice for fire safety in the design, management and use of buildings* (BSI, 2008) and BS EN 81-72 (BSI, 2003d).

It is also expected that this new standard will include the labelling of existing firefighters lifts to show what basic features were included at the time of its installation. This is because there have been many versions of 'firefighting', 'fire service' or 'fireman's' lifts installed in the UK in the last 50 years and it is important that attending firefighters, in the case of an emergency, can quickly ascertain which lift controls may be available and what limitations of use are in place.

Further information on this standard will be made available through the CIBSE Lifts Group website (<http://www.cibseliftsgroup.org>), as and when such information becomes available.

16.5.4 Improvement in performance

The performance of existing lifts can deteriorate in service as the equipment ages and wears. The requirements of the building in which the lift equipment is installed may also change, either in terms of the quantity of service, (e.g. an extra traffic handling demand), or in terms of quality of service, (e.g. improved passenger service times). These factors inspire the upgrading of the installation to meet these new requirements.

As an example consider increasing the rated speed. This will almost certainly require changing the drive system as the principal alteration. Consequential alterations may be to consider changing the safety gear and overspeed governor and to ensure the electrical power supply to the new equipment is sufficient to meet the changed electrical loading. A check might also need to be made that the traction provided at the new speed is adequate.

Consideration might also be given to upgrading the machine room lighting for safety reasons.

16.5.5 Improvement by (minor) replacement of major components

Sometimes less significant work is carried out to improve the major components without any improvement in performance. This work often involves fewer changes.

For example, a traction drive motor may be changed for one with different electrical characteristics, but the same mechanical characteristics, or a relay based drive controller may be upgraded to a solid state controller with the same performance characteristics, but a different interface to the installation.

16.6 Summary of modifications undertaken to existing lifts

The modernisation standards BS 5655-11 (BSI, 2005a) and BS 5655-12 (BSI, 2005b) list the following changes or replacements:

- [1] Change of rated speed*
- [2] Change of rated load*
- [3] Change of travel*
- [4] Change of mass*
- [5] Change of complete controller including door operations
- [6] Change of drive control system
- [7] Change of traffic control system
- [8] Change from manual to power-operated doors
- [9] Change of entrances
 - [9.1] Alteration to existing landing entrances
 - [9.2] Change in the number of landing entrances
 - [9.3] Addition of car entrances
- [10] Change of safety component
 - [10.1] Landing door locking devices
 - [10.2] Safety gear
 - [10.3] Overspeed governors
 - [10.4] Buffers
 - [10.5] Electronic safety devices
 - [E10.6] (Electric) Ascending car overspeed protection
 - [H10.6] (Hydraulic) Rupture valves and one-way restrictors
 - [H10.7] (Hydraulic) Clamping and pawl devices
- [11] Change of electric safety devices
 - [11.1] Electric safety devices; manually operated

[11.2]	Electric safety devices; non-manually operated	BSI (1986a) BS 5655-1: 1986, EN 81-1: 1985: <i>Lifts and service lifts. Safety rules for the construction and installation of electric lifts</i> (London: British Standards Institution) (obsolescent)
[E12]	(Electric) Change of the drive components	
[E12.1]	Lift Machine	BSI (1986b) BS 5655-10: 1986: <i>Lifts and service lifts. Specification for the testing and inspection of electric and hydraulic lifts</i> (London: British Standards Institution) (withdrawn; replaced by BS 5655-10.2.1 (BSI, 1995) and BS 5655-10.2.2 (BSI, 1995))
[E12.2]	Brake	
[H12]	(Hydraulic) Change of the jack and lift machine	
[H12.1]	Change of the jack	BSI (1995a) BS 5655-10.1.1: 1995: <i>Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Electric lifts. Commissioning tests for new lifts</i> (London: British Standards Institution)
[H12.2]	Pump and pump motor	
[H12.3]	Hydraulic control block	BSI (1995b) BS 5655-10.2.1: 1995: <i>Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Hydraulic lifts. Commissioning tests for new lifts</i> (London: British Standards Institution)
[H12.4]	Change of pressure relief valve	
[13]	Change of a car enclosure or interior finishes	
[14]	Change of a door operator	BSI (1998a) BS EN 81-1: 1998 + A3: 2009: <i>Safety rules for the construction and installation of lifts. Electric lifts</i> (London: British Standards Institution)
[15]	Change from gates to doors	
[16]	Change of guide rails or type of guide rails	BSI (1998b) BS EN 81-2: 1998 + A3: 2009: <i>Safety rules for the construction and installation of lifts. Hydraulic lifts</i> (London: British Standards Institution)
(* see section 16.7, below)		BSI (1999a) PAS 32-1: 1999: <i>Specification for examination and test of new lifts before putting into service. Electric traction lifts</i> (London: British Standards Institution)

The reference numbers shown in square brackets refer to Table 16.2, where the definitions of the changes/alteration, the motivation and the main resulting actions are summarised. Cross references are given in Table 16.2 to the relevant clauses in BS 5655-11 (BSI, 2005a), BS 5655-12 (BSI, 2005b), BS EN 81-1: 1998 + A3: 2009 (BSI, 1998a), BS EN 81-2: 1998 + A3: 2009 (BSI, 1998b) and BS EN 81-80 (BSI, 2003a).

Users of Table 16.2 should note that it provides guidance only and each cross reference must be carefully considered in order to identify if any other consequential alterations are required, or if other factors need to be checked.

16.7 Tests and records

Where any changes listed in 16.6 that are indicated by a star (*) are made, a full test of the complete lift installation should be carried out.

Where any of the other changes or replacements listed in 16.6 are made, there might be consequential changes and it is essential that appropriate tests be selected and conducted to ensure a safe installation. The tests indicated in BS 5655-10-1-1/10-2-1 (BSI, 1995a/b), PAS 32-1/2 (BSI, 1999a/b) and BS 8486 (BSI, 2007a/b) series of standards are likely to be appropriate and these documents can also be used to make a suitable record. The document used will depend on when the lift installation was first put into service and what parts are retained/replaced.

References

Barney GC and Al-Sharif LR (2015) *Lift (Elevator) Traffic Handbook* (Abingdon: Routledge)

BSI (1959–1972) BS 2655: *Specification for lifts, escalators passenger conveyors and paternosters* (10 Parts) (London: British Standards Institution) (obsolescent)

BSI (1979–1995) BS 5655: *Lifts and service lifts* (14 Parts) (London: British Standards Institution) (obsolescent)

BSI (1986a) BS 5655-1: 1986, EN 81-1: 1985: *Lifts and service lifts. Safety rules for the construction and installation of electric lifts* (London: British Standards Institution) (obsolescent)

BSI (1986b) BS 5655-10: 1986: *Lifts and service lifts. Specification for the testing and inspection of electric and hydraulic lifts* (London: British Standards Institution) (withdrawn; replaced by BS 5655-10.2.1 (BSI, 1995) and BS 5655-10.2.2 (BSI, 1995))

BSI (1995a) BS 5655-10.1.1: 1995: *Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Electric lifts. Commissioning tests for new lifts* (London: British Standards Institution)

BSI (1995b) BS 5655-10.2.1: 1995: *Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Hydraulic lifts. Commissioning tests for new lifts* (London: British Standards Institution)

BSI (1998a) BS EN 81-1: 1998 + A3: 2009: *Safety rules for the construction and installation of lifts. Electric lifts* (London: British Standards Institution)

BSI (1998b) BS EN 81-2: 1998 + A3: 2009: *Safety rules for the construction and installation of lifts. Hydraulic lifts* (London: British Standards Institution)

BSI (1999a) PAS 32-1: 1999: *Specification for examination and test of new lifts before putting into service. Electric traction lifts* (London: British Standards Institution)

BSI (1999b) PAS 32-2: 1999: *Specification for examination and test of new lifts before putting into service. Hydraulic lifts* (London: British Standards Institution)

BSI (2003a) BS EN 81-80: 2003: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of safety of existing passenger and goods passenger lifts* (London: British Standards Institution)

BSI (2003b) BS EN 81-70: 2003: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Accessibility to lifts for persons including persons with disability* (London: British Standards Institution)

BSI (2003c) BS EN 81-28: 2003: *Safety rules for the construction and installation of lifts. Remote alarm on passenger and goods passenger lifts* (London: British Standards Institution) (2003) TSO (1997) The Lifts Regulations 1997 Statutory Instruments 1997 No. 831 (London: The Stationery Office) (available at <http://www.legislation.gov.uk/uksi/1997/831>) (accessed June 2015)

BSI (2003d) BS EN 81-72: 2003: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Firefighters lifts* (London: British Standards Institution)

BSI (2005a) BS 5655-11: 2005: *Lifts and service lifts. Code of practice for the undertaking of modifications to existing electric lifts* (London: British Standards Institution)

BSI (2005b) BS 5655-12: 2005: *Lifts and service lifts. Code of practice for the undertaking of modifications to existing hydraulic lifts* (London: British Standards Institution)

BSI (2005c) BS EN 81-71: 2005: *Safety rules for the construction and installation of lifts. Particular applications to passenger lifts and goods passenger lifts. Vandal resistant lifts* (London: British Standards Institution)

BSI (2005d) BS EN 81-73: 2005: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Behaviour of lifts in the event of fire* (London: British Standards Institution) (2005)

BSI (2007a) BS 8486-1: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Electric lifts* (London: British Standards Institution)

BSI (2007b) BS 8486-2: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Hydraulic lifts* (London: British Standards Institution)

BSI (2008) BS 9999: 2008: *Code of practice for fire safety in the design, management and use of buildings* (London: British Standards Institution)

BSI (2009a) DD CEN/TS 81-83: 2009: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of the resistance against vandalism* (London: British Standards Institution)

BSI (2009b) BS EN 81-21: 2009 + A1: 2012: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. New passenger and goods passenger lifts in existing building* (London: British Standards Institution)

BSI (2011a) DD CEN/TS 81-11: 2011: *Safety rules for the construction and installation of lifts. Basics and interpretations. Interpretations related to EN 81 family of standards* (London: British Standards Institution)

BSI (2011b) BS 5655-6: 2011: *Lifts and service lifts. Code of practice for the selection, installation and location of new lifts* (London: British Standards Institution)

BSI (2012) BS 7255: 2012: *Code of practice for safe working on lifts* (London: British Standards Institution)

BSI (2013a) BS EN 81-82: 2013: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of the accessibility of existing lifts for persons including persons with disability* (London: British Standards Institution)

BSI (2013b) BS EN ISO 14798: 2013: *Lifts (elevators), escalators and moving walks. Risk assessment and reduction methodology* (London: British Standards Institution)

BSI (2014a) BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts* (London: British Standards Institution)

BSI (2014b) BS EN 81-50: 2014: *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components* (London: British Standards Institution)

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HMSO (1995) Disability Discrimination Act 1995 Elizabeth II Chapter 50 (London: Her Majesty's Stationery Office) (1995) (available at <http://www.opsi.gov.uk/acts/acts1995a>) (accessed June 2010)

OJ (1995) 'European Parliament and Council Directive 95/16/EC of 29 June 1995 on the approximation of the laws of the Member States relating to lifts' *Official Journal L213* 1–31 (07/09/1995) ('The Lifts Directive') (available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31995L0016:EN:HTML>) (accessed May 2015)

OJ (2014) 'Directive 2014/33/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to lifts and safety components for lifts (recast)' *Official Journal L96* (29.3.2014) 251–308 (available at <http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014L0033&from=EN>) (accessed June 2015)

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17 European Directives, legislation, standards and codes of practice

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17 European Directives, legislation, standards and codes of practice

17.1 Important note

This chapter is provided for information only. Of necessity it is brief, may not include all possible information and may or may not be applicable to all activities in the vertical transportation field. Responsible persons and duty holders must review the contents and decide applicability. The Institution cannot be held responsible for any loss or injury resulting from the use of this information. Other sources of information include:

- Department for Business, Innovation and Skills (BIS) (<http://www.bis.gov.uk>)
- British Standards Institution (BSI) (<http://www.bsigroup.com>)
- Communities and Local Government (CLG) (<http://www.communities.gov.uk>)
- European Commission (Enterprise and Industry) (http://ec.europa.eu/growth/sectors/mechanical-engineering/index_en.htm)
- Office of Public Sector Information (<http://www.legislation.gov.uk>)
- The Stationery Office (<http://www.tsoshop.co.uk>)
- Health and Safety Executive (HSE) (<http://www.hse.gov.uk>).

European and UK legislation is generally available free of charge through the internet and links to specific items of legislation are given in the list of references at the end of this chapter.

The sections below list entries alphabetically by title to avoid any presumption of relative importance.

17.2 European Directives

17.2.1 Electromagnetic Compatibility (EMC) Directive

European Directive 2004/108/EC (OJ, 2004) deals with the two elements of EMC, i.e. emission and immunity. Generic standards that support the Electromagnetic Compatibility Regulations 1992 (HMSO, 1992a) are BS EN 61000-6-1 (BSI, 2007) for residential, commercial and light industry and BS EN 61000-6-2 (BSI, 2005) for industrial environments. Industry standards for lifts are BS EN 12015 (BSI, 2014) and BS EN 12016 (BSI, 2013).

17.2.1 Framework Directive

European Directive 89/391/EEC (OJ, 1989a) deals with 'the introduction of measures to encourage improvements in the health and safety of workers at work.' The Directive is largely implemented in the Management of Health and Safety at Work Regulations 1992 (MHSWR) (HMSO, 1992b) (see section 17.1.13).

17.2.3 Lift Directive

Directive 84/529/EEC (OJ, 1984) was published in 1984 relating to electrically, hydraulically or oil/electrically operated lifts. It did not ensure freedom of movement for all types of lift and was declared to constitute barriers to trade within the Community. A new Lifts Directive 95/16/EC (OJ, 1995a) was published in 1995 permitting the national rules on lifts to be harmonized. Some small changes were made in 2009 to comply with the revised Machinery Directive that came into force on 29 December 2009. The latest edition is 2014/33/EU (OJ, 2014) published 26 February 2014 for application on 20 April 2016. See section 17.4.8 for UK enactment.

17.2.4 Low Voltage Directive

European Directive 2006/95/EC (OJ, 2006) is concerned that electrical equipment, when properly installed and maintained, shall not endanger persons, domestic animals and/or property and shall provide safe operation of the equipment by users free from risk of electric shock. Low voltage is defined as 50–1000 V AC or 75–1500 V DC. Electrical parts for passenger and goods/passenger lifts are excluded in Annex II of the Directive, as lifts can be treated for the purpose of the Directive, as a factory-built assembly. Escalators and moving walks are not excluded from the Directive.

17.2.5 Machinery Directive

First published as 89/392/EEC (OJ, 1989b) and amended by 91/368/EEC (OJ, 1991), 93/44/EEC (OJ, 1993a), 93/68/EEC (OJ, 1993b) and 2006/42/EC (OJ 2006b). See section 17.4.12 for UK enactment.

17.3 Acts of Parliament

17.3.1 Equality Act 2010

The Equality Act 2010 (TSO, 2010) brought together various equality issues such as disability, sexual and racial discrimination into one piece of legislation. The preamble to the Act says:

'An Act is to make provision to require Ministers of the Crown and others when making strategic decisions about the exercise of their functions to have regard to the desirability of reducing socio-economic inequalities; to reform and harmonise equality law and restate the greater part of the enactments relating to discrimination and harassment related to certain personal characteristics; to enable certain employers to be required to publish information about the differences in pay between male and female employees; to prohibit victimisation in certain circumstances; to require the exercise of certain functions to be with regard to the need to eliminate discrimination and other prohibited conduct; to enable duties to be imposed in relation to the exercise of public procurement functions; to increase equality of opportunity; to amend the law relating to rights and responsibilities in family relationships; and for connected purposes.'

Businesses and service providers have a duty, to make 'reasonable adjustments' to the 'physical features' of both old and new buildings, in order to overcome barriers to access. 'Reasonable adjustments' take account of practicality, financial and other costs, disruption, resources available, availability of financial assistance. Lifts, escalators and moving walks are examples of 'physical features'.

17.3.2 Health and Safety at Work etc. Act 1974

A primary piece of legislation also used to enact other safety regulations. The Act places duties on employers, the self-employed and employees. Persons concerned with lifts have duties under the Health and Safety at Work etc. Act 1974 (HMSO, 1974), which include the following:

- (a) Employers have a duty to ensure, so far as is reasonably practicable, the health and safety of their employees while at work. This includes:
 - the provision of plant and systems of work that are safe and without risk to health;
 - the means to safely use and handle articles and substances;
 - all necessary information, instruction, training and supervision;
 - a safe means of access and egress;
 - a safe working environment.
- (b) Employers, the self-employed and employees have a duty to conduct their undertakings in such a way as to ensure, so far as is reasonably practicable, that all persons who might be affected by the work activity are not exposed to risks to their health and safety.
- (c) Manufacturers, suppliers etc. of articles for use at work have a duty to ensure, so far as is reasonably practicable, that the articles are so designed and constructed that they will be safe and without risk to health when they are being set, used, cleaned or maintained.
- (d) Erectors and installers of articles for use at work have a duty to ensure, so far as is reasonably practicable, that nothing about the way articles are erected or installed is unsafe or a risk to health.
- (e) Persons concerned with premises have a duty to persons other than employees who use non-domestic premises made available to them as a place

of work. It is the duty of the person who controls the premises to take such measures as it is reasonable for them to take to ensure, so far as is reasonably practicable, that the premises, the means of access and egress to and from the premises, and any plant of substance in the premises, are safe and without risk to health.

17.4 Regulations

17.4.1 Construction (Design and Management) Regulations 2015

The design, installation and maintenance of lifts and escalators is always subject to risk assessments being carried out and their installation and continued operation will be subject to the CDM Regulations (TSO, 2015).

17.4.2 Control of Asbestos at Work Regulations 2012

The Control of Asbestos Regulations 2012 (TSO, 2012) came into force on 6 April 2012, updating previous asbestos regulations to take account of the European Commission's view that the UK had not fully implemented the EU Directive on exposure to asbestos (Directive 2009/148/EC (OJ, 2009)).

17.4.3 Control of Substances Hazardous to Health Regulations 2002

The Control of Substances Hazardous to Health Regulations 2002 (TSO, 2002) and subsequent amendments set out a framework of action for employers and self-employed persons to follow, which aims to protect the health of all people who might be exposed to hazardous substances at work. Employers must protect employees and others who may be affected by: carrying out a risk assessment; identifying and implementing control measures; ensuring that the control measures are used; ensuring that employees are properly informed, trained and supervised. Hazardous substances include chemicals, dust, gases and fumes. Asbestos is excluded from the Control of Substances Hazardous to Health Regulations 2002 as it is covered by separate regulations (see section 17.1.2).

17.4.4 Electricity at Work Regulations 1989

These Regulations (HMSO, 1989) came into force on 1 April 1990 and introduced a control framework incorporating fundamental principles of electrical safety applying to a wide range of plant systems and work activities. They apply to all places of work, and electrical systems at all voltages. They apply to employers and self-employed persons and set out requirements for all electrical systems, including construction, integrity, maintenance and isolation.

17.4.5 Electrical Equipment (Safety) Regulations 1994

The Electrical Equipment (Safety) Regulations 1994 (HMSO, 1994) implement the requirements of composite Directive 93/68/EEC (OJ, 1993b) and cover the supply of electrical equipment which, when properly installed, does not endanger persons, domestic animals or property and provides safe operation of the equipment by users free from electric shock. Low voltage is defined as 50 V AC to 100 V AC or 75 V DC to 1500 V DC.

Schedule 2 of these Regulations excludes parts for escalators and moving walks, as these are considered to be a factory-built assembly.

17.4.6 Health and Safety (Safety Signs and Signals) Regulations 1996 (HSSSS)

Certain safety signs are required by law to communicate essential safety directions and information. Where applicable, such signs should comply with the HSSSS (HMSO, 1996), which puts into practice the European Safety Signs Directive (92/58/EEC (OJ, 1992)), to ensure the standardisation of safety signs so that they have the same meaning thus reducing the risk of misunderstanding. Safety signs are categorised as prohibition, mandatory, warning and information. The first three must follow the shape and colours stipulated. Certain information signs, such as those which indicate a safe place, emergency exit, first aid or firefighting equipment must comply with the regulations, other more prescriptive signs should follow the shape, i.e. rectangular or square, but may use pictograms and different colours providing they are not confusing. The regulations only apply to employers in respect to their employees; however, they are considered good practice in all applications.

17.4.7 Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)

The Regulations (TSO, 1998a) give effect to Directive 89/655/EEC (OJ, 1989) on the health and safety requirements for the use of work equipment by persons at work as amended by Directive 95/63/EC (OJ, 1995b) and came into force on 5 December 1998.

'Lifting operations' means an operation concerned with the lifting or lowering of a load. 'Lifting equipment' means work equipment for lifting or lowering loads and includes its attachments for anchoring, fixing or supporting it. An accessory for lifting means work equipment for attaching loads to machinery for lifting. 'Work equipment' means any machinery, appliance, tool or installation for use at work. 'Load' includes a person and the Regulations include passenger lifts.

LOLER applies to lifting equipment for lifting persons, but does not apply to escalators and moving walks.

LOLER requires that a 'thorough examination'* be carried out every six months (or by a written scheme determined by risk assessment) by a competent person and a report

issued. The report should notify any defect which in the opinion of the competent person could be, or become, a danger to persons. Where there a serious risk of personnel injury the competent person should inform the duty holder immediately and a report should be sent as soon as reasonably practical to the relevant enforcing authority (HSE or Local Authority).

More information can be found in HSE publications INDG 290: *Lifting equipment at work* (HSE, 2013) and INDG 422: *Thorough examination of lifting equipment — A simple guide for employers* (HSE, 2008).

Provision and Use of Work Equipment Regulations 1998 (PUWER) (TSO, 1998b) also applies to lifting equipment, see section 17.4.10.

17.4.8 Lifts Regulations 1997

These Regulations† (TSO, 1997) implement Directive 95/16/EC (OJ, 1995a) (the Lifts Directive) in order to meet the Essential Health and Safety Requirements (EHSRs) defined in the Directive. The Regulations came into full force on 1 July 1999. The Regulations contain fifteen complex Schedules setting out the arrangements. The most important of these is Schedule 1, which sets out the EHSRs relating to the design and construction of lifts and safety components. Among the definitions included are: 'lift', 'harmonized standard', 'installer', 'safe', 'placing on the market', 'essential health and safety requirements', 'responsible person'. 'Putting into service' is not specifically defined. The Lift Directive was slightly amended by the publication of the Machinery Directive (2006/42/EC (OJ, 2006b)), when the boundary between lifts on one hand and machine that transported persons on the other hand was elaborated.

The Lifts Regulations 1997 require new lift installations to comply with EHSRs laid down in Schedule 1 of the Regulations. These requirements apply to the entire lift installation including the building fabric and supporting building services. Compliant installations will carry a CE mark in the lift car. The CE marking denotes that either (a) the entire installation complies in full to harmonised standards or to a pre-approved 'model' standard, or (b) the installation meets the minimum essential health and safety requirements approved by a 'Notified Body'. These are known as the 'Routes to Conformity'. The most common routes to conformity are the installation of 'model' lifts and lift installations meeting harmonised standards. Schedule 1 is summarised below.

- | | |
|--------|--|
| 1 | General: |
| 1.2(a) | Car to be designed for adequate space and strength for rated load. |
| 1.2(b) | Provide (if possible) unimpeded access to disabled persons. |
| 1.3(a) | Provide adequate means of suspension. |
| 1.3(b) | Provide at least two ropes or chains. |

* The Safety Federation (SAFed) in association with HSE published in 2006 *Guidelines on the supplementary tests of in-service lifts* (SAFed/HSE, 2006)

† Currently under review; to meet the requirements of Directive 2014/33/EU the Lifts Regulations will be revised.

- 1.4.1 Provide an overload device.
 - 1.4.2 Provide overspeed limitation.
 - 1.4.3 Provide speed monitoring and speed limiting on fast lifts.
 - 1.4.4 Adequate traction is required.
 - 1.5.1 Each lift has its own machine.
 - 1.5.2 Machinery is inaccessible to public.
 - 1.6.1 Controls for use of disabled may be provided.
 - 1.6.2 Function of controls to be clearly indicated.
 - 1.6.3 Group call circuit interconnections provided.
 - 1.6.4(a) No confusion with lift supply.
 - 1.6.4(b) Possible to switch off lift under load.
 - 1.6.4(c) Movement dependent on an electrical safety circuit.
 - 1.6.4(d) A fault in the electrical system not dangerous.
- 2 Hazards to persons outside the car:
- 2.1(a) Adequate well size.
 - 2.1(b) Entering well, stops lift.
 - 2.2 Provision of refuge spaces.
 - 2.3(a) Provide strong landing doors.
 - 2.3(b) Provide landing door interlocks
- 3 Hazards to persons in the car:
- 3.1(a) Fully enclosed cars.
 - 3.1(b) Doors cannot open between floors.
 - 3.2(a) Prevention of free fall/uncontrolled upward movement.
 - 3.2(b) The device is capable of stopping lift with rated load and speed.
 - 3.3 Buffers to be provided.
 - 3.4 If device in 3.2 set then lift cannot move.
- 4 Other hazards:
- 4.1 Power doors not to crush passengers.
 - 4.2 Doors to have fire resistance.
 - 4.3 Counterweights to be guided.
 - 4.4 Provision of equipment to release trapped passengers.
 - 4.5 Two-way permanent communication with rescue service.
 - 4.6 Lift machine over-temperature detection.
 - 4.7 Car ventilation to be provided.
 - 4.8 Car lighting (normal and emergency) to be provided.
 - 4.9 Alternative power for communication and lighting.
 - 4.10 Fire control.

5 Marking:

5.1 Car rating plate.

5.2 Release of trapped passengers without outside help (if so designed).

6 Instructions for use:

6.1 Provide instruction manual for safety components.

6.2(a) User instruction manual to be provided.

6.2(b) Log book to be provided.

For installations where conformity is to be obtained other than by installing to harmonised standards, the specific requirements for the lift installation's environment should be sought. This is defined in the model lift's technical documentation, or otherwise approved by a Notified Body. The harmonised standards which satisfy the EHSRs are the BS EN 81 series of safety standards.

For lift modernisations where the lift is not deemed to be new, the installation falls outside of the scope of the Lifts Regulations and older standards such as BS 5655 and earlier EN 81 series of standards, still apply, see chapter 16.

The Regulations do not apply to lifts installed and put into service before 1 July 1999 and a number of specialist lifts listed in Schedule 14.

17.4.9 Management of Health and Safety at Work Regulations 1999 (MHSWR)

The MHSWR (TSO, 1999) outline the responsibilities and actions regarding the management of health and safety. Implements most of the European Directive 89/391/EEC (OJ, 1989a) and European Directive 91/383/EEC (OJ, 1991) dealing with the health and safety of persons employed on a fixed term or temporary basis.

Regulation 3 requires:

'Every employer and self employed person to make a suitable and sufficient assessment of safety risks to employees and others not directly employed, but who are affected by the employers undertakings, in order to put in place appropriate control measures. Reviews of the assessments shall be made and significant findings recorded if more than five people are employed.'

In particular the duty holder is required to assess the risks to health and safety from their undertaking. This includes risks from the use, operation, repair and examination of escalators and moving walks on their premises. The risk assessment should be 'suitable and sufficient' and undertaken by a person who is competent.

The purpose of the assessment is to identify and quantify the risk. Employers are required to implement preventative and protective measures to eliminate risk, and to put in place effective control measures to address residual risks and hazards.

The employer is required to appoint competent persons to assist the employer in order to develop controls and procedures for health and safety management. The

regulations include requirements for training, health and safety assistance, information, organisation, control, monitoring and review.

17.4.10 Provision and Use of Work Equipment Regulations 1998 (PUWER)

The Regulations (TSO, 1998b) revoke and re-enact the Provisions and Use of Work Equipment Regulations 1992 (HMSO, 1992c), which gave effect to Directive 89/655/EEC (OJ, 1989c) on the minimum health and safety requirements for the use of work equipment by workers at work, and came into force on 5 December 1998.

The Regulations require risks to the health and safety of persons from equipment they use at work, to be prevented or controlled by ensuring that it is:

- suitable for use
- maintained in a safe condition, and
- inspected in certain circumstances.

‘Use of work equipment’ means any activity involving work equipment and includes starting, stopping, programming, setting, transporting, repairing, modifying, maintaining, servicing and cleaning.

‘Work equipment’ covers all machinery, appliance, tool, equipment or installation used by an employee or a self-employed person at work and includes static and mobile machinery, installations, lifts, escalator and moving walks equipment. It includes hoists and elevating work platforms.

The regulations also cover: thorough examination, guarding, controlling, provision of information, training in the use of work equipment.

The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) (TSO, 1998a) additionally applies to lifting equipment (see section 17.4.7).

17.4.11 Personal Protective Equipment (PPE) Regulations 2002

The Personal Protective Equipment Regulations 2002 (TSO, 2002) implement the requirements of Personal Protective Equipment Directive 89/686/EEC (OJ, 1989d) (as amended).

Personal protective equipment means: ‘All equipment designed to be worn or held by a person at work to protect against one or more risks, and any addition or accessory designed to meet this objective.’

Personal protective equipment includes helmets, eye protection, ear protection, safety footwear, gloves, safety harness, protective clothing, high visibility clothing.

Employers are required to provide suitable personal protective equipment to each of their employees who might be exposed to risk.

Personal protective equipment is to be used as a last resort after all measures to prevent or control risks at source are exhausted.

The Regulations cover suitability, compatibility, maintenance, replacement, information, loss, defect etc.

17.4.12 Supply of Machinery (Safety) Regulations 2008

The Supply of Machinery (Safety) Regulations 2008 (TSO, 2008) implements the requirements of the Machinery Directive 2006/42/EC (OJ, 2006b), and came into force on 29 December 2009. The Machinery Directive applies to a wide range of machines including chain saws, power presses, mechanical diggers etc. It also applies to lifting equipment of various types such as escalators, moving walks and other vertical transportation equipment not appropriate to be regulated by the Lifts Directive, e.g. lifting platforms, stairlifts and home lifts.

Directive 2006/42/EC represented a complete overhaul of the original Machinery Directive (consolidated as 98/37/EC (OJ, 1998)), which was repealed with effect from 29 December 2009. As such it re-draws the previous boundary between itself and the Lifts Directive by directly amending that directive. Accordingly the UK Regulations that transposed it in turn amended the Lift Regulations.

The Supply of Machinery (Safety) Regulations 2008 implements the requirements of the Machinery Directive 2006/42/EC and amends Directive 95/16/EC (OJ, 1995a) (the Lifts Directive).

Annex 1 of the Machinery Directive lists the essential health and safety requirements that apply to all machines.

The harmonized standard that supports the Machinery Directive and the Supply of Machinery (Safety) Regulations for escalators and moving walks is BS EN 115-1 (BSI, 2008).

17.4.13 Workplace (Health, Safety and Welfare) Regulations 1992

These Regulations (HMSO, 1992d) implement most of the requirements of the Workplace Directive (89/654/EEC (OJ, 1989e)) and are concerned with the minimum standards for workplace health and safety and the reduction of risk. The Regulations have been applied in full since 1 January 1996. The provisions have long been part of UK law but their application was not. Areas covered include: maintenance of workplace, maintenance of workplace equipment, ventilation, temperature, lighting, cleanliness, traffic routes, fall protection, doors and gates, sanitary and washing facilities, etc.

Regulation 19 requires lifts, moving walks and escalators to function safely, be equipped with any necessary safety devices and have one or more identifiable and accessible emergency stop controls.

17.4.14 Work at Height Regulations 2005 (WAHR)

The Work at Height Regulations 2005 (TSO, 2005) (WAHR) are specifically aimed at reducing the risks of falling from height. They set out requirements relating to precautions and actions to be taken or considered when there are exposed voids or persons are at risk from falling, e.g. over open atria. These are not specific to escalators or moving walks but considered generally in respect of all risks from falls at height.

17.5 Standards and codes of practice

This section is provided to indicate some of the standards and codes of practice pertinent to vertical transportation equipment.

An up-to-date list (at the time of publication) of standards is provided in Appendix A3. Responsible persons must review the list and decide their applicability.

17.5.1 British Standards Institution

The British Standards Institution (BSI) was founded in 1908 and incorporated by Royal Charter in 1929. It is an independent organisation that works with industry, trade associations and government to produce British, European and International standards. BSI is also involved in product testing and certification and quality assurance management systems. BSI's aim is 'to help British business become more efficient and competitive'.

The Mechanical Handling Equipment (MHE/4) technical committee for lifts, escalators and moving walks is responsible for the production of standards and provides experts for the various CEN (TC10) and ISO (TC178) committees in developing harmonised standards.

In the production of national standards, BSI aims to ensure that they are consistent in content and format. For some time now this has included international work, which is eventually either produced as a national standard or, more usually, as a BS EN or BS ISO. BSI is heavily involved in the work of the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) in the harmonisation of standards.

The MHE/4 technical committee is made up of members from trade associations, professional institutions, user groups, government departments, notified bodies and local authorities representing the many different requirements and opinions.

The technical committee is large and to deal with the work efficiently and speed up the decision making process, the MHE/4 technical committee has delegated particular tasks to an Advisory Panel (standing committee) and a number of subcommittees and panels.

The Advisory Panel includes in its terms of reference the possibility to 'take executive decisions on the behalf of MHE/4 where agreed by the chairman'.

The subcommittees and panels include members from the main MHE/4 committee, with a direct interest and specialist knowledge in the particular tasks and it is possible to co-opt persons with a particular expertise, when required. Each subcommittee and panel has its terms of reference and reports back to MHE/4 and its advisory panel on progress and for guidance on policy matters. Chairmen of sub-committees are usually nominated by MHE/4, although it can be left to the subcommittee members to elect their own chairman. Generally, the sub-committees and panels are not permanently constituted and once they have completed their task(s) they are either disbanded or retained to deal with future amendments.

Once national work has been approved by MHE/4 it is edited by BSI and the draft standard or code of practice is circulated as a draft for public comment (DPC). Comments received are collated by the secretary, circulated to the originating sub-committee or panel for resolution. Once this process is complete the draft can be signed off by the chairman.

Draft CEN standards (prENs) and draft international standards (DIS) are circulated for comment and dealt with in a similar manner.

It is becoming increasingly clear that purely national work is diminishing and being superseded by international and European harmonised standards work.

17.5.2 Interpretation of standards

The content of British and European Standards is often not clear owing to textual ambiguities or changes in technology. To allow these difficulties to be resolved the responsible committee at the European Standards Committee (CEN/TC10) has a procedure where a user of a standard can make an Interpretation Request.

In the UK such a request is channelled through the responsible MHE/4 committee at BSI. The procedure is for the interpretation request to be made to the Secretary of MHE/4. The Secretary may be able to resolve the query, e.g. advise the correct standard to apply. If the Secretary is not able to do this the query is passed to the Chairman of MHE/4, who with the help of other members of MHE/4 may be able to provide an answer. Should this not be possible then MHE/4 will make a formal Interpretation Request to the appropriate committee at CEN. Usually the Convenor of the appropriate committee proposes an answer, which is circulated for approval and subject to that the answer is published. This process can take some time.

A list of interpretations is given in Appendix A3.6.

17.5.3 The development of an ISO prescriptive standard for lift safety

There are two influential standardisation bodies in the world: CEN and ISO. The remit of CEN runs legally in Europe and ISO offers global standards. CEN and ISO have

a proposal for a 'road map' for EN 81-20/50 to become ISO 'X' and ISO 'Y'.

At the time of writing there are three main standards for lifts, with globally relevant use, which have been developed independently. These are:

- ASME A17/CSA B44 series of standards developed in North America
- EN 81 series of standards developed in Europe
- JIS/JEA series of standards developed in Japan

Of these three the EN 81 series has the most penetration across the world. The influence of the ASME/CSA standard is small owing to its small installed estate of lifts. Similarly for the JEA family of standards.

Each standards family achieves safe lifts, but in different ways. Unfortunately, these standards have significant differences in their detailed requirements, which cause manufacturing problems and create barriers to trade. In order to remove such barriers there is a need for ISO prescriptive standards.

The North American and Japanese standardization bodies have agreed to work with CEN in Europe and ISO towards an ISO family of lift standards and a road map has been agreed. For the purpose of discussion these new standards will be referred to as ISO 'X', ISO 'Y' and ISO TS 'Z'. [ISO 'X' would be equivalent to EN 81-20, ISO 'Y' equivalent to EN 81-50 and ISO TS 'Z' would be created to deal with

North American and Japanese variations, similar to the special markets of EN 81-12. The phasing is as below.

- *Phase 1:* 2014–2017 (CEN lead): identical adoption of EN 81-20/50 as ISO 'X'/'Y' and creation of a regional TS 'Z'
- *Phase 2:* 2017–2020 (CEN lead): first amendment to ISO 'X'/'Y' and creation of EN ISO 'X'/'Y'
- *Phase 3:* 2020–2023 (ISO lead): regular (3-yearly) revisions and incorporation of regional TS 'Z'.

It is possible to trace this welcome development back to BSI. The first EN 81-1/2 standards were based on BS 5655-1/2. Many of the other British Standards were adopted by CEN and improved. By the time the next edition of CIBSE Guide D is published in 2020 much of this work should be complete.

17.5.4 Structure of the EN 81 series of standards

A revision of the structure of the EN 81 family of standards has been undertaken since the previous (2010) edition of Guide D was published. Many annexes of the current EN 81-1/2 have been moved to EN 81-50. Most of the construction content of EN 81-1/2 has become EN 81-20, which covers both traction and hydraulic lifts in one document. Figure 17.1 illustrates the structure and shows where the standards published at the time of publication of this Guide fit into the structure.

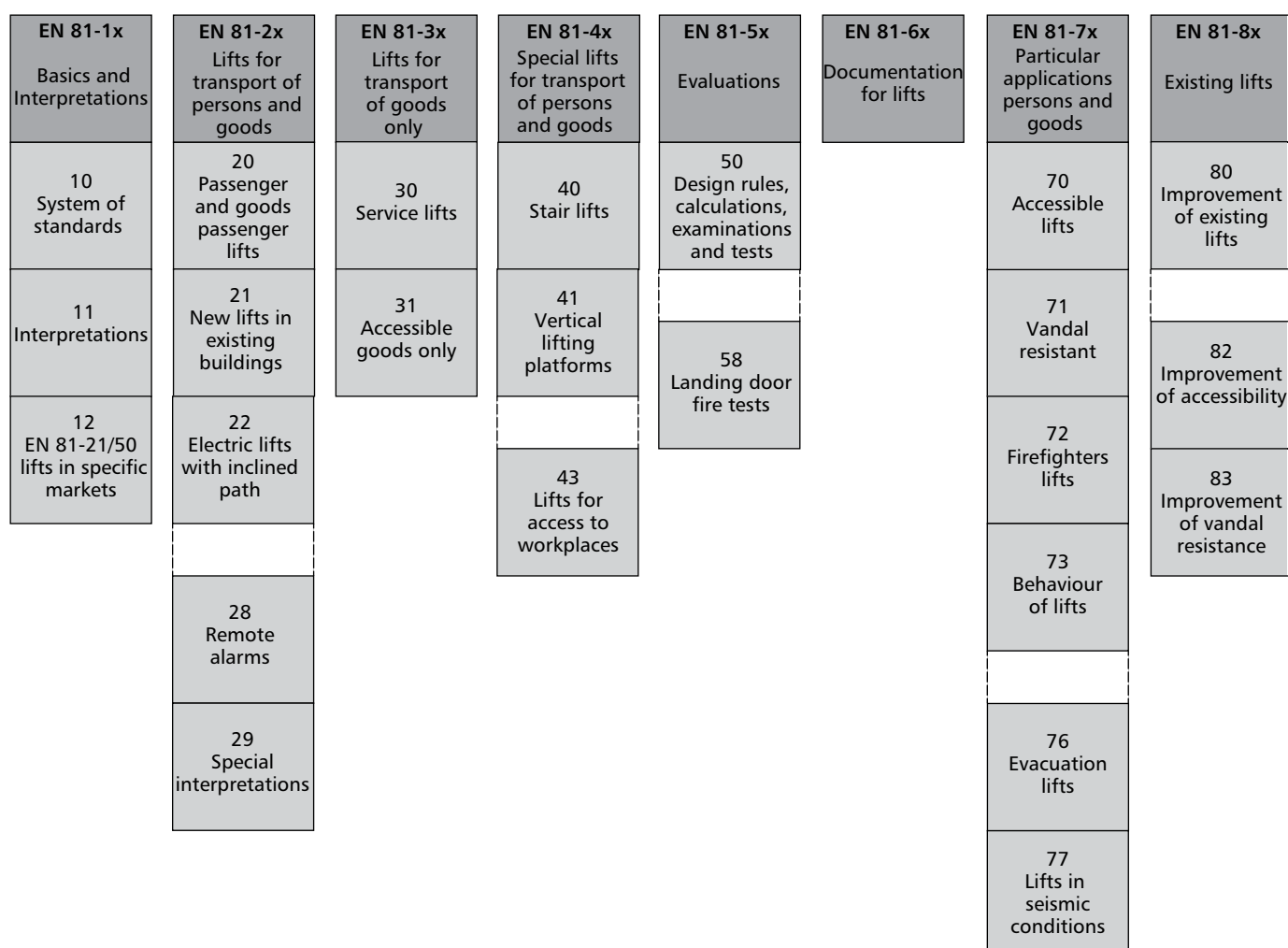


Figure 17.1 Illustration of the structure for the EN 81 family of standards

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18 Construction (Design and Management) Regulations 2015

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18 Construction (Design and Management) Regulations 2015



Warning: the guidance on the Construction (Design and Management) Regulations published in the previous (2010) edition of CIBSE Guide D is now not current and its content should not be relied upon.

18.1 Background

Chapter 18 of CIBSE Guide D has always provided guidance on the important health and safety regulations as they apply to the lift and escalator industry. The Lift and Escalator Industry Association (LEIA) kindly provided guidance to the CDM Regulations 1994 for the 2005 edition of CIBSE Guide D and to the CDM Regulations 2007 for the 2010 edition.

As the present (2015) edition of CIBSE Guide D was being prepared for publication the Construction (Design and Management) Regulations 2007 were replaced on 6 April 2015 with the Construction (Design and Management) Regulations 2015. These 2015 regulations came into force with immediate effect, with a six month transition period ending in October 2015.

The final text of the regulations was not available for proper consideration and analysis until 6 April 2015. Thus it was not possible for LEIA to provide an authoritative guide to the CDM Regulations 2015 for CIBSE Guide D (2015). LEIA is actively preparing such a guide, which will be relevant to the lift and escalator industry. It is hoped that this will be made available to CIBSE.

The CIBSE Lifts Group intends to produce interim updates to the 2015 Guide. This will provide an opportunity to publish an authoritative analysis of the CDM Regulations 2015 prior to publication of the next edition of the Guide in 2020. In the meantime the following is offered.

18.2 Where to obtain information

The full text of the Construction (Design and Management) Regulations 2015 may be downloaded as a PDF free of

charge from the UK Government website (http://www.legislation.gov.uk/ukxi/2015/51/pdfs/ukxi_20150051_en.pdf) and this should be consulted for details.

The Health and Safety Executive (HSE) offers a guidance document (though not an 'Approved Code of Practice' (ACoP)): *Managing health and safety in construction: Construction (Design and Management) Regulations 2015 Guidance on Regulations* (HSE, 2015). This may also be downloaded as a PDF free of charge from the HSE website (<http://www.hse.gov.uk/pubns/books/l153.htm>)

The ACoP supporting the 2007 regulations was withdrawn on 6 April 2015.

18.3 The CDM Regulations

UK regulations include an Explanatory Note, which is not part of the regulations. This is reproduced below.

18.4 HSE Guidance to CDM 2015

The HSE's guidance document *Managing health and safety in construction: Construction (Design and Management) Regulations 2015 Guidance on Regulations* (HSE, 2015) contains a useful flowchart, which is reproduced below as Figure 18.1. This flowchart would apply to many lift projects.

References

HSE (2015) *Managing health and safety in construction: Construction (Design and Management) Regulations 2015 Guidance on Regulations* HSE L153 (Bootle: Health and Safety Executive) (available at <http://www.hse.gov.uk/pubns/books/l153.htm>) (accessed July 2015)

TSO (2015) *Construction (Design and Management) Regulations 2015* (London: The Stationery Office) (available at <http://www.legislation.gov.uk/ukxi/2015/51>) (accessed July 2015)

EXPLANATORY NOTE

(This note is not part of the Regulations)

1. These Regulations revoke and re-enact, with modifications, the Construction (Design and Management) Regulations 2007 (S.I. 2007/320) (the “2007 Regulations”). They implement in Great Britain the requirements of Directive 92/57/EEC (OJ No L245, 26.8.92, p6) (“the Directive”) on the implementation of minimum safety and health requirements at temporary or mobile construction sites (eighth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), except certain technical requirements in the annexes to the Directive which are implemented by other health and safety regulations relating to specific hazards or circumstances. These include the Work at Height Regulations 2005 (S.I. 2005/735) and the Workplace (Health, Safety and Welfare) Regulations 1992 (S.I. 1992/3004).

2. Part 2 sets out the client duties under the Regulations. Part 3 provides for various health and safety duties and roles, namely general duties, the duties of the principal designer, principal contractor, designers and contractors. Part 4 provides the general requirements for all construction sites which remain largely unchanged from the 2007 Regulations. Part 5 sets out general provisions including the requirement for a review of the Regulations by the Secretary of State.

3. The main changes from the 2007 Regulations are—

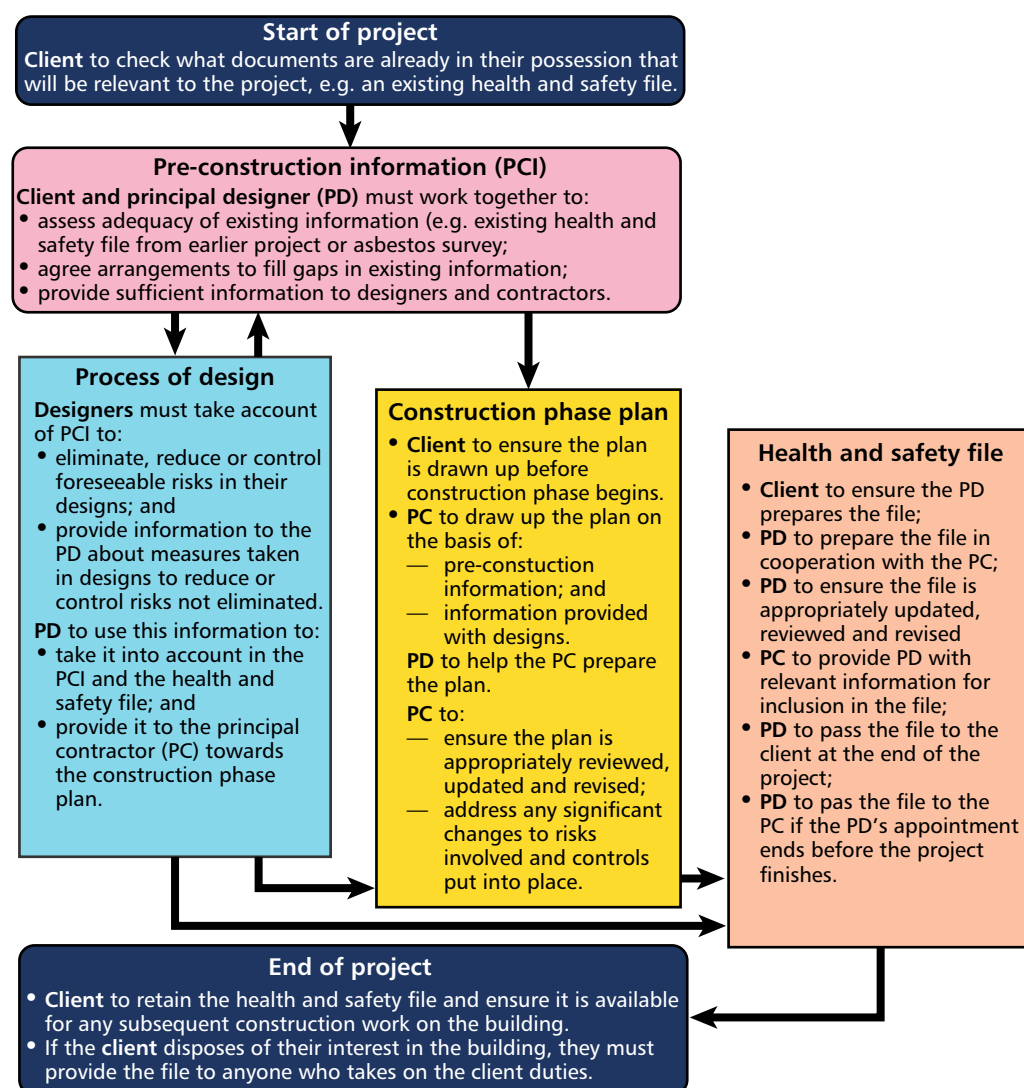
- (a) These Regulations apply to all clients of construction projects, whether or not a person is acting in the course or furtherance of a business (regulation 2(1)).
- (b) Pre-construction archaeological investigations are not included within the scope of the definition of construction work (regulation 2(1)).
- (c) The role of CDM co-ordinator has been removed and various duties have been recast including client duties (regulation 4) and general duties (regulation 8).
- (d) A client is required to appoint a principal designer as well as a principal contractor in any project where there is, or it is reasonably foreseeable that there will be, more than one contractor working on the project (regulation 5). Under the 2007 Regulations appointments for similar roles were required for notifiable projects.
- (e) The duty to notify now lies with a client and the threshold for notification is raised (regulation 6).
- (f) If a client is a domestic client, most of their duties will be carried out by the contractor, principal contractor, or principal designer (regulation 7).
- (g) The duties of the principal designer are set out in regulations 11 and 12.
- (h) Modified duties of the principal contractor are set out in regulation 12 to 14.
- (i) Modified duties of contractors are set out in regulation 15.
- (j) Transitional provisions are set out in Schedule 4.
- (k) The Secretary of State will carry out a review of the Regulations under the provisions of regulation 39.

4. The key changed role in these Regulations from the 2007 Regulations is that of the principal designer. This role fulfils the function of a safety and health coordinator for the project preparation stage as required by article 3.1 of the Directive which was previously carried out by the role of CDM co-ordinator. The principal designer has a more central role in the project than that of a CDM co-ordinator as they must be a designer with control over the pre-construction phase of the project (regulation 5(1)(a)). The pre-construction phase includes all design and preparation work for the construction project (regulation 2(1)). The principal designer is required to coordinate all health and safety matters relating to the pre-construction phase alongside the overall planning, management and monitoring of the pre-construction phase of the project (regulation 11(1)).

5. Schedule 4 provides transitional provisions for existing projects. Where an existing project has a CDM co-ordinator, a principal designer must be appointed within six months of the date these Regulations come into force unless the project ends before that date (paragraph 4 of Schedule 4). During the interim period the existing CDM co-ordinator must fulfil the duties in paragraph 5 of Schedule 4.

6. The principal contractor role fulfils the role of safety and health coordinator for the project execution stage as required by article 3.1 of the Directive. The core duties of the principal contractor have only minor modifications from those imposed under the 2007 Regulations and a principal contractor who has been appointed to an existing project under the 2007 Regulations will be treated as if they had been appointed as a principal contractor under these Regulations (paragraph 8 of Schedule 4).

7. A full impact assessment of the effect that these Regulations will have on the costs of business has been prepared. A copy of this document and the transposition note in relation to the implementation of the Directive have been placed in the Library of each House of Parliament and are annexed to the Explanatory Memorandum which is available alongside these Regulations at www.legislation.gov.uk.



Note: This diagram shows how the various types of information relate to each other and influence the content of other types of information during the construction process (the arrows show the possible different flows of information). So, for example, as pre-construction information is developed, this influences the risks designers should consider and the information they provide about how their designs reduce or control foreseeable risks. In turn, this may influence further development of the pre-construction information, as well as the construction phase plan and the health and safety file.

Figure 18.1 How different types of information relate to and influence each other in a construction project involving more than one contractor (reproduced from *Managing health and safety in construction: Construction (Design and Management) Regulations 2015 Guidance on Regulations* (HSE, 2015); Crown copyright)

Appendix A1: Glossary of terms

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Introduction

The following glossary of terms has been reproduced by kind permission of the authors from the *Elevator and Escalator Micropedia* by GC Barney, DA Cooper and J Inglis, published by the International Association of Elevator Engineers, PO Box 7, Sedbergh, LA10 5GE. It contains a glossary defining some 1950 terms and cross references used in the vertical transportation industry, i.e. lifts (elevators), escalators and passenger conveyors. These include approximately 1100 electric traction, 250 hydraulic and 500 escalator entries, specific to their speciality, all extensively cross referenced.

The individual entries do not constitute a dictionary definition, as characteristics such as pronunciation and word etymology are not given. Owing to the desire for preciseness and conciseness, the entries are very terse, being the minimum to give a term an authoritative meaning. Nevertheless there are over 35 000 words needed to achieve this objective.

Entries are generally arranged in noun order so that an entry such as:

bail type governor *See* governor: bail type.

will be found under 'governor' with the definitions for twelve other governor related entries. Occasionally this arrangement is not appropriate, e.g:

inspection unit

where a single entry is made in the normal word order. There should be no difficulty finding a term, owing to the extensive cross referencing.

The entries have been prepared using a number of authoritative sources. The source of each entry is given at the end of the entry, usually in the form of a letter code and a page/chapter reference number. The sources used are as follows:

AS	ANSI/ASME Handbook A17.1 (Donoghue, 1984)
BA	Author generated definition (Barney)
BE	<i>Elevator Traffic</i> (Barney and dos Santos, 1985)
BO	BS 2655 series (BSI, 1959–1972)
BS	BS 5655 series (BSI, 1988–2011)
BS70	BS EN 115 (BSI, 1995)
BS78	BS 7801 (BSI, 1995)

CO	Author generated definition (Cooper)
ET	<i>Elevator Technology</i> (Barney, 1986)
HH	<i>Hydraulic Handbook</i> (Trade and Technical Press, 1962)
J	<i>Elevator Mechanical Design</i> (Janovsky, 1993)
JI	Author generated definition (Inglis)
LO	<i>London Underground Glossary of Terms</i> (private publication)
N	<i>Elevator Terms</i> (NEIEP, 1980)
O	<i>Shorter Oxford English Dictionary</i> (OUP, 1973)
P	<i>Electric Lifts</i> (Phillips, 1973)
S	<i>Vertical Transportation</i> (Strakosch, 1983)

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A-side. The left side of an elevator car or hoistway, when viewed by standing in front of the entrance and facing the hoistway. AS12

abstract. A general order or sales summary sheet that indicates duty, control, power supply, machine, signals and all other major features of an escalator or passenger conveyor installation. NE1

AC control. *See* control: AC

acceptance test. *See* test: acceptance.

acceptance. A form signed by the owner or his agent which indicates that the contract for installation is essentially complete, and that the customer accepts the equipment. NE1

access door. *See* doors: access.

accidents. Unintentional incidents, which may cause injury or damage. CO

accumulator. A device that stores hydraulic fluid under pressure so that it can be available immediately for use when required. HH

acoustic noise. *See* noise: acoustic.

active oil. The amount of oil available in a tank of a hydraulic elevator that can be circulated into a system. JI

actuator. Any hydraulic device which applies force: e.g. a cylinder or motor. HH

adaptor rings. The top and bottom ring in a vee packing assembly. JI

addendum. A change to a previously written specification or proposal, usually published prior to the bid date. NE1

adjacent entrance. An arrangement where an elevator car has two entrances arranged at 90° to each other.

adjunct. An applied section of architectural metal fastened to the edge of the escalator or passenger conveyor decking for the purpose of increasing the effective width. CO

adjustable chain tension device. A carriage usually mounted on rollers located in the lower head which, through springs or weights, maintains proper tension on the step chain of an escalator. CO

adjustable flow control. A valve used to restrict the flow of hydraulic oil whose setting is adjustable, generally from shut off to no restriction. JI

adjustable resistor. *See* resistor: adjustable.

adjustable track. *See* track: adjustable.

adjuster. An elevator, escalator or passenger conveyor technician, who carries out the final inspection of new and modernised installations to ensure that all the equipment has been properly installed and set up according to specification. N1

adsil. *See* anti-friction coating.

advance door opening. *See* door: advance opening.

air bleed. A device which allows the release of trapped air in the fluid system of an hydraulic elevator. BOpt9

air bleed cock. Enables air to be expelled from the upper parts of the hydraulic system. JI

air bleed line. The small diameter line that is connected to a waste oil container allowing the collection of oil as the air is bled from the system, usually at the cylinder. JI

air bleed screw. *See* air bleed cock.

air breather. The device usually placed on the tank lid to allow the entry of air into the tank as the oil is discharged and allows the discharge of air to atmosphere as the oil returns to the tank. JI

air cord. Part of the driving mechanism of a door operator, which is made from a small diameter wire rope. N2

air entrapment. Refers to pockets of air that can be left in a system when charging the system with oil. JI

air temperature differential. The difference between the ambient air outside the machine room and the air temperature inside the machine room. JI

airborne noise. *See* noise: acoustic.

alarm bell. *See* bell: alarm.

alarm system. An emergency system installed on all cars, which comprises a bell, a pushbutton in the car and an uninterruptible source of power, usually a battery. SS145

algorithm. A set of rules, to which a system (often a control system) must conform. BE94

algorithm: group supervisory control. A set of rules defining the control policy that must be obeyed by an elevator supervisory control system in order that it may pick up passengers from their arrival floors and transport them to their desired destination floors. BE94

alteration. Any change to equipment other than maintenance, repair or replacement. CO

ambient temperature. The temperature of the surrounding air at a particular point in time. JI

and gate. A solid state logic device, where the output value is true, if both the input values are true; and is false, if either, or both, the input values are false. BA

angle bracket. *See* bracket: angle.

angle of contact. *See* angle of wrap.

angle of inclination. The maximum angle to the horizontal in which the steps move on the inclined part of an escalator. LO5/32

angle of traction. *See* angle of wrap.

angle of wrap. The proportion of a sheave, which is in contact with the suspension ropes, measured in degrees of contact. P68

annular space. In the case of a ram and cylinder is the space between the outside of the ram and the inside of the cylinder. JI

annunciator. A signalling device, which provides to passengers information regarding elevator car position etc by means of indicator lamps, audio announcements etc. AS2

anode. A positive terminal. NE4

anti-creep. A feature found on hydraulic elevators, which prevents the car from changing its relative position with respect to the landing floor by compensating for any leakage of oil etc. N4

anti-extrusion rings. A ring of material usually harder than the packing and placed on the side of the packing away from the pressure, which prevents the pressure on the softer packing being extruded through the gap between the ram and gland head. JI

anti-friction coating. An application applied to the skirt panels of escalators and passenger conveyors to reduce the likelihood of static electricity. CO

anti-nuisance device. A device found on some supervisory control systems, whereby the number of passengers in the car are determined, and compared to the number of calls registered, in order that unnecessary trips are prevented. BE97

anti-reversal device. A device provided to prevent the unintentional reversal of an escalator. CO

anti-slide knobs. Material, usually metal, of various shapes and sizes, depending upon manufacture, mounted on the deck boards to prevent riding passengers from sliding packages or baggage on top of the deck boards as they ride the unit. CO

apron: car. A guard installed onto the underside of an elevator car, which employs advance opening doors, to prevent the trapping of objects or passenger limbs, whilst a descending car is levelling at a landing. BOpt9

apron: landing. A guard installed onto the underside of a landing sill to protect against entrapments should a car stop below the landing level. BA

arc. A flame formed by the passage of an electric current between two conductors. NE4

arc quencher. Any device used to eliminate or reduce the arc formed when current carrying contacts are opened. NE5

architect's drawings. Drawings made to show the necessary features of the entire construction of a building. NE5

architrave. The various parts surrounding a doorway, in order to present a neat appearance; a moulding. O59

armature. The member of an electric machine in which an alternating voltage is generated by virtue of relative motion with respect to a magnetic field flux. NE5

arrangement: criss-cross. An escalator installation where the adjacent units have boarding and alighting at opposite ends from each other. CO

arrangement: multiple parallel. An arrangement of escalators where a number of installations running in both directions are located parallel to each other. CO

arrangement: zig-zag. An escalator installation where the adjacent units have boarding and alighting at opposite ends from each other. CO

arrival bell. *See* bell: arrival.

arrival gong. *See* bell: arrival.

arrival rate: down peak passenger. The number of passengers arriving at an elevator system for service during a five minute peak period, when traffic is predominately in the down direction. BE220

arrival rate: interfloor passenger. The number of passengers arriving at an elevator system for service during any five minute period, with no dominant traffic pattern. BE238

arrival rate: up peak passenger. The number of passengers arriving at an elevator system for service during a five minute peak period, when traffic is predominately in the up direction. BE11

arrival rate: up peak percentage. The number of passengers arriving at the main floor of an elevator system for service during the worst five minute period during an up peak traffic condition expressed as a percentage of the total building population. BE11

arrow: direction. An illuminated arrival symbol to indicate the direction of travel; *see* arrow: down and arrow: up. BA

arrow: down. An illuminated arrow symbol either mounted in the rear of an elevator car, or mounted above or alongside the car entrance, or both, which indicates to intending passengers that the direction of travel of the arriving car is to be in the downward direction. AS16

arrow: up. An illuminated arrow indicating an up travelling car in a similar fashion to a down arrow. AS16

astragal. A moulding, usually made of rubber or metal, on the leading edge of hoistway and car doors and extending the full height on centre opening doors or the full width of bi-parting doors, in order to reduce the effects of injury should the doors touch a passenger and to quieten door operation. AS12

astragal: safety. A resilient, incompressible safe edge mounted onto the bottom of the upper section of a bi-parting hoistway door of a freight elevator. AS22

asymmetric relay. *See* relay: asymmetric.

atmospheric pressure tank. A tank that has an air breather allowing the air in the tank to pass into or out of the tank to atmosphere freely and so preventing pressure build up in the tank as the oil volume varies. JI

attendant. A person who is permanently located in the elevator car in order that passengers do not need to operate the controls, such as the car switch (in older systems), destination pushbuttons and car/hoistway doors (in manual systems). N6

authorised persons/personnel. An individual who has (a) received general elevator, escalator or passenger conveyor awareness/training and competency appropriate to their job function, and (b) been instructed on the detail of the work to be undertaken, and (c) received authority from the client for the work to be undertaken. BS78p1

automatic by-pass. A feature of an elevator supervisory control system, which causes the elevator car to automatically by-pass landing calls under certain circumstances, such as when a car is fully loaded and has no room for further passengers, or a car is making a special trip to serve a demand at a distant floor e.g. lobby service, heavy demand call etc. SS77

automatic closer. *See* closer: car door.

automatic control. A generic term, which is used to define any error activated, power amplifying, negative feedback, closed loop control system. B11.2

automatic lubricator. *See* lubricator: automatic.

automatic pushbutton control. A term used to define the simplest means of automatically controlling a single car, where a car may be called to a floor by the pushing of a landing pushbutton (provided it is not already busy) and commanded to travel to a destination floor by the operation of a car call pushbutton. BE86

automatic remote monitoring system. *See* system: automatic remote monitoring.

auxiliary brake. *See* brake: auxiliary.

auxiliary drive chain. *See* chain: auxiliary drive.

auxiliary isolating switch. *See* switch: auxiliary isolating.

auxiliary motor. *See* motor: auxiliary.

auxiliary ram guides. The guiding system attached to the moving heads on telescopic cylinders, designed to prevent buckling of the ram assemblies. JI

auxiliary supply. An alternative supply to the main power supply source. CO

average car load. The total number of passengers carried in one direction of travel, divided by the number of trips in that direction, averaged over a certain time period, usually taken as five minutes, hence up peak or down peak average car load. BE14

axle. A pin or rod in the nave of a wheel(s) on which the wheel turns. LO6/32

B-side. The right side of an elevator car or hoistway, when viewed by standing in front of the entrance and facing the hoistway. AS14

babbitt. Soft alloy of tin, antimony and copper used as an anti-friction material for the socketing of wire ropes for elevators. J34

backlash. Excessive clearance between the teeth of the worm and worm gear of a geared machine; it permits a rocking action of the gear when the worm is held stationery. NE8

baggage stops. Protuberances mounted on deck boards of an escalator to prevent passengers from sliding packages or baggage on top of the deckboards as they ride the escalator. NE8

bail type governor. *See* governor: bail type.

balance line. Required on twin ram systems where each ram and cylinder has its own pipe rupture valve fitted, which is arranged to balance the pressure between cylinders and ensure both valves close at the same time. JI

balanced traffic. A term used in connection with the interfloor traffic condition to indicate that the traffic flows in both up and down directions are substantially equal. BE9

ball valve. *See* valve: ball.

balustrade. The side of an escalator extending above the steps, which includes skirt panels, interior panels, decks and handrails. NE8

balustrade bracket. *See* bracket: balustrade.

balustrade decking. *See* decking: balustrade.

balustrade lighting. *See* lighting: balustrade.

balustrade supportwork. The bolted fabricated steel framework that supports the balustrade. LO6/32

bank (1). A number of groups of cars placed physically together, with each group serving a particular zone of a building, where more than one group may serve the same zone and it is possible to have a bank comprising one group only. BE92

bank (2). A number of escalators in close proximity. CO

bar lock. Type of interlock used with manually operated doors. AS13

barney. A small car attached to a rope and used to push cars up a slope. O159

basement service. Service provided to a floor or floors below the main terminal in a building, which may be restricted at times in order to improve the service to other parts of the building. BE95

bearing. A device that supports and minimises the friction between moving and static surfaces. LO6/32

bearing plate. The building support member on which the truss of an escalator is mounted. CO

bed lift. *See* elevator: bed.

bed-plate. The foundation or support to which the hoist machine is attached, usually made of steel beams: a pedestal. AS13

bell: arrival. A bell either mounted on the elevator car or as part of a fixture on the landing, which signals the arrival of the car at a floor, where it is to pick-up passengers. BA

bell: alarm. A bell, located either in the hoistway, or on a suitable landing, or on the car, which when operated by a passenger pressing a

pushbutton inside the car, is used to call attention and assistance. N2

bi-directional. The ability to operate in two directions. CO

bi-parting doors. Consist of two counterweighted panels, which slide vertically, one in the upward direction and one in the downward direction, interconnected so as to move in synchronism, and strongly constructed to facilitate their use in freight elevators (goods lifts). P220

borehole. A vertical hole bored in the elevator pit to accommodate the cylinder assembly of a direct acting hydraulic elevator. BOpt9

borehole liner. *See* liner: borehole.

bottle cylinder. A cylinder in the shape of a bottle, the displacement ram passes through the gland packing at the top or neck of the bottle. JI

bottom landing. The lower end of an escalator where passengers board or exit. CO

bottom terminal floor. *See* bottom terminal landing.

bottom terminal landing. The lowest landing in a building, which an elevator serves, where passengers may enter and leave the car. N13

bottom runby: car. *See* runby: bottom — elevator car.

bottom runby: counterweight. When an elevator car is level with the upper terminal landing, the counterweight bottom runby is the distance between the striking surface of the counterweight buffer and the counterweight buffer striker plate. AS10

box: halfway (1). A junction box mounted in the hoistway near the halfway point of the elevator car travel to which the stationary ends of the travelling cables(s) are attached. AS18

box: halfway (2). A terminal box provided in an escalator installation to run wiring to for onward connection to the controller. CO

bracket: angle. Formed steel mechanical component used to securely attach guide-rails to the building structure or to securely attach two or more components together. N4

bracket: balustrade. One of the several structural steel members which support the escalator balustrade. NE9

bracket: guide-rail. Formed steel mechanical components to which guide-rails are attached. AS18

bracket: spreader. A U-shaped bracket fastened to two counterweight rails in order to strengthen them. AS23

brake. An electro-mechanical device, consisting of a spring assembly, which is held in compression by the energising of an electro-magnet, and which holds the friction shoes from contact with the brake drum or disc, thus allowing the elevator car or escalator step band to move. *See also* brake: elevator and brake: escalator and passenger conveyors. J86/CO

brake arm. The lever that supports and transfers movement to the brake shoes. LO6/32

brake armature. The magnetic part of the brake mechanism which, when attracted to the brake coil, moves the levers and linkages to release the brake. LO6/32

brake callipers. An assembly of two pivoted levers, linked by a tie rod at one end and fitted with brake pad carriers at the other, released by an electromagnet or hydraulic pressure assembly and applied by compression springs. LO6/32

brake coil. The coil that when energised provides the force to cause the brake to lift, either by movement of the solenoid core or the brake armature. LO7/32

brake cooling switch. *See* switch: brake cooling.

brake dashpot. The dashpot that dampens the braking action of an electromagnetic brake. LO7/32

brake drum. A smooth surface usually mounted on the hoist machine drive shaft, with which the brake shoes make contact whenever the brake magnet is de-energised, in order to absorb the energy of motion. AS13

brake: elevator. In the event of the elevator car exceeding its rated speed, or a power failure, or a control system demand to hold the car stationary, the brake is de-energised and the brake operated, thus stopping the car in safe distance or holding the car in position. J86/CO

brake: escalator and passenger conveyors. In the event of the operation of any one of a number of safety devices and/or a power failure, the brake operates and stops the escalator in a safe distance. J86/CO

brake lift detector. The switch used to detect mechanically that the escalator brake has fully released (lifted). LO7/32

brake lining. Material used to line brake shoes, which has a high coefficient of friction. AS13

brake magnet. A magnet usually provided in the form of a solenoid, which is used to cause the brake shoes to move away from the brake drum, whenever it is energised. J87

brake motor. *See* motor: brake.

brake pad. The high friction replaceable material that acts on the brake disc comprising two pads held in carriers to act on either side of the disc when applied. LO7/32

brake release lever. A lever used to automatically release the brake during handwinding. LO7/32

brake shoes. *See* shoes: brake.

brake solenoid. The solenoid whose core moves to operate the levers and linkages to release the brake. LO7/32

brake-stopping distance. The distance taken for the escalator to stop upon application of the brake. CO

brake: auxiliary. A fail safe brake, which is used to stop an escalator under all normal conditions or under certain fault conditions only. It is typically situated on one side of the main drive shaft. LO6/32

brake: disc. An assembly where lined pads slow, by friction, a disc mounted on a rotating shaft, which is spring applied, or electro-magnetically or hydraulically released and is only used as an auxiliary brake at present. LO11/32

brake: emergency. An auxiliary mechanically automatically operated brake, which will stop a fully loaded escalator, if the drive chain breaks. NE48

brake: main. A fail safe brake sometimes provided which is used to stop an escalator under all normal conditions or under certain fault conditions only, typically situated on one side of the main drive shaft. LO6/32

brake: operational. *See* brake: service.

brake: rated load. The load which the brake of the escalator must be designed to stop and hold. CO

brake: service. An electro-mechanical device, consisting of a spring assembly, which is held in compression by the energising of an electromagnet and which holds the friction shoes from contact with the brake drum or disc, thus allowing the escalator step band to move. In the event of the operation of any one of a number of safety detection devices and/or a power failure, the brake is de-energised and the brake automatically operates, thus stopping the escalator in a safe distance and holding the step chain in position. CO

bridge rectifier. A type of full wave rectifier using four diodes. NE14

broken handrail switch. *See* switch: broken handrail.

broken step chain safety switch. *See* switch: broken step chain safety.

broken drive chain switch. *See* switch: broken drive chain.

brush applicator. Attached the end of feed pipes these apply lubricant to a chain by means of light contact. LO7/32

brush: deflector. A brush provided above the escalator steps and affixed to the skirt panels which is designed to keep passengers feet away from the gap between the edge of the steps and the skirt panels. CO

brush: newel entry. A brush provided at the newel end of an escalator to cover the internal components of the newel entry switch and to prevent passengers fingers entering this space. CO

buffer. Device capable of absorbing the kinetic energy of motion of a descending car or counterweight, when they have passed a normal limit of travel by providing a resilient stop, and comprising a means of braking using fluids or springs (or similar means). AS3/BSpt1

buffer return spring. Spring used to return an energy dissipation type of buffer back to its operating position. J143

buffer switch (1). A switch which is activated should a buffer be operated, which removes power to the elevator drive system. AS14

buffer switch (2). A switch, which is activated should the oil in an oil buffer fall below a minimum allowable level and which prevents further operation of the elevator. AS14

buffer: car. A final emergency device to bring an elevator car to rest by absorbing the energy of motion should the car pass the normal downward limit of travel. J134

buffer: counterweight. A final emergency device to bring a counterweight to rest by absorbing the energy of motion should the counterweight pass the normal downward limit of travel. J134

buffer: energy accumulation type. A buffer where the kinetic energy of motion is stored in the gradual compression of a spring, which provides a progressive retarding force. J135

buffer: energy dissipation type. A buffer where the kinetic energy of motion is dissipated, by converting the energy into heat by the flow of oil through a series of holes, and hence applying a constant force of retardation. J142

buffer: oil. An energy dissipation type of buffer. J142

buffer: spring. An energy accumulation type of buffer. J135

buffer: stroke. The distance that a buffer can be compressed. N15

building population. *See* population: building.

building: commercial. A building in which people work; such as offices, stores, industrial. BE55

building: institutional. A building in which people receive a service; such as hospitals, school, universities, public buildings. BE55

building: residential. Buildings in which people live; such as houses, hotels, flats, hostels. BE55

building: retail. A building from which a product or service is sold. CO

bulkhead. *See* safety bulkhead.

bumper. Device other than a spring or oil buffer capable of absorbing the kinetic energy of motion of a descending car or counterweight, when they have passed a normal limit of travel. AS3

bunching. A traffic pattern, where a number of elevators move around a building together, instead of being evenly separated about the building, often caused by a sudden heavy traffic demand or to an inadequate traffic supervisory system. SS446

burst pressure. *See* rupturing pressure.

busbar. A heavy, rigid metallic conductor usually insulated and used to carry a high current and make a common connection between several circuits. LO7/32

bush. A cylinder sleeve forming a bearing surface for a shaft or pin, usually as a lining. It has two diameters and the cylindrical length is usually greater than the larger diameter. LO8/32

button. *See* pushbutton.

button: car call. *See* pushbutton: car call.

button: door close. *See* pushbutton: door close.

button: door open. *See* pushbutton: door open.

button: landing call. *See* pushbutton: landing call.

button: push. *See* pushbutton.

button: stop. *See* pushbutton: stop.

by-pass floors. Floors, which are by-passed in a building, as a result of a supervisory control action or because the car is fully loaded. SS77

by-pass valve. *See* valve: by-pass.

cab. That part of an elevator car, comprising a self contained enclosure, mounted on an elevator platform, in which passengers or goods are carried. N17

cabin. *See* car.

cable. A wire for carrying electric current. CO

cable end box. The junction box used for the connection of the incoming electrical supply prior to distribution to each switchboard. LO8/32

cable: trailing. *See* cable: travelling.

cable: travelling. A cable made up of electrical conductors, which trails behind the car of an elevator, dumbwaiter or material lift to provide an electrical connection between the car and a fixed outlet in the hoistway or machine room. AS11

cad. *See* computer aided design.

call. A demand for service by a passenger, which is entered into an elevator supervisory control system, by the passenger pressing either a landing or car call pushbutton. AS14

call accepted. The acceptance of a landing or car call by an elevator's supervisory control system. BA

call accepted indicator. An indicator contained within or adjacent to a landing or car call pushbutton, which is illuminated by an elevators supervisory control system when it accepts a call. AS14

call allocation. The action of an elevator supervisory control system, when allocating a landing call to a specific car for service. BE112

call button. *See* call pushbutton.

call back. A service visit, at the request of an elevator, escalator or passenger conveyor operator, made by a maintenance technician, which is not scheduled, and which arises because the equipment has gone out of service owing to a fault condition. N17

call memory. Part of an elevator supervisory control system, where all landing and car calls are stored before being serviced. BA

call pushbutton. A pushbutton situated either in car or on a landing, on which passengers may indicate their travelling intentions. BA

call registration. The action of registering a call. BA

call registration indicator. *See* call accepted indicator.

call: car. A passenger demand registered from within a car requesting that the car stop at a specified landing. N18

call: down. A passenger demand registered on a landing, requesting transportation by an elevator in the down direction. BA

call: hall. *See* call: landing.

call: heavy duty. In some circumstances a landing call is given extra emphasis by the elevator supervisory control system, when either (1) a new landing call is registered within a short predefined time, or (2) several cars have left the floor fully loaded, or (3) too many landing and car calls have been assigned to a single car, thus requiring the supervisory control system to take special priority action. BE106

call: highest reversal. The highest landing that an elevator visits during a trip in the upward direction before reversing its direction of travel. BE88

call: landing. A passenger demand registered on a pushbutton on a landing for transportation to other floors in a building. N63

call: lowest reversal. The lowest landing an elevator visits during a trip in the downward direction before reversing its direction of travel. BA

call: registered. *See* call accepted.

call: up. A passenger demand registered on a landing, requesting transportation by an elevator in the up direction. BA

cam. Piece of machinery used to convert linear motion into circular motion employed in elevator installations to operate (1) hoistway door interlocks (2) hoistway floor selectors (3) car mounted terminal switches (4) hoistway mounted terminal switches. AS14

cam: door. [syn: vane] Device mounted on a car door and used to unlock and drive the landing doors. AS16

cam: retiring. A cam mounted on an elevator car, which remains in a retracted or retired position, whilst the car is moving, until the car is about to stop, when it drops, in order to unlock the landing door interlock. AS21

canopy. The top of an elevator cab, which is supported by the walls and contains the ceiling. AS14

canopy: car. *See* canopy.

cantilevered car frame. *See* frame: cantilevered car.

capacitor. An electrical device made of two flat conductors separated by a thin insulator capable of retaining or storing electrical energy after the charging voltage is disconnected. NE18

capacity: contract. *See* capacity: rated.

capacity: handling (elevator). The total number of passengers that an elevator system can transport in a period of five minutes during the up peak traffic condition with a specified car loading, usually taken as 80% of rated capacity. BE12

capacity: rated. The maximum legal load, which an elevator car is permitted to carry measured in a number of passengers or a specific weight in kg. BOpt9

capacity: theoretical escalator handling. The total number of passengers that an escalator system can transport in theory in the knowledge of factors such as step width, speed, rise, etc. CO

car. The load carrying unit comprising enclosure (cab), car frame, platform and door(s). AS3

car allocation. The action of an elevator supervisory control system, when allocating a specific car to a set of landing calls for service. BE94

car apron. *See* apron: car.

car bounce. Where the ride in the car of an hydraulic elevator is not smooth, but exhibits an irregular motion (bounce) often caused by air entrapped in the system being compressed and expanded as the pressure in the system changes. *See also* stick-slip. J1

car buffer. *See* buffer: car.

car button. *See* pushbutton: car call.

car call. *See* pushbutton: car call.

car call panel. *See* panel: car operating.

car call stop. *See* stop: car.

car canopy. *See* canopy.

car control panel. *See* panel: car operating.

car coming indicator. *See* indicator: car coming.

car counterweight. A counterweight roped directly to the elevator car in a drum drive installation and approximately equal to 70% of the weight of the car. AS14

car despatch. A term used to indicate the type of supervisory control system employed, where cars are despatched from terminal floors in a building at scheduled intervals. BE97

car door. *See* door: car.

car door closer. *See* closer: car door.

car door lock. *See* lock: door.

car door interlock. *See* interlock: car door.

car enclosure. *See* enclosure: car.

car entrance. *See* entrance: car.

car fan. *See* fan: car.

car floor. *See* floor: car.

car frame. *See* frame: car.

car isolation. The isolation of the car platform by means of rubber or other sound absorbing material in order to reduce or absorb the transmission of vibration and noise. N73

car operating panel. *See* panel: car operating.

car panel. *See* panel: car operating.

car platform. *See* platform: car.

car position indicator. *See* indicator: car position.

car preference. A system used on simple traffic controllers, where for a period of time a car call can be registered preferentially before a landing call. Also *see* service: independent.

car push button. *See* pushbutton: car call.

car safety gear. *See* safety gear.

car sling. *See* frame: door.

car stop. *See* stop: car.

car switch. *See* switch: car.

car top. The top of the car enclosure. AS146

car top clearance. *See* clearance: car top.

car top control station. *See* station: car top inspection.

car top inspection station. *See* station: car top inspection.

car travel distance. The distance that the car of an hydraulic elevator travels from the lowest landing to the top landing, excluding overruns or ram travel. J1

car ventilation. *See* ventilation: car.

car: free. A car to which the supervisory control system has not allocated any further calls and is therefore free to be given a new assignment. BE131

car: next. Usually the next car to leave a main floor as defined by the group supervisory control system. BE37/95

car: rear opening. Where the car is furnished with doors at the rear of the car in addition to the normal doors provided at the front. SS192

car: side opening. Where the car is furnished with doors at the side of the car in addition to the normal doors provided at the front. SS48

car: through. A car which is fitted with doors to the front entrance and a further set to the rear of the car. BA

carriage. A carriage usually mounted on rollers located in the lower head which through springs or weights maintains proper tension on the escalator step chain. CO

carriage gap. The smallest gap between a fixed member of the escalator truss and the carriage frame. LO8/32

carriage rollers. The four vertically mounted rollers that support the weight of the tension carriage and permit its longitudinal movement within the escalator truss. LO8/32

carriage shaft. The driven shaft in the tension carriage carrying two sprockets that tension and reverse the direction of the escalator step chains. LO17/32

carriage switch. *See* switch: carriage.

carriage tensioners. Compression springs or weighted levers linked to the carriage to provide the tension on the escalator step chains. LO8/32

carriage track. The tracks that support and give lateral and horizontal restraint to the tension on the escalator step chains. LO8/32

carriage: return. A carriage usually mounted on rollers located in the lower head which though springs or weights maintains proper tension on the escalator step chain. CO

carriage: sliding lower. A carriage usually mounted on rollers located in the lower head which though springs or weights maintains proper tension on the escalator step chain. CO

carriage: tension. The mobile assembly (carriage) in which the running track is mounted to guide the escalator steps around return sprockets mounted on the idler shaft within it comprising two carriage tensioners within the assembly provide the tension on the step chains which is mobile to account for the elongation of the step chains over time. LO28/32

carrying capacity. *See* capacity: rated.

castell key. The unique key that operates the castell lock often provided at the escalator switch. LO p8/32

castell lock. *See* lock: castell.

catenary roller. One of a series of rollers fitted in the roller bow of an escalator. LO9/32

cathode. A negative terminal. NE18

caution signs. Signs provided to draw attention to risks and/or hazards. CO

cavitation. A noise created when the available oil at the pump intake is less than the nominal

pump output, thus creating a vacuum condition and a very loud noise. HH

central ram. A ram and cylinder placed under the car platform in a central location. JJ

centre decking. The decking between escalators. LO9/32

centre opening doors. *See* doors: centre opening.

centreline. A basic reference line used in the erection of elevators and escalators. NE21

centrifugal governor. *See* governor: centrifugal.

chain. Connected flexible series of metal or other links. O309

chain anchors. Devices to allow the step chains to be locked by providing a physical link between the chain and a fixed part of the escalator. LO9/32

chain anchor switch. *See* switch: chain anchor.

chain drive (elevator). Alternative means of suspension to wire ropes for electric and hydraulic elevators. S464/P96

chain drive machine. An indirect drive machine having a chain connecting the driving motor to the drive sheave. N21

chain guide. A solid strip that sits within the step chain link plates to give lateral (side) guidance to the escalator step band. LO9/32

chain lubrication. An application applied to a chain for the purposes of lubrication to prevent premature wear and also to achieve noise reduction. CO

chain roller. The wheel mounted on either side of the escalator step on the chain wheel axle used to support the weight of the step band and passenger loading. LO9/32

chain sheave. *See* sheave: chain.

chain stretch switch. *See* switch: chain stretch.

chain wheel. The wheel mounted on either side of the escalator step on the chain wheel axle used to support the weight of the step band and passenger loading. LO9/32

chain wheel axle. Generally the common axle that links the escalator step frame with the two step chains and is supported at either end by a chain wheel; on some machines separate stub axles are used instead of a common axle. LO9/32

chain wheel track. The chain wheel running and upthrust track. LO9/32

chain: auxiliary drive. A chain driving an auxiliary piece of equipment such as a countershaft, handrail, lubricator, governor, etc especially on an escalator. LO6/32

chain: compensating. A chain used to offset the varying effect of the hoisting ropes, one end of which is attached to the underside of the elevator car and the other to the counterweight or to a fixed point in the hoistway. AS15

chain: drive (escalator). The chain provided to transmit power from the worm reduction unit

to the escalator step band and thus cause rotation. CO

chain: handrail. A chain provided to drive the handrail. CO

chain: ladder. Left and right hand sections of an escalator step chain that are supplied joined at every three pitches by a step axle. LO18/32

chain: step band drive. The chain provided to transmit power from the worm reduction unit to the escalator step band and thus cause rotation. CO

check valve. *See* valve: check.

chevron packing. *See* vee packing seal.

choke line. A restriction or hydraulic resistance deliberately introduced to restrict the flow. JJ

chord members. The longitudinal members of the escalator truss assembly. NE22

cill. *See* sill.

circuit. The path of an electric current. NE22

circuit breaker. A device designed to open a circuit when excessive current flows in that circuit. NE23

circuit protective conductor (CPC). An earthing cable connecting an exposed conductive part of an installation to the main earth terminal. LO9/32

circulation. The process by which persons in a building move around the building in both horizontal and vertical modes. G

cladding. A covering. CO

clearance. The space by which one object avoids contact with another object. G

clearance: bottom car. When the elevator car rests on its fully compressed buffers the bottom car clearance is the clear vertical distance from the pit floor to the lowest structural part, mechanical part, equipment or device installed beneath the car platform, with the exception of guide shoes, guide rollers, safety jaw assemblies, platform aprons and platform guards. AS3

clearance: counterweight top. When the elevator car floor is level with the bottom landing floor the top counterweight clearance is the shortest distance between any part of the counterweight structure and the nearest part of the overhead structure or any other obstruction. AS3

clearance: running. The clearance between fixed and moving or rotating components, e.g. the distance between the elevator car sill and the hoistway entrance sill. AS22

clearance: step to comb. The gap between the tread of an escalator step or pallet and the underside of a comb plate. CO

clearance: step to balustrade. The gap between the edge of a step or pallet and the escalator skirt panel. CO

clearance: step to step. The gap between the escalator steps or pallets. CO

clearance: top car. When the car floor is level with the top terminal landing floor, the top car clearance is the shortest vertical distance between the top of the car crosshead, or car top if no crosshead is provided, and the nearest part of the overhead structure or any other obstruction. AS3

cleat. The tread section teeth or the slats. LO9/32

cleated riser. *See* riser: cleated.

closed pilot valve. *See* valve: closed pilot.

closer: car door. A mechanical device attached to a car door whose function is to ensure the car door automatically closes after use, using the stored energy in a set of weights or a spring. AS4

closer: landing door. A mechanical device attached to a landing door whose function is to ensure the landing door automatically closes after use, using the stored energy in a set of weights or a spring. AS4

code. [syn: standard] A system of rules or regulations. O361

coil. A number of turns of insulated wire on a former, typically used in relays and contactors, solenoids, transformers and chokes. LO9/32

collective control. *See* control: simplex collective.

collective selective control. *See* control: directional collective.

comb. The aluminium sections, or steel plates with teeth that mesh with the escalator step tread as the step passes underneath. LO9/32

comb assembly. The assembly of aluminium comb sections (or steel plate type comb) and treadplate, mounted upon the comb plate. LO9/32

comb light. *See* light: comb.

comb lighting. *See* lighting: comb.

comb plate switch. *See* switch: comb plate.

comb plate. The section of floor plate on which the comb teeth segments are mounted at the upper and lower landings of an escalator where the teeth are mounted on the inner edge while the outer edge butts against the floor plate. NE25

comb release tool. A special tool or screwdriver that is used to release and/or lift the comb or comb sections. LO9/32

comb section. A replaceable section of the comb. LO9/32

comb switch. *See* switch: comb plate.

comb teeth. A series of teeth which ride the grooves of the escalator step tread as the step passes underneath and are designed to be extremely brittle which allows them to break off if a wedging action should occur at their point of contact with the step tread. CO

commercial building. *See* building: commercial.

common sector. *See* sector: common.

compact escalator. *See* escalator: compact.

compatibility. The compatibility characteristics of hydraulic oils such that they can be mixed. JI

compensating chain. *See* chain: compensating.

compensating rope. *See* rope: compensating.

compensating rope sheave. *See* sheave: compensating rope.

competent person. A person with enough theoretical and practical knowledge to be able to detect defects and their seriousness. CO

compound motor. *See* motor: compound.

comprehensive maintenance contract. *See* maintenance: comprehensive.

compression line fitting. A fitting designed to join or terminate solid pipe lines using a special compression ring that cuts into the pipe due to the tapered fitting compressing the ring as it is tightened. JI

computer aided design (CAD). A system where a digital computer carries out the tedious and time consuming aspects of an engineering design. BE152

concentric newel. *See* newel: concentric.

conduit. Part of a closed system, of connecting tubes and junctions forming an enclosure for the protection of cables. Usually of circular cross section. LO10/32

constant flow rate. Where the oil flow from a pump or through a valve in a hydraulic system remains substantially constant, despite any changes in pressure and oil temperature. The acceptable variation should be specified at the time of selecting the components. JI

constant velocity ram. *See* telescopic ram.

contact angle. *See* angle of wrap.

contact: door. An electric switch device operated by a door panel, which is closed when the door panel is in the closed position, allowing the operation of the elevator car. N38

contact: gate. A mechanically operated switch, which prevents the operation of the elevator unless the elevator gate is closed. N58

contactor. An electromagnetic device for making and breaking a power circuit. NE28

contactor: directional. A contactor with its contacts arranged so as to provide power to the main motor in a pre-set direction (i.e. up or down) CO

contactor: down. A contactor with its contacts arranged so as to provide power to the main motor to rotate the escalator step band in a down direction. CO

contactor: main. A contactor provided to supplement a directional contactor in the motor circuit. CO

contactor: up. A contactor with its contacts arranged so as to provide power to the main motor to rotate the escalator step band in an up direction. CO

contaminated oil. Oil that has been over heated; used at excessive pressure for long periods of time; has previously been used and has not been filtered; contains dirt or other foreign matter; or condensation in the tank has introduced water into the oil (which creates a bacteria that causes odours when heated). JI

contract speed (escalator). *See* speed: rated (escalator).

contract speed (elevator). *See* speed: rated (elevator).

contract capacity. *See* capacity: rated.

contract load. *See* capacity: rated.

contraction of oil. Changes in oil temperature which cause a change in the volume of oil, and in the case of an hydraulic elevator can cause the car to move a short distance. JI

control component. An electrical device used to control elements of escalator operation; either by the switching of circuits or the altering of supplies. LO10/32

control logic. The defined sequence and precedence of escalator operations, both manually and automatically initiated for normal, maintenance and fault conditions. LO10/32

control: AC. A form of motion control achieved by the use of an ac motor to drive the hoist machine or escalator step band. N1

control: attendant. Where the direction of travel, door closing and car starting are under the control of an attendant. N6

control: automatic pushbutton. Where the travelling passengers are able to command an elevator car to move from floor to floor without the need of an attendant, as door control and car direction and starting are all automatic. BE86

control: collective. *See* control: simplex collective.

control: DC. A form of motion control achieved by the use of a dc motor to drive the hoist machine or escalator step band. N33

control: directional collective. Where landing calls are registered on a set of up and down landing call push buttons, the landing and car calls being registered in any order but are answered strictly in floor sequence in the direction of travel, taking account of the direction of travel of the registered landing calls. BE88

control: door. The control system which opens and closes the car and landing doors of an elevator installation. BA

control: down collective. *See* control: up-distributive, down-collective.

control: drive. The system which controls the starting, stopping, direction of motion, acceleration, retardation, and speed of the elevator car or escalator. AS4

control: full collective. *See* control: directional collective.

control: group supervisory. A control system which commands a group of interconnected elevator cars with the aim of improving the elevator system performance. BE93

control: group collective. A simple form of group control system, where two (duplex) or three (triplex) cars are interconnected and collectively controlled, but providing a means of allocation of the best placed car to each landing call. BSpt6

control: non-collective. The simplest form of control whereby a car will only answer a landing call if it is available. BSpt6

control: on-call. An elevator supervisory control system where cars are despatched to serve landing calls according to a fixed or tunable algorithm. BE97

control: scheduled. An elevator supervisory control system where cars are despatched to serve landing calls according to a fixed schedule from terminal floors. BE97

control: simplex collective. [syn: non-selective] Where landing calls are registered on a single set of landing call push buttons, and landing and car calls may be registered in any order, but are answered strictly in floor sequence in the direction of travel, passengers being unable to indicate their desired direction of travel. BE87

control: supervisory. An open loop control system which is used to manage a plant or process, such as an elevator traffic control system. G

control: up-distributive, down-collective. Where a single set of landing push buttons indicate a down demand on floors within a building, thus allowing the elevator system to distribute upward going passengers when travelling in the up direction and to collect downward going passengers when travelling in the down direction. BE87

controller. A controlling device in the form of an electrical panel, normally located in the upper head of a compact escalator and consisting of the electrical devices required to assure proper operation of the drive mechanism. CO

controller: programmable. A controlling device which can have its operating rules altered by means of a program. G

conveyor. An endless moving belt for the movement of goods or people. CO

cooler. *See* heat exchanger.

cooling core. A core constructed with metal fins arranged around the pipes carrying the oil, similar in design to a car radiator. JI

cooling switch. *See* switch: cooling.

cooper. A maker of wooden vessels. O421

cord: air. [syn: aircraft cable] A small diameter wire rope frequently used as part of the driving mechanism on door operators, door hangers, gates and selector devices. AS12

corridor. A passage or covered way between two places. O431

countershaft drive chain switch. *See* switch: countershaft drive chain.

countershaft. The intermediate shaft used to transmit power from main drive or idler shaft to the handrail drive. LO10/32

counterweight. A component which is employed to ensure traction between the drive sheave and the suspension ropes and which comprises a set of weights to balance the weight of the car and a proportion of the load in the car often taken as 50% of the rated load. AS15

counterweight buffer. *See* buffer: counterweight.

counterweight filler. A metal component of predetermined size and weight which when stacked with other fillers in the counterweight frame forms the counterweight assembly. AS15

counterweight guard. A screen installed in the pit, and sometimes at the mid point of the hoistway, to prevent persons from encroaching into the counterweight runway space. AS15

counterweight header. A weight component larger than a standard filler, which extends around the counterweight guide-rails and guides the counterweight. AS15

counterweight safety. A mechanical device attached to the counterweight frame designed to stop and hold the counterweight in the event of an overspeed or free fall or the slackening of the suspension ropes. AS10

counterweight: car. A counterweight, which is directly roped to the elevator car on a winding drum installation, and which is approximately 70% of the car weight. AS14

counterweight: guide-rails. Steel T-shaped sections which guide the counterweight in its vertical travel in the hoistway. N31

cover: plates. The cover plate at top and bottom landings of an escalator, which is flush with the building floor and the comb plate and is removable for access to the equipment. NE55

cranked link. A step chain link that can be incorporated to enable the escalator to be installed with an odd number of steps (and odd number of chain links). LO11/32

creep. The small downward movement of a hydraulic elevator owing oil leakages or temperature changes. BA

criss cross arrangement. *See* arrangement: criss cross.

cross beam. *See* crown bar.

crown bar. The upper member of the car frame of an elevator car. AS15

curved track. *See* track: curved.

cushioned stop. *See* stop: cushioned.

cylinder. The outermost lining of a hydraulic jack. AS15

cylinder (displacement type). A single-acting cylinder where the cylinder ram is sealed at the cylinder gland against fluid losses and where the output force is proportional to the ram area. BOpt9

cylinder (piston type). A single-acting or double-acting cylinder, where the piston, which is attached to the cylinder ram, seals against the inside of the bore of the cylinder tube and where the output force is proportional to the piston area in one direction and to the piston area minus the ram area in the other direction. BOpt9

cylinder: double acting. A cylinder in which pressure can be applied at either end, so giving complete hydraulic control. HH

cylinder gland. The seal used to prevent loss of fluid. BOpt9

cylinder head. The part of the cylinder that holds the seal and guiding rings that make contact with the ram as it moves in and out of the cylinder. JJ

cylinder head guide yoke. The guide fitted to intermediate stages of telescopic cylinders to maintain the alignment and prevent the buckling of the ram and cylinder assembly when extended. JJ

cylinder ram. The smooth circular moving part of a hydraulic jack, which is forced out of the cylinder by fluid pressure. BOpt9

cylinder tube. *See* cylinder.

dado. A decorative moulding or facing on the lower part of a cab wall. O305

dashpot. A mechanical device comprising a piston moving in a cylinder against air or oil, used to control or cushion the movement of an arm, lever or rod particularly those used to prevent the slamming of doors. AS16

data-logging. The process of logging (acquiring) and analysing data automatically using a digital computer based equipment. BE

DC control. *See* control: DC.

deck board. The capping member of the balustrade of an escalator, usually considered as that portion of the balustrade extending from the handrail outward to the exterior line of the escalator. NE34

deck. The transverse members of the balustrade with a high deck located immediately below the handrail stand and a low deck located immediately above the skirt panel and having an interior and/or exterior section. CO

deck: inner. A second deck of glass balustrade escalator covering from the glass inward to the inner face of the skirts. CO

deck: outer. The deck of a glass balustrade escalator covering from the glass to the outermost edge of the escalator. CO

decking. The top cover to the balustrade beneath handrail level. LO11/32

decking: balustrade. The cladding affixed to the balustrade. CO

decking cover strip. A strip or moulding joining the balustrade decking of two adjacent escalators. LO11/32

dee track. *See* track: dee.

deflector. A metal plate fitted to each dust tray access. It deflects dust and debris into the dust tray. LO11/32

deflector device. An additional device to minimise the risk of trapping between the escalator steps and the skirting. BS95p5

deflector sheave. *See* sheave: deflector.

demand sector. *See* sector: demand.

demarcation lights. *See* lights: demarcation.

demarcation line. Located near the edge of the step tread, consisting of a machined groove or contrasting material provided to assist passengers in boarding the escalator by designating the step outline as the step band profile unfolds. CO

despatch floor. *See* floor: despatch.

despatch interval time. *See* time: despatch interval.

despatch signal. *See* signal: despatch.

despatcher panel. *See* panel: despatcher.

detector: passenger. An automatic electronic device, which causes door re-opening whenever a passenger is detected in the threshold using photo-electric, electromagnetic, electrostatic or ultrasonic detection methods. AS20

detritus. A flammable accumulation of oil and grease, which can easily accumulate in an escalator truss. CO

device: anti-nuisance. A device which attempts to reduce the effect of mischievous or malicious passengers registering more car calls than there are passengers in the car or attempting to send a car away when no passengers are present in the car. BE138

device: door re-opening. A device which detects the obstruction of automatic power doors and causes them to either re-open or go into another mode of operation such as nudging. AS16

device: hoistway door locking. Means of securing the closed hoistway door and preventing it from being opened from the landing except under specified conditions. AS6

device: levelling. A mechanism, which will move an elevator car, when it is in the levelling zone, at a reduced speed towards a landing and stop it there. BOpt9

device: signalling. An annunciator (light, indicator, bell, buzzer, etc), which provides information to passengers about car direction, car position, car arrival, call acceptance etc. AS10/11

devices: earthquake protection. A device or group of devices which regulate the operation of an elevator or group of elevators during or after an earthquake. AS499

diamond stop. *See* stop diamond.

die cast step. *See* step: die cast.

differential pressure valve. *See* valve: differential pressure.

dip stick. The measuring stick or rod usually fitted to the filler cap, which allows the depth of oil in the tank to be measured. JI

direct coupled pump. *See* pump: direct coupled.

direct drive. *See* drive: direct.

direct drive machine. *See* machine: direct drive.

direct on line start (DOL). Motors that are connected directly to the full voltage without some form of resistance or other current or voltage limiting device in the circuit. JI

direct plunger driving machine. *See* machine: direct plunger driving.

direction arrow. *See* arrow: direction.

direction indicator. *See* indicator: landing direction.

directional contactor. *See* contactor: directional.

directional collective control. *See* control: full collective.

directional limit switch. *See* switch: directional limit.

directional sector. *See* sector: directional.

directional start switch. *See* switch: directional start.

disc brake. *See* brake: disc.

discrete electrical components. Devices such as diodes, capacitors or resistors used as distinct control elements in electrical circuits. LO11/32

displacement piston. *See* displacement ram.

displacement type governor. *See* governor: displacement type.

diversity factor. A factor which may be applied to reduce the sizing of services, for example electric power cables, on the basis of a mathematical probability that not all connected equipment will require serving at the same time. SS179

diverter. *See* pulley: diverting.

dividing screen. Screen installed between the paths of travel of two elevators sharing the same hoistway to enable the safe working on one elevator whilst the other elevator is still operational. BA

door. The movable portions of the car or hoistway entrance, which control the safe access to and from the moving car. AN4

door cam. *See* cam: door.

door close button. *See* button: door close.

door close limit. *See* limit: door close.

door closed time. *See* time: door closed.

door closer: car. *See* closer: car door.

door closing time. *See* time: door closing.

door contact. *See* contact: door.

door control. *See* control: door.

door dwell time. *See* time: door dwell.

door gib. *See* gib: door

door guide. *See* gib: door.

door guide-rails. *See* guide-rails: door.

door hanger. *See* hanger: door.

door hanger sheave. *See* sheave: door hanger.

door hanger track. *See* track: door hanger.

door header. *See* header: door.

door holding time. *See* time: car call dwell and time: landing call dwell.

door interlock. *See* interlock: door.

door interlock zone. *See* zone: door.

door limit switch. *See* switch: door limit.

door linkage. *See* linkage: door.

door lock. *See* lock: door.

door open time. *See* time: door open.

door open button. *See* push button: door open.

door operator. *See* operator: door.

door power operator. *See* operator: door.

door premature opening. *See* door: advance opening.

door re-opening device. *See* device: door re-opening.

door sill (cill). *See* sill: door.

door switch. *See* switch: door.

door track. *See* track: door.

door vane. *See* vane: door.

door zone. *See* zone: door.

door: access. Means of access to equipment areas and other spaces pertaining to an elevator or escalator installation such as machine rooms, overhead machine spaces, etc and with access usually restricted to authorised persons. AS12/NE1

door: advance opening. The initiation of door opening whilst a car is slowing into a floor, under normal operating conditions, usually when the car is in a door zone of plus or minus 200 mm of floor level and such that the car is

substantially level at the floor before passengers can attempt to exit. AS16

door: car. The door, which is part of the passenger carrying enclosure, and serves to protect passengers from contact with the hoistway walls and equipment. BA

door: hoistway. The door sealing access to the hoistway from the landing floors. AS4

door: inspection. Means of access to equipment areas and other spaces pertaining to an escalator installation such as machinery spaces etc and with access usually restricted to authorised persons. CO

door: landing. *See* door: hoistway.

door: multiple panel (leaf). Door(s) comprising two or more panels which are arranged to telescope behind each other as the door(s) opens. P219

door: pre-opening. *See* door: advance opening.

door: side opening. A single or multiple panel, horizontally sliding door. P216

door: single panel (leaf). A horizontally sliding, side opening door comprising a single leaf. P216

door: slide up-down. *See* doors: bi-parting.

door: two speed. An arrangement, for either side or centre opening doors, where one panel slides behind the other panel at twice the speed, in order that both panels arrive at the opening position simultaneously. P216

doors: bi-parting. A vertically sliding door, often found on freight elevators, which consists of two sections, so interconnected that they open simultaneously away from each other. AS4

doors: centre opening. A horizontally sliding door, with two or more panels, so interconnected that they open simultaneously away from each other. AS4

double acting cylinder. *See* double acting rams.

double acting rams. Rams which incorporate a piston head and two cylinder connections one at each end, where connecting the pressure line to one and the exhaust line to the other causes the piston and ram to move in one direction; and reversing the oil connections causes the piston and ram to move in the opposite direction. JI

double acting seal. *See* seal: double acting.

double deck(er) elevator. *See* elevator: double deck(er).

double wrap. *See* wrap: double.

down peak. A down peak traffic condition exists, when the dominant or only traffic flow is in the downward direction, with all or the majority of the passengers leaving the building at the main terminal floor of the building. BE7

down peak interval. *See* interval: down peak.

down peak passenger arrival-rate. *See* arrival-rate: down peak passenger.

down peak traffic. *See* traffic: down peak.

down arrow. *See* arrow: down.

down collective control. *See* control: up-distributive, down-collective.

down contactor. *See* contactor: down.

down stop. *See* stop: down.

drain line. *See* oil drain line.

dress guard. *See* guard: skirt.

drip pan. *See* drip tray.

drip tray. A pan which is welded or bolted to the truss of an escalator along its full length and width. NE42

drive chain. *See* chain: drive.

drive control. *See* control: drive.

drive controller. A separate controller provided on some larger escalators containing electrical and/or electronic components or devices which interpret the outputs from the logic controller and set the drive motors speed and direction. CO

drive machine (elevator). A power unit which provides the means for raising and lowering the car and which comprises: the electric motor or hydraulic power unit; gearing, brake; sheave or drum; couplings and bedplate. J14

drive machine (escalator). The combination of motor and gear reduction unit which forms the drive mechanism for all moving parts on an escalator. NE42

drive sheave. *See* sheave: drive.

drive unit. *See* drive machine.

drive wheels. The sprockets over which the escalator drive chain or chains and step chain(s) pass. CO

drive: direct. A drive where the driving part is directly connected to the driven part, either with or without intermediate gears. AS7

drive: drum. A positive elevator drive system whereby the car and the counterweight are secured to a multi-grooved drum, such that as one set of ropes unwind from the drum the other set of ropes wind on. J71

drive: indirect. A drive system where the driving part is connected to the driven part by means of V-belts, tooth drive belts, or drive chains. AS181

drive: linear. A drive which utilises the electromagnetic propulsion, provided by a linear motor, between a fixed part (often the guides) and a moving part (often the car) with or without a counterweight. BA

driving station. The area of free space within the truss at the top/drive end of the escalator or passenger conveyor for use by maintenance and inspection personnel. BS78p2

dropped step support. The ramps that act on the escalator trailer wheel axle or step frame and

step chain and support the steps through the comb in the event of one or more wheels or their tyres becoming detached. LO12/32

dropped step switch. *See* switch: dropped step.

drum. The cylinder of a drum type driving machine, on which the hoisting ropes wind and unwind, when raising or lowering the elevator car. AS17

drum brake. *See* brake drum.

drum drive. *See* drive: drum.

duck board. An insulated platform/stand for raising operative personnel above floor level, and provide insulation protection to earth. (Used in machine room areas where there is a possibility of moisture or water ingress). LO12/32

dumbwaiter. An elevator used for the vertical transportation of materials only and comprising a car whose dimensions are such as prevent the transportation of passengers, and which moves in guides, often situated beneath a counter or sited at counter top level. AS4/BSpt9

duplex. Two interconnected cars, sharing a common signalling system, controlled under a simple group control system operating under directional collective principles. BE88

dust tray. A metal tray supported under the main drive and tension carriages that catches any small objects and dust that falls from the steps as they return under the escalator. LO13/32

duty range. The designed performance range of an escalator or passenger conveyor. CO

dwelt time. *See* time: door dwelt.

dynamic oil pressure. The oil pressure during the starting and/or running of the system, which (owing to system friction) will always be higher than the static oil pressure. JI

dynamic seal. *See* seal: dynamic.

dynamic sector. *See* sector: dynamic.

earth. The main terminal used to connect the installations earthing and bonding system to the conductive mass of earth normally by a conductor provided as part of the power distribution. LO13/32

earth leakage circuit breaker. A circuit breaker designed to break the supply in the event of a current flowing to earth. LO13/32

earthing. The act of connecting the exposed conductive parts of an installation to earth. LO13/32

earthquake protection devices. *See* devices: earthquake protection.

earthquake sensors. Sensors which can detect the incidence of earthquake ground waves prior to the actual earthquake shock and which are used to operate control devices in order to bring the elevator safely to rest. S391

eccentric ram loading. The loading on the ram, which occurs when the load does not press directly on the centre of the ram, or when the

direction of the load is not in-line with the axes of the ram. JI

electrical drawings. Plans showing electrical circuits. CO

electrical interference. *See* interference: electrical.

electrical noise. *See* noise: electrical.

electro-mechanical brake. *See* brake.

electronic valve. *See* valve: electronic.

elephant ear. The 'ear-shaped' replaceable rubber insert that forms part of the handrail entry guard on some escalators. LO13/32

elevator. [syn: lift] A permanent lifting equipment, serving two or more landing levels, provided with a car or platform for the transportation of passengers and/or freight, running at least partially in rigid guides either vertical or inclined to the vertical by less than 15 degrees. J13

elevator: bed. Elevators for the conveyance of patients being moved on beds or stretchers in hospitals, clinics, nursing homes etc with a platform shape which is narrow and deep, capable of carrying a load of 20 persons or more and equipped with solid doors of a width of at least 1300 mm and capable of excellent levelling accuracy. P52

elevator: direct-plunger hydraulic. A hydraulic elevator having a plunger or cylinder directly attached to the platform or car frame. AS5

elevator: direct acting. *See* elevator: direct-plunger hydraulic.

elevator: double decker. An elevator having two compartments located one above the other. SS337

elevator: electric. A power elevator, which uses an electrical drive machine to provide energy for the movement of the car. AS5

elevator: electro-hydraulic. A direct plunger machine, where liquid is directly pumped under pressure into the cylinder by a pump driven by an electric motor. AS5

elevator: firefighting. An elevator, which may be supplied with additional fire resistant protection, installed in a fire protected zone and designated to have controls that enable it to be used under the direct control of the firefighting services for emergency purposes. BA

elevator: fireman's. An elevator, which may or may not be supplied with additional fire resistant protection, designated to have controls that enable it to be used under the direct control of the firefighting services for emergency purposes. BSpt6

elevator: freight. An elevator primarily used to transport freight and goods, where only the operator and persons necessary to load and unload the freight are permitted to travel. AS5

elevator: gravity. An elevator where gravity is used as the motive force to move the car. AS5

elevator: hand. An elevator where manual energy is used to move the car. AS5

elevator: hydraulic. A power elevator, which uses the energy stored in a liquid under pressure to provide the energy for the movement of the car. AS5

elevator: inclined. An elevator which travels at an inclination to the vertical of 15° or more. BSpt1

elevator: indirect acting. A hydraulic elevator where the plunger or cylinder is indirectly connected to the platform or car frame by ropes or chains. BA

elevator: maintained-pressure hydraulic. A direct plunger elevator where liquid under pressure is available for application to the cylinder at all times. AS5

elevator: multideck. An elevator having two or more compartments located above each other to form a multi-level stack. AS5

elevator: observation. An elevator designed as an architectural feature to give passengers a panoramic view while travelling in a partially enclosed well. BSpt6

elevator: passenger. An elevator primarily used to carry passengers other than the operator (if any). AS5

elevator: passenger/freight. An elevator of such dimensions that only goods and restricted classes of passengers (such as freight handlers, employees) may be carried. AS175

elevator: power. An elevator utilising energy other than gravitational or manual to provide motion for the car. AS5

elevator: roped-hydraulic. A hydraulic elevator where the piston is connected to the car by means or wire ropes. AS5

elevator: service. A passenger elevator used to transport materials, which conforms to the standards for passenger conveyance, but is often specially strengthened to carry freight or goods. SS307

elevator: sidewalk. An elevator of the freight type used to carry materials, except automobiles, between a street level and a level or levels below AS5

elevator: stair. Elevators provided for persons with impaired mobility, which can be permanently or temporarily installed on a stairway, which provide a seat for the person to ride on. SS351

elevator: wheelchair. A platform elevator, which can be fitted to a stairway for the transportation of wheelchairs and which generally can be folded away when not in use. SS350

elongated newel. *See* newel: elongated.

EMC. Electromagnetic compatibility: comprises immunity and emission. BA

emergency brake. *See* brake: emergency.

emergency coils. *See* emergency solenoids. JI

emergency hand pump. *See* pump: emergency hand.

emergency lighting. *See* lighting: emergency.

emergency solenoids. Solenoids provided with two coils in the one housing, with one coil for normal operation and a low voltage coil for emergency operation from a battery in the event of a mains supply failure. JI

emergency stop switch. *See* switch: emergency stop.

enclosure: car. The top and the walls of the car resting on and attached to the car platform. AS5

encoder shaft. A rotary digital encoder, which when rotated by a toothed tape attached to the car can provide a very accurate value for the position of a car in a hoistway, as a binary number. BII15

energy accumulation type buffer. *See* buffer: energy accumulation type.

engineer. A person who is capable of innovation and possesses graduate academic qualifications and subsequent responsible experience in the industry. BA

engineer surveyor. A person who undertakes a periodic thorough examination of equipment. CO

entrance: car. The protective assembly which closes the hoistway enclosure openings normally used for entrance to and exit from the car. AS5

entrance floor. *See* floor: main.

entrapped air. *See* air entrapment.

EPROM. A device of storing computer data in a semi permanent form, erased using an electrical signal. LO13/32

equal lay. *See* lay: equal.

erection working line. The theoretical line parallel to the escalator step nose line between erection working points. LO14/32

erection working point. The theoretical point on the intersection of escalator centre line, finish floor level and erection working line. LO14/32

escalator. A power driven endless moving stairway inclined at between 28° and 35° for the short range upward and downward transportation of passengers. AS5/BS70p5

escalator: compact. An escalator with the drive machine incorporated within the bounds of the truss and typically without separate machine areas. LO10/32

escalator flight time. *See* time: escalator flight time.

escalator: heavy duty public service. A public service escalator with major non wearing components suitable for operating for 40 years in an underground railway environment. LO17/32

escalator: spiral. An escalator that can follow a curved path. BA

escalator: wheelchair. An escalator designed to transport a wheelchair. BA.

escutcheon rubber. The 'ear-shaped' replaceable rubber insert that forms part of the handrail entry guard on some escalators. Also known as the elephants ear. LO13/32

excess load indicator. *See* indicator: excess load.

exhaust flow. The oil being drained back to the tank from cylinders, actuators or other parts of the system usually via a valve. JI

expansion of oil. *See* oil expansion.

expansion chamber. [syn: muffler] A large chamber placed in the pressure line, usually close to the pumping unit, which allows the pulsation waves in the pipeline to expand when entering the chamber and which causes their amplitude and frequency not to revert to the original form on leaving the chamber. JI

express jump. The distance between the main terminal floor of a building and an express zone terminal floor. BA

express lobby. *See* lobby: express.

express zone. *See* zone: high rise.

express zone lobby. *See* floor: express zone terminal.

express zone terminal floor. *See* floor: express zone terminal.

express-run. When a car makes a non stop run from its current floor to a destination floor ignoring any possible stopping floors on the trip. BE17

extended heads. Extensions of the truss proper at either the lower or upper head to reach the building support steel when it is located beyond the standard dimensional requirements of the escalator. CO

extended newel. *See* newel: extended.

exterior panels. Covering on the escalator truss on the exterior side of the balustrading. CO

external pump. *See* pump: external.

fan: car. A means of mechanically ventilating the passenger car enclosure of an elevator, aiding the air movement through the vent openings provided. AS147

fault condition switch. *See* switch: fault condition.

fender casting. The casting that forms a corner piece at the end of the skirting, on some escalators, and to which the handrail entry guard is fitted. LO14/32

filter. A fine mesh panel or tube located in the oil or air flow path to prevent the entry or expelling of foreign or unwanted materials that could damage the system moving parts. HH

filter contamination detection. The detection of the contamination of hydraulic oil by means of a pressure gauge or other method of detecting a pressure increase at the inlet side of the filter. JI

final limit switch. *See* switch: final limit.

finish floor level. The level of the floor adjacent to the escalator landing. LO14/32

fire shutter. An automatic or manual fireproof horizontal rolling steel curtain completely enclosing the escalator wellway in case of fire within the building and to eliminate the stack effect created by the wellways in the event of fire. CO

fire shutter switch. *See* switch: fire shutter.

fireman's elevator. *See* elevator: fireman's.

fireman's lift. *See* elevator: fireman's.

fireman's service. *See* service: fireman's.

fireman's switch. *See* switch: fireman's.

fishplate. A flat steel plate, which is machined on one side, used to connect together, in rigid alignment, two end to end sections of elevator guide-rail or sections of escalator tracking. AS17

fixed flow control. Pumps or valves designed to transfer fluid at a fixed flow either by the design characteristics or pressure and/or temperature compensation. JI

fixed sector. *See* sector: static.

fixture. Term used to denote a variety of signalling and indicating devices, such as landing and car call pushbuttons, position indicators, direction indicators, card access devices etc. BA

fixture: intelligent. A fixture commonly the car operating panel or lobby call registration panel, which has the ability to present information to passengers in an interactive manner and which may be able to process its input-output via a computer communication bus instead of via a multi pair travelling cable. BA

fixture: talking. A fixture which is programmed to provide passengers with information by means of a simulated speech output. BA

flared joint. A system designed to prevent a hydraulic pipe and its fitting from separating under pressure, where the ends of pipes are flared to match the pipe fitting. JI

fleet angle. Angle of deviation at which the rope leaves the centre of the sheave groove, usually less than two degrees. BA

flexible conduit. A pliable conduit which can be bent by hand with a reasonable small force, but without other assistance, and which is intended to flex frequently throughout its life. LO15/32

flexible guide clamp safety. *See* safety: flexible guide clamp.

flexible pressure line. *See* hose, flexible.

flight. A number of escalators, and/or stairs within the same shaft. LO15/32

flight time. *See* time: flight.

float switch. *See* switch: float.

floor. The layer of boards, brick, stone etc, on which people tread; the under surface of the interior of a room. O771

floor plate. A removable steel plate finished with a hard wearing floor material, typically situated above the escalator trusswork, where there is insufficient clearance for floor trays. LO15/32

floor population. *See* population: floor.

floor selector. *See* selector: floor.

floor stopping switch. *See* switch: floor stopping.

floor to floor cycle time. *See* time: cycle.

floor to floor height. *See* interfloor distance.

floor to floor time. *See* time: flight.

floor tray. The removable steel tray infilled with concrete or ribbed aluminium and finished with a hard wearing floor material. LO15/32

floor: bottom terminal. Lowest floor in a building zone from which elevator cars can load and unload passengers. AS7

floor: bypass. Floors at which a landing call has been registered, but which are passed by the elevator car under circumstances when the car is fully loaded (load bypass) or when the car has other higher priority duties to perform (control bypass). SS77/103

floor: car. The under surface of the interior of an elevator car, on which passengers stand. BA

floor: dispatch. Floors in an elevator zone, often the terminal floors, from which cars were dispatched under the control of the scheduling supervisory control system. BE97

floor: entrance. *See* floor: main.

floor: express zone terminal. The lowest floor of a high rise zone in a building which is served by an elevator car after it leaves the main terminal floor. BE92

floor: heavy duty. A floor at which a considerably larger than average number of passengers are demanding service often detected by successive cars leaving the floor fully loaded or the immediate re-registration of a landing call as soon as a car has left a floor. BE133/340

floor: highest. The highest, occupied or otherwise, floor within a building. CO

FLOOR: HIGHEST REVERSAL. The floor at which a car reverses direction, when travelling in an upward direction having completed its last car call, in preparation to serve registered down landing calls. BSpt6

floor: lowest. The lowest, occupied or otherwise, floor within a building. CO

floor: lowest reversal. The floor at which a car reverses direction, when travelling in a downward direction having completed its last car call, in preparation to serve registered up landing calls, particularly during an interfloor traffic condition. BA

floor: lowest terminal. *See* floor: bottom terminal.

floor: main. The main or principal floor of a building. BA

floor: main terminal. *See* floor: main.

floor: parking. A floor at which an elevator car is parked when it has completed serving its car calls and the supervisory control system does not reallocate it to serve further landing calls. BE96

floor: terminal. The highest and lowest floors at the extremities of travel of an elevator car within a building zone. AS7

floor: top terminal. Highest floor in a building zone from which elevator cars can load and unload passengers. AS7

floor: upper terminal. *See* floor: top terminal.

flow fuse. *See* pipe rupture valve.

flow restriction valve. *See* valve: pipe rupture.

flow divider. Where the oil line is divided into two or more lines either through branching pipe fittings or a manifold. JI

fluid level switch. *See* switch: float.

flyball governor. *See* governor: flyball.

flywheel. A rotating mass usually attached to the electric motor shaft, sized to provide inertia in the system sufficient to prevent a sudden stop of the low inertia motor rotor, if the power is removed from the motor when running full speed. JI

flywheel (1). A disc located on the motor shaft of an elevator and normally used for hand winding. CO

flywheel (2). A disc located on the motor shaft of an escalator. CO

footlight. *See* light: foot.

foundation. The reinforced concrete base on which the escalator truss supports are mounted. LO15/32

four way traffic. *See* traffic: four way.

frame: cantilevered car. The type of frame that is only guided or supported on one side, with the cabin support beams cantilevered out from the uprights. *See also* rucksack elevators. JI

frame: car. [syn: sling] A supporting frame consisting of stiles, cross beam, safety plank and platform to which the guide shoes, car safety and hoisting ropes or hydraulic plunger or cylinder is attached. AS3

frame-size. Commonly used to indicate the size of an electrical drive motor. BA

free car. *See* car: free.

freight elevator. *See* elevator: freight.

front. The front (of an elevator car) is the side in which the entrance is situated or in the case

of multiple entrances the side containing the entrance nearest to the car operating panel. N57

frothing (of oil). The condition of hydraulic oil that has air entrapped in it (aeration), due to the bad design of the components and their piping often where air bleeding is inadequate or air bleeding systems are not installed, which seriously effects system performance. JI

full collective control. *See* control: directional collective.

full load current. Maximum continuous operating current. LO15/32

full wave rectifier. A rectifier that allows current to pass in one direction through the load during the full cycle of ac. NE57

fuse. A safety device that opens the electrical feed line to a circuit of more than the designated amount of current should flow through it. NE57

gate. *See* door.

gate closer. *See* closer: car door.

gate contact. *See* contact: gate.

gate operator. *See* operator: door.

gate power operator. *See* operator: door.

gate pump. *See* pump: gear.

gear. Wheels working one upon another, by means of teeth (or otherwise) for transmitting or changing motion and power. O838

gear: helical. Gear wheels running on parallel axes with the teeth twisted obliquely to the gear wheel axes. BA

gear: safety. A mechanical device attached to the car frame or to the counterweight designed to stop and hold the elevator car in the event of free fall or of a predetermined overspeed or rope slackening. BOpt9

gear: worm. A gear, used to connect non-parallel, non-intersecting shafts, with the teeth of the intersecting wheels cut on an angle. BA

gearbox. Wheels working one upon another, by means of teeth (or otherwise) for transmitting or changing motion, power and/or speed (often called a worm reduction unit). CO

geared machine. *See* machine: geared traction drive.

geared traction machine. *See* machine: geared traction drive.

gearless traction machine. *See* machine: gearless traction drive.

generator. An electromechanical device which converts mechanical energy in the form of motion into electrical energy strictly as dc power. BA

gib: door. A door component fixed to the bottom edge of a sliding door panel which runs in a machined groove in the sill to guide and correctly hold the door panel in position. AS18

gib: guide shoes. A liner for car or counterweight guide shoes. AS18

gland. A mechanical component which is used to hold the sealing material, that prevents oil leakage between the ram and cylinder, but still allows the ram to move freely into or out of the cylinder. JI

gland packing. The sealing material that forms a seal between a fixed and moving part, i.e. the seal between the cylinder and ram. JI

gland seal. *See* gland packing.

gong. *See* hall lantern and gong.

goods lift. *See*: elevator: freight.

governor drive chain switch. *See* switch: governor drive chain.

governor rope. *See* rope: governor.

governor switch. *See* switch: governor.

governor. Strictly a mechanical device which is a closed loop, error activated means of automatically controlling the speed of a machine, but in the elevator context it is used to detect an overspeed situation. BA

governor: bail type. Horizontal shaft type governor. AS165

governor: centrifugal. A mechanical device which utilises the effects of centrifugal forces operating on weights rotating in a horizontal or vertical plane to provide a movement which can in turn be used to operate a control device. BA

governor: displacement type. Horizontal shaft centrifugal type governor, which uses the movement of weights mounted on the governor sheave to operate the rope gripping device. AS165

governor: flyball. Vertical shaft centrifugal type governor, which utilises the movement of a pair of flyballs, driven by the vertical shaft, to lift a collar or sleeve, which in turn operates the rope gripping device. AS165

governor: horizontal shaft. Governor where the activating shaft rotates in the horizontal plane. BA

governor: overspeed. A governor used to detect the occurrence of a predetermined speed. BA

governor: pull through. Governors of any type where the rope is gripped by spring loaded jaws and can 'pull through' rather than being solidly locked to the rope gripping jaws thus preventing damage to the rope. AS165

governor: vertical shaft. Governor where the activating shaft rotates in the vertical plane. BA

groove. A long narrow channel machined into a surface. BA

groove: 'U'-profile. A groove cut into a drive sheave, which is semi circular in shape, and of a radius which is approximately equal to the diameter of the suspension rope. P66/7

groove: undercut. A groove cut into a drive sheave, which is a modified 'V'-groove having the lower sides cut in the shape of a 'U'. N152

groove: 'V'-cut. A groove cut into a drive sheave in the shape of a 'V'. N155

group supervisory control. *See* control: group supervisory.

group supervisory control algorithm. *See* algorithm: group supervisory control.

group. A group of cars is a number of cars placed physically together, using a common signalling system and under the control of a supervisory control system. BE89

guard. A device placed over or enclosing an item where access is to be prevented for reasons of safety or security. CO

guard: counterweight. Unperforated metal guards installed, whenever necessary, in the pit, on all open sides of a counterweight runway AS49

guard: dress. *See* guard: skirt.

guard: handrail. A guard usually made of brush or rubber, that fits over the outside of the handrail where it enters or leaves the balustrade and designed to keep a person's fingers out of the handrail opening. CO

guard: intersection. A triangular shaped piece, usually plastic, located at the point where the escalator decking intersects the horizontal underside portion of the ceiling in the wellway, in order to prevent injury to passengers if they are looking over the side of the escalator and a part of their body should enter this intersecting angle. CO

guard: sheave. A protective guard around a rope carrying sheave. N128

guard: sight. A vertical strip of material, which is mounted adjacent to the leading edge of a side sliding landing door and used to block out any view of the hoistway space, whenever the elevator doors are in the open position. N130

guard: sill. [syn: toe guard] A smooth often bevelled apron, extending downwards from the sill of the landing or car entrance, with the intention of removing shear hazards to passengers from structural members projecting into the hoistway. BS/ENpt1

guard: skirt. A continuous rubber strip attached to the escalator skirt panel to deflect feet and long clothing away from the edge of a step. CO

guard: toe. *See* guard: sill.

guard: wedge. A piece of triangular shaped material located at the point where the decking on an escalator intersects the underside of a wellway ceiling. NE158

guide bracket. *See* bracket: guide-rail.

guide: door. *See* gib: door.

guides. *See* guide-rail.

guides: handrail. Polished metal guides on which the handrail runs throughout its entire travel. CO

guide-rail. A set of vertical machined surfaces installed in the hoistway to guide the travel of an elevator car or counterweight. AS18

guide-rail: car. Guide-rails used to direct the travel of an elevator car in a hoistway. AS18

guide-rail: counterweight. Guide-rails used to direct the travel of a counterweight in a hoistway. AS18

guide-rail: door. Vertical tracks used to guide the travel of bi-parting freight doors. N38

guide-shoes. Devices used to guide the movement of doors, cars and counterweights along their associated guide-rails. N61

guide-shoes: door. Guiding devices mounted on both horizontal and vertically moving doors to guide their travel. N62

guide-shoes: slipper. Guide-shoes used to guide an elevator car or counterweight, which are 'U' shaped so that the gibs surround and bear onto the machined surfaces of the tongue part section of the guide-rails. AS132

guide-shoes: roller. Guide-shoes used to guide an elevator car or counterweight, which are constructed of a set of rollers (three or six) which run on the machined surfaces of the guide-rails. AS131

half track. *See* track: half.

halfway box. *See* box halfway.

HALL. [syn: floor, e.g. floor call; landing, e.g. landing push-button; corridor, e.g. corridor call.]

hall call. *See* call: landing.

hall direction indicator. *See* indicator: landing direction.

hall lantern and gong. Unit providing a visual and acoustic indication of the availability of an elevator car to accept passengers for a specific direction of travel, which is mounted adjacent to each elevator. BA

hall push button. *See* push button: landing.

hall stop. *See* stop: landing call.

hallway. The lobby or entrance passage to a building and other floors a corridor or passage. O917

hand lowering. The action of lowering an hydraulic elevator in the event of an emergency. BA

hand powered lift. *See* lift: hand powered.

hand pump. *See* pump: hand.

hand pumping. The action of raising an hydraulic elevator in the event of an emergency. BA

hand rope. *See* rope: hand.

handling capacity. *See* capacity: handling (elevator).

handrail. The moving handhold provided for escalator passengers which moves over the top of the balustrade and newel. NE63

handrail brush. A brush provided at the newel end to cover the internal components of the newel entry switch. CO

handrail drive. The mechanism including sprockets, chains and wheels which drives and directs the travel of an escalator handrail. NE63

handrail entry switch. *See* switch: handrail entry.

handrail guard. *See* guard: handrail.

handrail guides. *See* guides: handrail.

handrail spacers. Inserts of contrasting colour to indicate direction and speed of the handrail. CO

handrail speed detector. A device that measures the handrail speed and in the event of underspeed or overspeed opens a switch in the safety circuit. LO16/32

handrail support moulding. The extruded section of the balustrading that connects the vertical interior panelling to the horizontal decking and supports the handrail track. LO16/32

handrail tensioning device. The assembly of components, and their adjustable fixing, used to tension handrails. LO16/32

handrail track. *See* track: handrail.

handwinding. The action of using a manual device to permit the emergency movement of an electric traction elevator or the manual movement of an escalator. BOpt9

handwinding device. The mechanical means provided to manually rotate the escalator step band or to wind an elevator up or down. CO

handwinding instructions. A notice showing instructions how to operate the handwinding equipment in the event of an elevator or escalator failure. LO17/32

handwinding ratchet. A ratchet that is fitted to the end of the drive motor shaft and turned by hand to move the escalator. LO17/32

hanger: door. An assembly, which is fastened to the top of a door panel, supporting and permitting the sliding movement of the door panel(s), comprising the hanger sheave and hanger track. AS18

hanger sheave. *See* sheave: door hanger.

hanger track. *See* track: door hanger.

hatch. *See* hatchway.

hatchway. An obsolete term used to describe the elevator hoistway, derived from the use of a framed and covered opening in a floor; a miniature access door. AS19

hauling rope. *See* rope: hauling.

head. The area under the landing plates at either end of an escalator. NE65

head jamb. *See* jamb: head.

head room. The dimension from the escalator step tread to the underside of the wellway opening immediately above. CO

header: door. A horizontal structural member located on the hoistway side of an elevator entrance used to support the door hanger. AS16

headroom. Clear working space provided above machinery. N65

heat dissipation. Is the ability of the tank housing and cylinder to lower the temperature by natural or artificial means. JI

heat exchanger. Device that causes hot oil to be cooled to the desirable working temperature by circulating the oil through pipes fitted with cooling fins, or through a form of radiator core, sometimes assisted by a fan to increase the efficiency of the cooling system. JI

heat transfer. The transfer of heat between the equipment and the air, to ensure good hydraulic performance, where in some cases additional items such as heat exchangers and cooling systems may be required. JI

heavy duty call. *See* call: heavy duty.

heavy duty floor. *See* floor: heavy duty.

heavy duty public service escalator. *See* escalator: heavy duty public service.

helical gear. *See* gear: helical.

helper. In USA the lowest classification of an employee working in an elevator company. N65

high call reversal. *See* call: highest reversal.

high chord truss. *See* truss: high chord.

high rise zone. *See* zone: high rise.

highest floor. *See* floor: highest.

highest reversal floor. *See* floor: highest reversal.

hoist machine. *See* machine.

hoistway. A vertical opening through a building or structure in which elevators, material lifts, dumbwaiters etc travel extending from the pit at the bottom to the underside of the roof or machinery space above. AS6

hoistway door. *See* door: hoistway.

hoistway door combination mechanical lock and electrical contact. A device with two functions where (a) the operation of the driving machine is prevented unless the hoistway doors are in the closed position and (b) the hoistway doors are locked in the closed position to prevent them being opened from the landing side unless the car is in the landing zone. AS6

hoistway door (electrical) contact. *See* contact: door.

hoistway door interlock. *See* interlock: hoistway door.

hoistway door mechanical lock. *See* lock: door.

holding time. *See* time: door dwell.

hollow rams. Rams manufactured from tubes compared with solid round material. JI

honed finish. A machining system that improves the surface finish of rams or the bores of cylinders. JI

hood. The solid protective screen projecting upwards from the roof of a paternoster car, which continues with the apron of the paternoster car above, to form a continuous cover over the space between cars. BOpt9

horizontal shaft governor. *See* governor: horizontal shaft.

hose, flexible. Hoses used to transmit fluid between parts, which move relatively to each other, sometimes made of synthetic rubber reinforced with wire or canvas to give strength and provided with union-type end fittings, often fitted by the hose manufacturers. HH

hydraulic lift. *See* elevator: hydraulic.

hydraulic lift: direct acting. *See* machine: direct plunger driving.

hydraulic lift: suspended type. *See* machine: roped hydraulic drive.

hydraulic power unit. Part of the elevator drive system and comprising pump, pump motor, control valves and fluid storage tank. BOpt9

hydraulic synchronised rams. *See* telescopic rams.

idler shaft. The driven shaft in the tension carriage carrying two sprockets that tension and reverse the direction of the escalator step chains. LO17/32

idler sheave. *See* sheave: idler.

idler sprocket. A sprocket used to change the direction of chain movement. LO17/32

inch. To move an escalator at maintenance speed. LO17/32

inch directional contactors. The up and down interlocking contactors that connect the escalator power supply to the drive motor for maintenance, permit inching speed and fix the mode of rotation. LO17/32

inch speed. The escalator speed used for inspection and maintenance purposes, typically a quarter of rated speed. LO17/32

inching (1). A manual operation, usually carried out on freight elevators, where a car switch or a push button is used to cause the car platform to move in small increments until it is level with the landing sill. AS19

inching (2). A manual operation carried out under maintenance situations, where the escalator step band is rotated in small increments. CO

inclination. The angle to which the escalator is manufactured. CO

incline. The sloped area between the upper and the lower landings/machine rooms. LO17/32

inclined section. The portion of an escalator which is inclined, in general trigonometric terms could be referred to as the hypotenuse. CO

inclined transportation. Means of moving people or goods which is not on a level plane. CO

independent service. *See* service: independent.

index: performance. Term used in control engineering where a variable is selected and its performance is maximised. BA

indicator: call accepted. An indicator adjacent to or contained within a landing call or car call push button, which is illuminated when the elevator supervisory control system has accepted the call into its memory. BA

indicator: call registration. *See* indicator: call accepted.

indicator: car coming. An indicator adjacent to or contained within a landing call push button, fitted on installations which are controlled by very simple supervisory control systems, and which is illuminated whenever the elevator car is coming to the calling landing. BA

indicator: car position. An indicator adjacent to or above a car or landing entrance, which is illuminated to indicate the position of the elevator car in the hoistway. BA

indicator: direction. *See* indicator: landing direction.

indicator: direction landing. An indicator adjacent to or above a car entrance, which is illuminated whenever that car is to stop at that landing and which indicates the intended direction of travel for the car. BA

indicator: excess load. An indicator located on the car operating panel, which is illuminated whenever the passenger load in the car exceeds the rated value. BA

indicator: lift in use. An indicator adjacent to or contained within a landing call push button, which is illuminated whenever the elevator is busy serving a demand, usually fitted on installations controlled by a very simple supervisory control system. BA

indicator: lift coming. *See* indicator: car coming.

indicator: next car. An indicator adjacent to a car entrance or installed inside an elevator car, which illuminates to indicate the next car, in a sequence, to leave a specific floor. BA

indicator: overload. An indicator, usually installed inside an elevator car, which indicates by an acoustic alarm together with an illuminated sign, that the passenger load in the car is in excess of the rated value. BA

indicator: position. *See* indicator: car position.

indirect coupled pumps. *See* pumps: indirect coupled.

indirect drive. *See* drive: indirect.

indirect drive machine. *See* machine: indirect drive.

inductor. An electrical device made of a coil of wire on a former, which is capable of storing energy and which tends to oppose the current flowing in it. BA

in-line filter. A filter assembly mounted in the main piping system to prevent foreign material passing into the valve or cylinder usually of the high pressure type. JI

inner deck. The second deck of a glass balustrade escalator; covering from the glass inward to the inner face of the skirts. NE71

inspection door. *See* door: access.

inspection outlet. A hard wired socket provided in various locations of an elevator or an escalator for the connection of the inspection unit. CO

inspection unit. A portable plug-in unit used to control the inching of an escalator during inspection and maintenance. LO17/32

institutional building. *See* building: institutional.

insulation resistance. The electrical resistance between a conductor and earth. CO

integrated rupture valve. *See* valve: integrated rupture.

intensive duty traffic. *See* traffic: intensive duty.

interface: mechanical. Resistance to motion provided by friction and/or mechanical means or devices. CO

interference: electrical. Unwanted signals transmitted via the electrical supplies or as electromagnetic radiation, which can interact with properly generated signal sequences to produce incorrect or hazardous operation of equipment. BA

interfloor distance. The vertical distance between two adjacent landing floors. BA

interfloor flight time. *See* time: flight.

interfloor jump time. *See* time: flight.

interfloor passenger arrival-rate. *See* arrival-rate: interfloor passenger.

interfloor traffic. *See* traffic: (balanced) interfloor.

interior panel. The major panel portion of the balustrade located immediately above the skirt panel, canted outwards and extending from the skirt panel to the deck boards. CO

interlock: car door. A device which prevents the operation of the driving machine unless the hoistway doors are closed. BA(eitb)

interlock: door. A switch provided to mechanically and/or electrically lock a door, generally fitted to a car or hoistway door, usually a mechanically operated electrical contact, which prevents the operation of the driving machine unless certain conditions are satisfied. BA

interlock: hoistway door. A device having two functions, where the operation of the driving machine is prevented unless the hoistway doors are in the closed position and the hoistway doors are locked in the closed position and prevented from being opened unless the elevator car is within the landing zone. AS6

interlock: landing door. *See* interlock: hoistway door.

intermediate support. Often required on escalators with extreme rises to give additional support at a point near the centre of the longitudinal length of the truss thus reducing the loading on the building members at each end of the escalator. CO

internal pump. *See* pump: internal.

internal ram pressure. A pressure created when hollow rams are used and the oil either flows through the ram as in the case of telescopic rams or is allowed to fill the inside of the ram of the displacement type. JI

intersection guard. *See* guard: intersection.

interval. The average time between successive car arrivals at the main terminal (or other defined) floor with no specified level of car loading or traffic condition. BE14

interval: down peak. The average time between successive car arrivals at the main terminal (or other defined) floor with no specified level of car loading during a down peak traffic condition. BE213

interval: loading time. *See* time: passenger loading.

interval: loading. The minimum time an elevator car is held at the main terminal (or other defined) floor, under the up peak traffic condition, after the first passenger has registered a call, before it is allowed to depart. BE163

interval: up peak. The average time between successive car arrivals at the main (or other defined) floor with cars assumed to be loaded to 80 percent of rated capacity during the up peak traffic condition. BE15

interval: waiting. A term sometimes used to designate the up peak interval and at other times to designate the time a passenger waits for service. BE14

isolation: car. Means of isolating the passenger cabin from vibration and sound borne noise. BA(fem)

isolator. A manually operated mechanical switch used to open or close electrical circuits under no load conditions. LO17/32

jack. The plunger and cylinder of a hydraulic elevator. AS19

jamb. The two vertical side posts of an elevator entrance, strike jamb and return jamb, plus the 'lintel' or head jamb. AS19

jamb: head. The horizontal member of the three members constituting an elevator entrance, which connects to the side vertical members. AS19

jamb: return. A vertical member of the three members constituting an elevator entrance, behind which the sliding portion of the door passes, whenever it opens and closes. AS21

jamb: slide. *See* return jamb.

jamb: strike. A vertical member of the three members constituting an elevator entrance, against which a side sliding door closes. AS23

jaws. Parts of overspeed safety gear, which grip the governor rope (in the case of an overspeed governor) and grip the machined surfaces of the guide-rails (in the case of car or counterweight safeties). N75

jewel. A coloured or translucent, lens or protective cover, which is placed in front of a signal indicator. BA

joint moulding. Metal extrusion used to cover and support the joint between two panels. LO17/32

jointed ram. *See* ram joint.

journey time. *See* time: passenger journey.

jump time. *See* time: flight.

junction box. An enclosure for the protection of electrical terminals and conductors. LO17/32

key switch. *See* switch: key.

kick(er) plate. *See* plate: kicker.

kinked link detector. The switch that detects kinked escalator step chain links and provides either alarm or protection. LO18/32

ladder chain. *See* chain: ladder.

laminar flow. The flow of fluids, where the original stratification of the fluid is not disturbed and which occurs below certain critical velocities, usually where the Reynolds number is less than 1500. *See also* Reynolds number. HH

landing. A portion of floor or corridor adjacent to elevator car entrances or escalator terminal end, where passengers may board or exit. BA

landing apron. *See* apron: landing.

landing call. *See* call: landing.

landing door. *See* door: hoistway.

landing door closer. *See* closer: landing door.

landing door combination mechanical lock and electrical contact. *See* contact: landing door combination mechanical and electrical.

landing door electrical contact. *See* contact: door.

landing door interlock. *See* interlock: hoistway door.

landing door locking device. *See* device: hoistway door locking.

landing door mechanical lock. *See* lock: door.

landing lantern and gong. *See* hall lantern and gong.

landing plates. *See* floor plate.

landing push button. *See* push button: landing call.

landing stop. *See* stop: landing call.

landing zone. *See* zone: door.

landing: bottom terminal. *See* floor: bottom terminal.

landing: direction indicator. *See* indicator: landing direction.

landing: terminal. *See* floor: terminal.

landing: top terminal. *See* floor: top terminal.

Lang's lay. *See* lay: Lang's.

lay. The twisting of yarn (wires) to form a strand or the twisting of strands to form a rope. O1187

lay: equal. The wires in the strand are so spun that they all have an equal lay length. J21

lay: Lang's. The direction of the lay of the wires in the strand is the same as the direction of the lay of the strands in the rope. J21

lay: left. The strands of a rope are spun in an anticlockwise direction. J22

lay: ordinary. The direction of the lay of the wires in the strand is opposite to the direction of the lay of the strands in the rope. J21

lay: regular. *See* lay: ordinary.

lay: right. The strands of a rope are spun in a clockwise direction. J22

lay: rope. *See* lay.

leakage. The amount of fluid lost out of a system due to faulty joints or seals designed to contain the fluid under specific pressures and temperatures. JI

levelling. An operation which improves the accuracy of stopping at a landing, and which ensures the car platform is level with floor. BS/ENpt1

levelling device. *See* device: levelling.

levelling zone. *See* zone: levelling.

lift. [syn: elevator.] *See* elevator.

lift car. *See* car.

lift coming indicator. *See* indicator: car coming.

lift in use indicator. *See* indicator: lift in use.

lift machine: drum machine. *See* machine: winding drum.

lift machine: geared machine. *See* machine: geared traction drive.

lift machine: gearless machine. *See* machine: gearless traction drive.

lift management. The management of elevator systems to provide in-service indication, equipment diagnosis, traffic monitoring and supervisory controller optimisation. BE361

lift well. *See* well.

lift: bed. *See* elevator: bed.

lift: firemans. *See* elevator: fireman's.

lift: goods. *See* elevator: freight.

lift: hand powered. *See* elevator: hand.

lift: hydraulic. *See* elevator: hydraulic.

lift: passenger. *See* elevator: passenger.

lift: passenger/goods. *See* elevator: passenger/freight.

lift: service. *See* elevator: service.

lift: wheelchair. *See* elevator: wheelchair.

lifting lug. A point provided from which to lift or raise the escalator, normally only used during installation. CO

lifting beam. A iron or steel beam that is suitable for attaching lifting tackle and that has been certified for a safe working load (SWL). LO18/32

light duty traffic. *See* traffic: light duty.

light emitting diode. A device consisting of a semiconductor junction enclosed in a plastic case, which emits light when an electric current is passed through it, in one direction only. LO18/32

light: comb. Small flush type light panels located in the skirt panels on both sides of the unit at both upper and lower head and immediately adjacent to the comb teeth. These lights illuminate the comb and step tread to assist in boarding and alighting the escalator. CO

light: foot. Small flush type light panels located in the skirt panels on both sides of the unit at both upper and lower head and immediately adjacent to the comb teeth, which illuminate the comb and step tread to assist in boarding and alighting the escalator. CO

lighting: balustrade. A lighted panel running the length of the balustrade, newel to newel, located parallel to immediately above the skirt panel, or full height plastic panels with lighting systems located behind them. NE9

lighting: comb. Lighting provided at comb level at a terminal end of an escalator or passenger conveyor. CO

lighting: emergency. Lighting provided in an elevator car in the event the car becomes stationary between floors and supplied from a standby generator or emergency batteries. S145

lighting: step demarcation. The illumination provided by multiple light fixtures located under the steps at the lower and upper landing of an escalator or at the entrance and exit of a

moving walk, which provide demarcation between the step treads as the light shines up through the steps. CO

lighting: under step. The illumination provided by multiple light fixtures located under the steps at the lower and upper landing of an escalator or at the entrance and exit of a moving walk which provide demarcation between the step treads as the light shines up through the steps. CO

lights: demarcation. Green fluorescent lamps mounted under the escalator steps in front of the comb teeth at both landings, which are visible between the leading edge of one step and the riser of the adjacent step. CO

limit switch. *See* switch: limit.

limit: door close. A contact mounted on the door operator, which is actuated when the doors are fully closed and reduces or removes the power from the door operator. AS16

limit: door open. A contact mounted on the door operator, which is actuated when the doors are fully opened and reduces or removes the power from the door operator. AS16

line: pilot. A line for fluid actuating a control. HH

linear drive. *See* drive: linear.

liner: borehole. A rigid capped tube inserted into the borehole of a hydraulic elevator to prevent its collapse or the ingress of water. BOpt9

liner: guide shoe. The replaceable part of a sliding guide shoe, sometimes called a gib, which slides against the guide-rails and steadies the car in its travel. AS18

liner: hydraulic. An insert placed inside the original cylinder of a hydraulic jack to stop leaks. N82

lining: brake. The lining of the brake shoes of an elevator made of material possessing a high coefficient of friction. J87

linkage: door. Connecting links controlling the motion of the doors and associated with the door operator or the door closer. AS16

lintel. The horizontal member of an entrance frame used to support the load above the entrance. O1219

load. The weight of passengers inside an elevator car. BA

load chord truss. A truss design where most of the supporting steel is located below the escalator step line. CO

load relieving ramp. A ramp with low friction insert that acts on the step chains to reduce the load on the chain wheels as they move round the upper curves of the escalator. LO18/32

load weighing. Process of determining the number of passengers in an elevator car by weighing the load of the car and passengers. BE277

load: average. The weight of passengers carried in an elevator car averaged over the number of trips made in a five minute period. BE14

load: brake. The load which the brake of the escalator must be designed to stop and hold. CO

load: contract. *See* load: rated.

load: percentage. The weight of passengers carried in an elevator car expressed as a percentage of the rated capacity. BA

load: rated. The weight of passengers which the elevator car is certified to carry. BE14

loading interval. *See* interval: loading.

loading supports. Points upon which the load of an escalator or passenger conveyor are imposed, normally at or close to the terminal ends of the unit. CO

loading time. *See* time: passenger loading.

lobby. [syn: main terminal (floor), foyer, ground (UK), first (USA).] An entrance or corridor used as a waiting place. O1228

lobby panel. *See* panel: despatcher.

lobby: express. *See* floor: express zone terminal.

lobby: sky. A terminal floor at the highest floor served by a low zone group of elevators, where passengers may wait for service by a high rise group of elevators. S331

local zone. *See* zone: local.

lock: bar. A form of door lock used on manually operated doors. AS13

lock: car door. *See* lock: door.

lock: castell. A mechanical interlock that ensures that when the key is removed the circuit breaker and isolator cannot be closed. LO8/32

lock: door. A mechanical lock of any type which is used to prevent the opening of a car or hoistway door, unless the car is in the door zone. BOpt9

lock: hoistway door. *See* lock: door.

loom: wiring. A group of wires cut to pre determined lengths and running parallel to each other. CO

low oil level protection. Generally an electrical float switch used to signal a low level of oil in the hydraulic reservoir. J1

low pressure switch. *See* switch: low pressure.

low step switch. *See* switch: low step.

lower head. The horizontal portion of the truss at the lower end of the escalator. CO

lower landing. The area at the bottom end of an escalator or passenger conveyor. CO

low(est) call reversal. *See* call: low(est) reversal.

lowest floor. The bottom floor of a building. CO

lowest reversal floor. *See* floor: lowest reversal.

lubrication. A fluid or grease applied to moving components for the purpose of noise reduction, friction reduction and to reduce operating temperatures. CO

lubrication float switch. *See* switch: lubrication float.

lubricator: automatic. A device to supply lubricant through non-corrosive seamless metallic feed pipes to various parts of an escalator or passenger conveyor. It is normally located in a readily accessible position in the upper tank or machine room. LO5/32

lubricators. Applicators located to assure proper lubrication by depositing oil on the various moving mechanisms located within the escalator. CO

M-G set. *See* motor generator set.

machine. A device for doing work. CO

machine room. A room or space in which the machine(s) and associated equipment are located. BS/ENpt1

machine room stop. A manually operated switch used to stop an escalator from the machine room area. CO

machine: basement drive. Where the elevator drive machine is located at the bottom of the elevator hoistway. BA

machine: belt drive. An indirect drive machine using a belt as the means of connection. AS8

machine: chain drive. An indirect drive machine using a chain as the means of connection. AS8

machine: direct drive. An electric driving machine where the motor is directly connected mechanically in elevators to the driving sheave, drum or shaft and in escalators to the step band, without intermediate mechanical gearing. AS7

machine: direct plunger driving. A hydraulic driving machine, where the cylinder is directly connected to the car. AS8

machine: driving. The power unit which provides the energy necessary to rotate the escalator step band or to raise and lower an elevator, material lift or dumbwaiter comprising some or all of: an electric motor or hydraulic motor; mechanical gearing; brake; sheave, drum or chain sprockets; couplings, shafts, journals and bearings; machine frame. J14

machine: drum. *See* machine: winding drum.

machine: electric drive. A driving machine where the energy is supplied by an electric motor. AS7

machine: geared. A machine utilising a gear for energy transmission. CO

machine: geared traction drive. A traction drive machine utilising a gear for energy transmission. AS8

machine: gearless traction drive. A traction drive machine with no intermediate gearing. AS8

machine: hydraulic drive. A driving machine where the energy is supplied by the stored energy in a hydraulic fluid applied by means of a moving ram in a cylinder. AS8

machine: indirect drive. An electric driving machine, where the motor is connected indirectly by means of belts, chains etc to the sheave, shaft or gearing. AS8

machine: overhead. Where the elevator drive machine is located at the top of the elevator hoistway. N101

machine: rack and pinion drive. An electric drive machine, where the movement of the car is achieved by power driven pinions mounted on the car travelling on a stationary rack fixed in the hoistway. AS8

machine: rated load. The load which the machine of the escalator, passenger conveyor or elevator must be designed to move. CO

machine: roped hydraulic drive. A hydraulic driving machine where the cylinder is connected to the car by roping. AS8

machine: screw. An electric driving machine where the motor drives a screw assembly to raise and lower the car. AS8

machine: traction. A direct drive machine, where the motion of the car is obtained through friction between the suspension ropes and the driving sheave. AS8

machine: winding drum. A geared drive machine, where the suspension ropes are fastened to a winding drum. AS8

machine: worm geared. A direct drive machine where the energy is transmitted to the elevator sheave or drum, or escalator step band, via worm gearing. AS8

machinery space. Space available for the various components required which form the escalator or passenger conveyor. CO

magnet: brake. A solenoid which, when energised, causes the brake shoes to move away from the brake drum. AS13

main brake. *See* brake: main.

main circuit breaker. The circuit breaker used to switch the main electrical supply for each elevator or escalator. LO19/32

main contactor. A contactor with its contacts arranged so as to provide power to the main motor to back up the directional contactors. CO

main directional contactors. The interlocking changeover contactors used for final connection of the drive motor to the incoming supply and directional control. CO

main floor. *See* floor: main.

main isolator. The isolator used to open or close the main electrical supply for each escalator or elevator. CO

main motor. The prime mover. CO

main supply. Power provided from which the prime mover power is derived. CO

maintenance. The action of preservation without impairment or the keeping in being. O1261

maintenance: breakdown. Maintenance undertaken in order that components and equipment may be returned to satisfactory operation. ET197

maintenance: comprehensive. A form of maintenance contract, where the system is inspected, oiled and greased, adjusted and breakdowns repaired during normal working hours, but excluding call backs outside normal working hours, repairs due to vandalism and work arising from legislation. ET201

maintenance: full (FM). *See* maintenance: comprehensive.

maintenance: performance guaranteed. A contract offered to an elevator, escalator or passenger conveyor owner, which guarantees certain performance, (for example: no of elevators simultaneously in service, high mean time between failures (MTBF), low periods of down time) and on the failure to perform results, in the lowering of the premium paid to the maintainer. ET201

maintenance: planned. Preventative maintenance scheduled to be performed at specified intervals of time or for specified numbers of operations. ET197

maintenance: preventative. Maintenance provided to ensure the satisfactory operation of components and equipment by delaying or preventing or reducing the severity of any breakdown that may occur. ET199

maintenance: replacement. The replacement of components and materials, which have worn out or reached the end of their useful life. ET198

maintenance: scheduled. *See* maintenance: planned.

manifold. A metal block in which passages are formed and on which valves are mounted permitting the elimination of many, but not all, interconnecting pipes and shortening the length of the fluid passages. HH

manual control switch. *See* switch: manual control.

manual lowering device. *See* handwinding: device.

mechanic. A person who is capable of maintaining the status quo, but not of innovation (engineer); a skilled elevator operative who has followed a prescribed plan of training and education. N88

mechanical interference. Resistance to motion provided by friction and/or mechanical means or devices. CO

mechanically synchronised. Hydraulic elevators that use a telescopic ram assembly to maintain constant velocity due to the rope or chain synchronising external to the cylinder. JJ

medium duty traffic. *See* traffic: medium duty.

micron filter. Filters, where the size of the particles that the filter will reject is determined in microns. JI

microprocessor. An electronic device which provides methods of control by reacting to input signals in accordance with an algorithm to provide predetermined output signals. CO

modernisation. The process of improving an existing system by bringing it 'up to date'. BA

modernisation overlay. *See* overlay: modernisation.

monitoring: remote. The signalling over a distance of the events (faults, passenger activity, elevator activity etc) occurring in an elevator installation. BE361

motor. A device which can convert electrical energy into mechanical energy. BA

motor generator set. A device comprising an ac motor driving a dc generator and therefore capable of converting one form of electrical energy to another using a mechanical coupling. BA

motor overload. An automatic device to protect a motor against damage as a result of electrical overload. CO

motor protection. An automatic device to protect a motor against damage as a result of electrical overload. CO

motor thermistor protection. Is where the electric motor is protected from overheating by thermistor junctions being placed on the winding of the motor, allowing the temperature to be monitored very accurately and without delay. JI

motor: auxiliary. A motor used for driving parts of an escalator, but not the main drive. LO6/32

motor: brake. A motor sometimes provided to open the brake shoes. CO

motor: compound. A motor with shunt and series coils giving combined characteristics of shunt and series type motors (e.g. high starting torque and limited maximum speed). LO10/32

motor: main. The prime mover. CO

mouldings. Extruded aluminium shapes which through hidden fasteners position and lock in place the interior panels of an escalator. CO

moving walkway. A type of passenger carrying device on which passengers stand or walk, and in which the passenger carrying surface remains parallel to its direction of motion and uninterrupted. NE90

moving walkway: belt pallet type. A moving walkway with a series of connected and power driven pallets, which form a continuous belt treadway. NE91

moving walkway: edge supported belt type. A moving walkway with the treadway supported near its edges by succession of rollers. NE91

moving walkway: pallet type. A moving walkway with a series of connected and power

driven pallets which together constitute the treadway. NE91

moving walkway: roller bed type. A moving walkway with the treadway supported throughout its width by a succession of rollers. NE91

muffler. *See* expansion chamber.

multi stage cylinders. *See* telescopic ram and cylinder.

multiple leaf door. *See* door: multiple (panel) leaf.

multiple parallel arrangement. *See* arrangement: multiple parallel.

multiplying pulley. *See* pulley: multiplying.

needle valve. *See* valve: needle.

newel base. The flat vertical portion of the newel assembly supporting the newel overhang. CO

newel entry switch. *See* switch: newel entry.

newel entry brush. A brush provided at the newel end to cover the internal components of the newel entry switch and to prevent passengers fingers entering this space. CO

newel wheel. A cast iron or steel wheel that carries the handrail around the top and bottom end of an escalator or terminal ends of a passenger conveyor. NE93

newel. Extensions of the balustrade of an escalator at both the lower and upper limits of travel located to assist passengers in boarding and alighting the escalator. NE93

newel: concentric. A newel configuration which utilises a semi-circle as its basic shape. CO

newel: elongated. A newel configuration which utilises a parabolic shape for its design, not to be confused with the extended newel which is required by the ANSI/ASME code. CO

newel: extended. A newel design, not associated with the shape of the newel, where the outer end of the newel extends beyond the comb teeth of the escalators. CO

newel: stand. An upright metal mounting that supports the newel wheels on an escalator or passenger conveyor. NE93

next car. *See* car: next.

next car indicator. *See* indicator: next car.

nib. *See* nosing.

no load start. A procedure whereby a hydraulic elevator motor can start under no load condition, by allowing the pump flow to pass direct to the tank during motor starting until the motor has reached nominal full speed, when the control valve closes to slowly cause the flow to be directed to the cylinder. JI

noise: acoustic. Noise which is transmitted through air and which may be generated by parts of: either an elevator installation, such as the machine, car movement, ropes and chains

in the hoistway; or of an escalator installation, such as the machine, and transmitted via parts of the structure to remote parts of a building. P42

noise: electrical. Noise generated in power devices such as m-g sets, thyristor (scr) controllers, etc and which is transmitted by electromagnetic radiation. *See also* interference: electrical. BA

non reversal device. A device provided to prevent the sudden reversal of an escalator or passenger conveyor. CO

nose line. The line formed by the intersection of the escalator step of the riser with the step tread. CO

nosing. Rounded edge of a step or cover for the edge of a step. O1415

notices. Written or pictographic signs placed on or near an escalator to warn of hazards. CO

nudging. With automatic door operation should the doors remain open for longer than a specified time then the doors are compulsorily closed at reduced speed, with the intention of removing any obstruction. AS20

'O'-ring. An endless packing ring of circular cross-section (toroidal ring) normally mounted in a groove in such a manner that the effectiveness of sealing increases with the pressure. HH

observation elevator. *See* elevator: observation.

oil buffer. *See* buffer: oil.

oil cooler. *See* heat exchanger.

oil cushion stop. *See* stop: cushioned.

oil drain line. The line that carries overflow oil, oil leakage from gland and exhaust oil from the valve pilot system back to a container but not to the tank if the oil is likely to be contaminated. JI

oil drip pan. *See* drip tray.

oil level indicator. The means to monitor the oil level in the tank of a hydraulic elevator to ensure that there is sufficient oil for the elevator car to reach the top floor, which can be in the form of a sight glass or dip stick. JI

oil temperature detection. The detection of unacceptable oil temperature rises by detection devices which are usually either thermistor or bi-metal sensors placed in the oil tank. JI

on-call control. *See* control: on-call.

one-to-one roping. *See* roping: one-to-one.

open pilot valve. *See* valve: open pilot.

opening: door advance. *See* opening: door pre-opening.

opening: door premature. *See* opening: door pre-opening.

opening: door pre-opening. The initiation of the door opening sequence, whenever the elevator car is within the door zone, in order to reduce the floor to floor cycle time. S129

operational brake. *See* brake: service.

operator. Person who rides in the elevator car and controls the movement of the car and the opening and closing of the doors. N100

operator: door. A power operated device which opens and closes the hoistway and/or the car doors, where the power is not derived from springs, car movement or manual means. AS4

OR gate. A solid state logic device, where the output value is true, when any input is true and is only false when both inputs are false. BA

ordinary lay. *See* lay: ordinary.

outer deck. The deck of a glass balustrade escalator covering from the glass to the outermost edge of the escalator. NE100

overhead. The upper end of the hoistway. N101

overhead beam. The steelwork and reinforced concrete located at the top of the elevator well, which supports the elevator equipment. BOpt9

overhead machine. *See* machine: overhead.

overhead structure. *See* overhead beam.

overlay: modernisation. Where a new control system is installed over the top of the existing control system and which takes over the function of the original controller. BA

overload. A condition where the rated capacity of a piece of equipment has been exceeded. BA

overload indicator. *See* indicator: overload.

overspeed. A condition which is said to occur when an elevator exceeds its rated speed by a specified amount or the step band or treadway of an escalator or passenger conveyor exceeds the nominal rated speed. CO

overspeed governor. *See* governor: overspeed.

overspeed governor switch. *See* switch: governor overspeed.

overtravel. The safe distance that a moving object may travel past its normal point of movement, without hitting any fixed objects. (*See* clearance.) N102

packing. The wearing material fitted into a gland assembly to provide an oil seal between the ram and cylinder. JI

pads: sound insulating. *See* pads: sound isolating.

pads: sound isolating. Pads made of a dense resilient material, which can be inserted between a noise/vibration producing equipment such as a machine, control cabinet or electrical transformer and their fastenings with the building structure, to reduce the intensity of the noise transmitted into a building structure and the air. S402

pallet. One of the series of rigid platforms which together form an articulated treadway or the support for a continuous treadway on a moving walkway. CO

panel: car call. *See* panel: car operating.

panel: car operating. An assembly of push buttons and indicators mounted on a panel inside an elevator car including, amongst other things: car call, door open/close, alarm and mechanics control push buttons; car call, position, direction and information indicators, together with a number of key operated switches for use by authorised persons. PXII

panel: despatcher. Combined starters' and building supervisors' panel comprising, amongst other things, indication of up/down car and landing calls, car position, direction and status together with a number of key operated switches for use by authorised persons. P262

panel: exterior. The panel enclosing the exterior side of the balustrade. CO

panel: vision. Small window located in elevator doors fitted with safety glass which permits passengers to *see* when a car has reached a landing. AS24

parallel installation. An escalator installation where the units are mounted directly parallel and in line with each other. CO

parking. Action of moving an elevator car to a specified floor or leaving it at its current floor, whenever the car has no further calls (landing or car) assigned to it for service. AS20

parking floor. *See* floor: parking.

parking zone. *See* zone: parking.

passenger. Any person transported by an elevator car. BS/ENpt1

passenger arrival rate. The rate at which passengers arrive for service by an elevator system. BE47

passenger average time to destination. *See* time: passenger average to destination.

passenger conveyor. A power driven installation with endless moving walkway (e.g. pallets, belts) for the conveyance of passengers either on the same or between different traffic levels. BS70p5

passenger elevator. *See* elevator: passenger.

passenger emergency stop switch. *See* switch: emergency stop.

passenger/freight elevator. *See* elevator: passenger/freight.

passenger/goods lift. *See* elevator: passenger/freight.

passenger journey time. *See* time: passenger journey.

passenger lift. *See* elevator: passenger.

passenger loading time. *See* time: passenger loading.

passenger transfer time. *See* time: passenger transfer.

passenger transit time. *See* time: transit.

passenger unloading time. *See* time: passenger unloading.

passenger waiting time. *See* time: passenger waiting.

paternoster. Form of lift machine, available in Europe but now obsolete, where a low speed (0.4 m/s) loop of continuously moving horizontal platforms, running in a dual hoistway, allow agile passengers to enter and leave the cars through open entrances. PXVIII

pawl device. A mechanical device used in hydraulic elevators to prevent creep. BA.

peak oil pressure. The maximum pressure developed in a system, usually caused by sudden stops and starts of the system, shock loading and/or waterhammer. JI

peek-a-boo. A method of door operation during firefighting service, where a constant pressure is required on the door open button, in order to cause the doors to open at a landing; the release of the pressure causing an immediate closure of the doors. CO

percentage load. *See* load: percentage.

performance guaranteed maintenance. *See* maintenance: performance guaranteed.

performance index. *See* index: performance.

personal protective equipment (PPE). Equipment provided to or purchased by maintenance or other personnel for protection, such as safety helmets, goggles etc. CO

PRFF. *See* relay: phase failure or reversal.

phase failure relay. *See* relay: phase failure.

phase reversal relay. *See* relay: phase reversal.

photo-electric passenger detector. *See* detector: passenger.

pilot line. Small lines or passages that carry the oil that controls larger valves. JI

pilot line filter. A fine mesh that prevents small particles of foreign matter entering and or blocking the pilot lines and valves. JI

pilot valve. A small valve that controls the fluid flow in the pilot lines. JI

pipe coupling. The connection between lengths of pipe. JI

pipe rupture valve. *See* valve: pipe rupture.

piston rod. The rod that moves in and out of the gland packing, and is attached to the piston head inside the cylinder. *See* ram, for large diameter rods. JI

piston seal. A plastic or composition material with good wearing properties, suitable for the fluid being used in the cylinder, fitted to the piston and to prevent oil passing the piston head during operation. JI

piston stroke. There are two different strokes associated with hydraulic elevators, (1) the total stroke of the cylinder, (2) the working stroke of the cylinder. *See* car travel distance. JI

piston type cylinder. *See* cylinder: piston type.

pit (1). That part of the hoistway or well situated below the lowest landing served by the elevator car. BSpt5

pit (2). A recess in the floor to receive that portion of the lower head and the lower end of the incline section which occurs below the floor line when there is no floor under the escalator such as in a basement. CO

pit stop switch. *See* switch: pit.

pit switch. *See* switch: pit.

pit tanking. Means of preventing the ingress of water into the pit area, which is normally situated at the lowest level in a building. BA

plastic flow. When excessive pressure is placed on a seal the seal is extruded through (plastic flow) the small space between the ram and the gland housing. JI

plate: kick(er). Plate used at the bottom of doors, cabinets and risers of steps and car enclosures to protect them from shoe marks. BA(eitb)

platform: car. Load bearing floor of the car enclosure. AS3

plunger. *See* ram.

plunger joint. *See* ram joint.

plunger stop. *See* stop: plunger.

police circuit. A circuit which maintains the directional contactors after the brakes have been lifted and the starting sequence is complete. CO

poppet valve. *See* valve: poppet.

population: building. Total population of a building. BE43

population: floor. Population of a specific floor in a building. BE161

position indicator. *See* indicator: car position.

positive head. Where the oil level in the tank is sufficiently above the pump intake, to ensure the pump is always supplied with enough oil to avoid cavitation. JI

PPE. *See* personnel protective equipment.

pre-formed groove. *See* groove: 'U'-profile, and groove: 'V'-profile.

pre-load on seals. Where the space provided for the seal or 'O'-rings is always slightly smaller in the direction of sealing than the dimension of the seal; the other dimension has to be slightly larger than the seal to allow expansion of the seal under pressure. JI

pressure compensated valve. *See* valve: pressure compensated.

pressure hose. *See* hose, flexible.

pressure line filter. The filter, usually of the high pressure type, placed in the main pressure line to filter oil in one or both directions. JI

pressure line. A line that carries the fluid at system pressure, which can be either metal tube or flexible hose, selected to suit the highest system plus a factor of safety. JI

pressure tank. A tank that does not open to atmosphere, and uses the fluid to build up pressure in the tank. JI

pressure: differential. Where a hydraulic component has a different pressure on either side; this difference is often referred to as pressure drop or pressure loss. JI

pressure: relief. *See* relief valve.

preventative maintenance. *See* maintenance: preventative.

probable stops. [syn: expected stops] *See* stops: probable.

process switch. An electromechanical device used to detect a physical condition as part of a control sequence. CO

profiled groove. *See* groove: 'U'-profile, and groove: 'V'-profile.

progressive safety gear. *See* safety-gear: progressive.

public service type. A type of escalator generally forming part of a public traffic system and of a more sturdy construction than a standard store type escalator. CO

pull down cylinder. An arrangement used on hydraulic elevators fitted with a counterweight whereby the counterweight is pulled down by a piston rod in tension operated by a ram unit installed in the pit. To allow space for a pull down cylinder to be installed under the counterweight the car is roped 1:1 and the counterweight roped 3:1 or 4:1. JI

pull through governor. *See* governor: pull through.

pulley. Simple mechanical device consisting of a grooved wheel over which a rope or similar may pass for the purpose of changing the direction of applied power. O1705

pulley: diverting (1). An idler pulley used to change the direction of the rope lead where the drive sheave diameter is less than the distance between the pick up points of the car and counterweight. BOpt9

pulley: diverting (2). An idler pulley used to change the direction of an escalator chain. CO

pulley: governor. The pulley, located with the overspeed governor in the machine room around, which the governor rope passes. J118

pulley: multiplying. A pulley mounted on the car frame or counterweight round which the suspension ropes pass in order to gain a 2:1 mechanical advantage. BOpt9

pulley: overhead. Pulleys used to alter the pick up points for the car and counterweight where the machine room is positioned other than directly above the hoistway. BA(EITB)

pulley: tension. The pulley, which is part of the governor tension sheave assembly located in

the pit, around which the governor rope passes. J118

pulsation. The throbbing or vibrating effect set up in fluids, often induced by the design of the pump, and which can cause damage to the system, if not damped. JI

pump: direct coupled. A type of hydraulic pump arranged to be directly connected to the electric motor by either a solid or a resilient in-line coupling. JI

pump: emergency hand. Fitted to hydraulic elevators of the indirect type to enable the car to be lifted out of the safety gear during a power failure or to other types of hydraulic elevators to enable a car to be raised to a landing, in order to rescue trapped passengers. JI

pump: external. A pump located outside the oil tank where both the suction and pressure ports of the pump are connected to the system by pipelines or flexible hoses. JI

pump: gear. A pump which has two intermeshing gears inside a housing such that the oil is transported around the gear in the cavity formed between the teeth and the housing. JI

pump: hand. A pump that is operated by hand. *See also* pump: emergency hand. JI

pump: internal. A pump, which is submerged in the oil tank and is always covered with oil, thus allowing the direct entry of oil into the suction filter mounted on the end of the pump. JI

pump: screw. A pump where two or three intermeshing screws mounted parallel to each other in a casing impel the liquid along the thread as they rotate, the screws also acting as mutual seals to prevent leakage. HH

pump: vane. A rotary pump where the oil is moved by axially sliding vanes set eccentrically on the rotating part. JI

pumps: indirect coupled. Pumps connected to an electric motor via a belt drive or gear system. JI

pushbutton. An insulated button which operates electrical contacts when pushed. BA

pushbutton: car call. A pushbutton which generates a car call, when pushed. BA

pushbutton: door close. A pushbutton which causes the car doors to close, when pushed. BA

pushbutton: door open. A pushbutton which causes the car doors to open, when pushed. BA

pushbutton: landing call. A pushbutton which generates a landing call, when pushed. BA

pushbutton: stop (1). A pushbutton which causes the elevator car to stop, when pushed. BA

pushbutton: stop (2). A push button, normally located in the same place as the escalator directional start switches, as part of the stop/start switch assembly. CO

quadruplex. A group of four cars sharing a common signalling system. BE88

quality of service. The passengers perception of the efficiency of an elevator installation measured in terms of passenger waiting time. BE14

quantity of service. The handling capacity of an elevator installation. BE14

queue. An orderly line of persons waiting their turn. O1729

rail. *See* guide-rails

ram. The male member of a substantial cylinder assembly. HH

ram coupling. *See* ram joint.

ram cushion stop. *See* stop: cushioned.

ram follower. The guide fitted to the ram and guided to prevent the ram buckling when it is extended and arranged to follow the ram at half the extended length. JI

ram joint. The screwed connection between sections of a ram allowing shorter sections to be assembled, thus forming one long ram. JI

ram stop. *See* stop: ram.

rated load. *See* load: rated.

rated load: brake. The load which the brake of the escalator must be designed to stop and hold. CO

rated load: machinery. The load which the machine of the escalator must be designed to move. CO

rated load: step. The load which the escalator step must be designed to support. CO

rated load: structural. The total stated load imposed on the structure of the building. CO

rated load: truss. The load which the truss of an escalator must be designed to support. CO

rated speed: elevator. *See* speed: rated (elevator).

rated speed: escalator. *See* speed: rated (escalator).

rated speed: moving walkway. *See* speed: (rated moving walkway).

RCD. *See* residual current device.

re-levelling. After an elevator car has stopped level at a floor, an operation permitting the stopping position to be corrected (if necessary) during unloading and unloading, by successive car movements. BS/ENpt1

reaction. Signifies the load imposed on the building structure by the escalator. CO

recessed floor pans. Pan type construction being used as a substitute for floor and landing plates, This construction allows the consumer to fill the pans with another material duplicating the floor surrounding. CO

registered call. *See* call accepted.

registration: call. Action of the passenger in the registration of a car or landing call. BA

regular lay. *See* lay: ordinary.

relay. An electromechanical device that is operated by a change in one electric circuit and serves to make or break one or more connections in the same or other electrical circuit. CO

relay: asymmetric. A relay provided to detect the failure of one or more supply phases and/or the incorrect sequencing of those phases. CO

relay: phase failure. Relay which detects a failure of a phase of an incoming electrical supply and which causes the elevator system to be shut down. BA

relay: phase failure or reversal. A relay provided to detect the failure of one or more supply phases and/or the incorrect sequencing of those phases. CO

relay: phase reversal. Relay which detects a phase reversal of an incoming electrical supply and, which causes the elevator system to be shut down. BA

relay: time delay. A relay which acts as a timing device by delaying the application of a control signal. BA

relief valve. *See* valve: relief.

remote monitoring. *See* monitoring: remote.

reserve oil. The oil in a tank that is in excess of the minimum oil required to operate the system. JI

residential building. *See* building: residential.

residual current device. A circuit breaker designed to break the supply in the event of a current flow to earth. LO13/32

resistor: adjustable. A resistor that has taps, sliding bands or a wiper which, when moved, allows all or part of the resistor to be used. NE1

retail building. *See* building: retail.

retiring cam. *See* cam: retiring.

return. To take or lead back at an angle, often 90 degrees, upon a former direction. O1818

return carriage. *See* carriage: return.

return jamb. *See* jamb: return.

reverse phase relay. *See* relay: phase reversal.

reversible. An escalator or passenger conveyor which has the ability to run in either direction. CO

Reynolds number. A dimensionless number used in considerations of fluid flow and given by the relationship: fluid velocity multiplied by pipe diameter divided by kinematic viscosity. HH

right hand lay. *See* lay: right.

rise. The vertical distance between two steps in a stair; the vertical distance between boarding and alighting levels of an escalator. BACO

riser. The upright part of a step; the vertical piece connecting two treads in a stair. O1837

riser: cleated. Vertical cleats on an escalator step riser, which mesh with slots on the adjacent step tread as the steps move from incline to the horizontal. NE23

riser: electrical. A vertical enclosed space in a building from which electrical distribution is made. BA

riser: step. The vertical portion or front of a step. NE139

roller guide shoes. *See* shoes: roller guide.

roller: step. The roller fitted to the escalator step which runs on a track to determine the profile of the escalator. CO

rope lay. *See* lay.

rope. A construction of twisted fibres or wire (wire rope) to form continuous load bearing element. N120

rope: compensating. Wire rope used to counterbalance or partially counterbalance the weight of the suspension ropes as the elevator car moves up and down the hoistway. AS10

rope: governor. A wire rope attached to the elevator car, which drives the governor. J117

rope: hand. A control rope passing through an elevator car allowing the travelling passenger to start and stop the car; now obsolescent. N64

rope: hauling. An endless rope used to manually raise and lower a hand powered elevator. BOpt9

rope: safety. A rope used on hydraulic elevators to actuate the safety gear, where one end is connected to the safety gear actuating arm at the car end, passing over a sheave mounted on the main ram sheave assembly to the pit equipment at the other end. JI

rope: shipper. *See* rope: hand.

rope: suspension. The ropes in an elevator system used to suspend the car and counterweight in the hoistway. BA

rope: tail. *See* rope: safety.

rope: wire. Rope made by twisting wires around an inner core. AS21

roping: one-to-one. An arrangement of ropes, where the mechanical advantage is one and hence the suspension ropes, car and counterweight all travel at the same speed. Jcp3

roping: two-to-one. An arrangement of ropes, where the mechanical advantage is two and hence the rope speed is twice that of the car and counterweight. Jcp3

rotary selector switch. *See* switch: rotary selector.

round trip time. *See* time: round trip.

rucksack elevators. The name given to elevators, where the car is only supported on one side. JI

runby. The unobstructed distance a car or counterweight may travel at the extremes of the hoistway before an obstruction is encountered. BA

runby: bottom — elevator car. The distance between the car buffer-striker-plate and the car-buffer striking-surface, when the elevator car floor is level with the bottom landing. AS10

runby: top — direct-plunger hydraulic elevator. The distance the elevator car can run above the highest terminal landing, before it strikes the mechanical stop. AS10

running clearance. *See* clearance: running.

rupture valve. *See* pipe rupture valve.

rupturing pressure. The pressure at which a hydraulic component bursts or leaks through fault cracks, when subjected to pressure test. JI

safe-edge. A mechanically actuated door re-opening device mounted on the leading edge of a car door which on colliding with a passenger or other object causes the car and landing doors to re-open. AS22

safety. A generic term used to describe the safety features employed in elevator installations. BA

safety astragal. *See* astragal: safety.

safety bulkhead. A second base or bulkhead welded inside the bottom of the cylinder of a hydraulic elevator (which is buried in the ground and could suffer corrosion) to prevent the sudden loss of oil in the event of a failure of the lowest bottom plate of the cylinder. JI

safety circuit switches. *See* switches: safety circuit.

safety edge. *See* safe-edge.

safety-gear. Mechanical devices used to stop a car or counterweight under specific conditions. Jcp8

safety-gear: instantaneous. A safety gear which applies a rapidly increasing pressure on the guide-rails during the stopping period. J117

safety-gear: instantaneous with buffered effect. A safety gear which applies a rapidly increasing pressure on the guide-rails during the stopping period, but with a buffered effect provided by oil buffers interposed between the lower members of the car frame and the safety plank. J117

safety-gear: progressive. A safety gear which applies a limited pressure on the guide-rails during the stopping period. J117

safety plank. Bottom member of the car frame supporting the car guide shoes and safety gear. AS22

safety rope. *See* rope: safety.

safety test. *See* test: safety.

safety: car. Mechanical device attached to the car frame to stop and hold the car should any of three conditions, free fall, predetermined overspeed or rope slackening, occur. AS10

safety: counterweight. Mechanical device attached to the counterweight frame to stop and hold the counterweight should any of three conditions, free fall, predetermined overspeed or rope slackening, occur. AS10

safety: flexible guide clamp. A form of car safety where a pair of wedge shaped jaws are actuated under unsafe conditions and grip the guide-rails to bring the car to a safe stop. J128

SAPB. *See* single automatic push button.

scheduled control. *See* control: scheduled.

SCR. *See* thyristor.

screw machine. *See* machine: screw.

screw pump. *See* pump: screw.

seal: double acting. Seals which are required to retain the oil pressure on either side, e.g. on the piston head of a double acting cylinder. JI

seal: dynamic. A seal placed between a fixed and moving part for example: a gland seal for a ram or piston. JI

seal: gland. *See* gland packing.

seal: ring. *See* 'O'-ring.

seal: static. A seal between two static parts to prevent oil leakage for example: a cover plate or mounting components together. JI

secondary sheave. *See* sheave: secondary.

sector. A group of landings or of landing calls considered together for elevator car allocation or parking purposes. BE94

sector: common. Static sector defined for both up and down landing calls originating from a number of contiguous landings. BE98

sector: demand. A sector in which there is a demand for service indicated by the registration of landing calls. BE98

sector: directional. Static sector that includes a number of contiguous landings defined for one landing call direction only. BE99

sector: dynamic. Sector whose boundaries are defined by the position of the cars and hence are continually changing. BE100

sector: static. Fixed number of landings grouped together. BE98

segments. The radius portions of the escalator assembly. CO

seismic sensor. *See* sensor: seismic.

seismic switch. *See* switch: seismic.

selector: floor. Part of the control system of some elevators which determines the position of the car in the hoistway and automatically stops it at the required landing. BOpt9

self re-levelling. *See* re-levelling.

sensor: seismic. Sensor capable of detecting the onset of an earthquake. BA

service brake. *See* brake: service.

service elevator. *See* elevator: service.

service switch. *See* switch: service.

service: basement. The provision of passenger service to the basement or basements of buildings on a special or regular basis. BE95

service: fireman's. Elevator, which serves all floors in a building, and which can come under the sole command of a fireman in the event of a fire in the building. P61

service: independent. Operation of an elevator such that it only answers car calls and which is brought into operation by the use of a special key switch located in the car. AS19

service: intensive duty. Where an elevator system makes 180 or more starts per hour. PcpVI

service: light duty. Where an elevator system makes 90 or less starts per hour. PcpVI

service: medium duty. Where an elevator system makes from 90 to 180 starts per hour. PcpVI

service: quality. *See* quality of service.

service: quantity. *See* quantity of service.

shaft encoder. *See* encoder: shaft.

shaft. *See* hoistway.

shaftway. *See* hoistway.

sheave. A wheel having a groove or grooves in its circumference, in order to receive a rope or ropes; a pulley. O1969

sheave guard. *See* guard: sheave.

sheave guide. A guide attached to the sheave located on the top of the ram of hydraulic elevators of the indirect type for diverting the ropes; the guide prevents lateral movement of the sheave assembly. JI

sheave: chain. Sheave with rectangular shaped groove over which a chain may run. AS15

sheave: compensating rope. A pit-mounted grooved sheave which guides and maintains the tension on the compensating ropes. AS15

sheave: deflector. Grooved sheave used to deflect ropes in order to place them in the correct lifting positions. AS16

sheave: door hanger. Small grooved sheave which runs on the door track and which allows the door to slide easily. N64

sheave: drive. A wheel, the rim of which is grooved to receive the suspension ropes, and which allows the motion of the driving machine to be transmitted to the ropes by friction. BOpt9

sheave: governor tension rope. A weighted pit-mounted sheave used to maintain tension on a governor control rope. AS23

sheave: hanger. *See* sheave: door hanger.

sheave: idler. Grooved sheave used to guide, to change direction or to apply tension to a rope. N70

sheave: secondary. A groove used to permit the double wrapping of the suspension ropes in order to increase traction. AS22

sheave: tension. A sheave used to maintain tension on a rope. BA

shim. A piece of metal or other material used to fill out a space. NE129

shim: kicker. Small slotted plate used to pack out, align or square-up guide-rails. N77

shim: trouser leg. A small slotted plate used to pack out, align or square up manufactured in the shape of the pair of trousers. CO

shipper rope. *See* rope: hand.

shock loads. *See* peak oil pressure.

shoes: brake. The moving component of a brake, to which the brake linings of high coefficient of friction material are fixed and which when in contact with the brake drum causes an elevator car, escalator or passenger conveyor step band to be held in a stationary position or brought to rest. AS13/J87

shoes: roller guide. Component used to guide an elevator car or counterweight along the guide-rails comprising a set of three (or six) spring loaded rubber tyred rollers. J114

shoes: slide. *See* shoes: slipper guide.

shoes: slipper guide. Component used to guide an elevator car or counterweight along the guide-rails comprising a set of swivel shoes lined with a low coefficient of friction material running against greased guide-rails. J112

side opening door. *See* door: side opening.

side ram. Rams installed at the side instead of under the car platform, in order to reduce or eliminate the need to drill bore holes in the case of long ram and cylinder units. JI

side stile. *See* stile.

sight glass. A small glass or plastic panel placed on the side of oil tank, in order to observe the oil level is sufficient. JI

sight guard. *See* guard: sight.

signal: despatch. Signal given to the elevator power control system to cause the elevator car to move. BA

signalling device. *See* device: signalling.

signalling system. *See* system: signalling.

silencer. *See* expansion chamber.

silicon controlled-rectifier. *See* thyristor.

sill. Lower horizontal part of a doorway. O1996

sill guard. *See* guard: sill.

sill-stop. Support member fastened to the guide-rails of vertical bi-parting doors. AS22

sill: door. Lower horizontal member of a landing entrance. AS16

simplex collective control. *See* control: simplex collective.

simulation. The development and use of models to aid in the evaluation of ideas and the study of dynamic systems or situations. BE151

single automatic push button. An automatic push button control system, where only one button is provided on the landing to indicate both directions of travel. BE87

single leaf door. *See* door: single panel (leaf).

skip-stop operation. Where a duplex pair of elevators in a building share a common lobby but one car serves even floors and the other serves odd floors. BA

single stage ram. A tube or solid column that has a constant diameter for the full length of its travel or stroke. JI

single wrap. Roping arrangement, where one end of the suspension rope is fastened to the car, passes over the drive sheave and is then fastened to the counterweight. J44

skirt. The panels located immediately adjacent to the escalator steps or treadway. CO

skirt guard. *See* guard: skirt.

skirt panel. The lowest panel within the balustrade, located immediately adjacent to the escalator steps and running parallel to the step travel on both sides. CO

skirt switches. *See* switches: skirt.

skirting (board). Narrow boarding placed at the base of a wall. O2011

sky lobby. *See* lobby: sky.

slack rope switch. *See* switch: slack rope.

slenderness ratio. A dimensionless number given by the relationship: the length of a column or ram divided by the radius of gyration of the member. JI

slide jamb. *See* jamb: return.

slide up-down door. *See* door: slide up-down.

sliding lower carriage. *See* carriage: sliding lower.

sling. Device for hoisting bulky or heavy articles. O2019

sling: car. *See* frame: car.

slipper guide shoes. *See* shoes: slipper guide.

slope: moving walkway. The angle which the treadway makes to the horizontal. CO

socketing. The preparation of suspension rope end fastenings. J33

soffit. The under horizontal surface of an architrave, cornice, lintel, arch or escalator truss. O2041

soft start. Uses a form of electrical control equipment that limits the current and/or voltage during the starting cycle of the motor, to reduce the starting current and provide a smooth acceleration. JI

solenoid. An electromagnetic device consisting of a movable iron core (or cores) surrounded by a coil, where the core (often referred to as plunger) is magnetically attracted to the centre of the coil when the coil is energised. CO

solenoid valve. *See* valve solenoid.

solid rams. A ram or piston made from solid bar not tube. JI

solid state. Electronic circuits making use of semiconductor physics. BA

sound isolating pads. *See* pads: sound isolating.

speed governor. A device provided to detect an overspeed condition of the escalator step band. CO

speed reduction unit. Wheels working one upon the other, by means of teeth (or otherwise) for transmitting or changing motion, power and/or speed (often called a worm reduction unit). CO

speed: contract (elevator). *See* speed: rated (elevator).

speed: contract (escalator). *See* speed: rated (escalator).

speed: rated (elevator). The linear car speed in the hoistway, which the elevator manufacturer contracts to supply. BOpt9

speed: rated (escalator). The rate of travel of the steps measured along the angle of inclination, with rated load on the steps, but in the case of reversible escalator the rated speed shall be the rate of travel of the steps in the 'up' direction. CO

speed: rated (moving walkway). The rate of travel of the treadway measured along the angle of inclination, with rated load on the treadway. In the case of the reversible inclined moving walkway the rated speed shall be the rate of travel of the treadway in the 'up' direction. CO

split seal. A circular shaped seal, which assists jack assembly as it has been cut to allow the placing of the seal around a ram or piston so that the two ends can come together. JI

spool valve. *See* valve: spool.

spreader bracket. *See* bracket: spreader.

spring buffer. *See* buffer: spring.

spring: buffer return. Spring used to return an energy dissipation type of buffer back to its operating position. J143

spud. *See* gib: door.

stair climber. A form of stair climbing elevator on which a mobility impaired person can sit in order to reach another floor. S351

stanchions. The vertical members of the truss assembly. CO

stand: newel. *See* newel: stand.

standard. An authoritative or recognised exemplar of correctness, perfection, or some definite degree of any quality. 02107

star delta starter. The interlocking changeover contactors used to start two speed ac drive motors. CO

starter. Originally a person who manually operated and despatched elevators, supervised attendants and directed passengers, but now is a piece of control equipment to stop and start the m-g set. AS23

starter switching solenoid (Watford starter). An accelerating rheostat unit that shorts out resistance in a stepped operation by means of solenoid operated actuation. CO

starts per hour: electric traction elevator. For an electric traction elevator the number of starts per hour is the number of motor starts per hour and is the sum of starts in both up and down directions. BA

starts per hour: hydraulic elevator. For a hydraulic elevator the starts per hour is the number of pump motor starts per hour, i.e. to move the elevator in the up direction. JJ

static friction (stiction). Is the friction or holding power between parts that move during the operation of the hydraulic elevator, e.g. ram and cylinder packing is the major example of static friction. *See also* dynamic friction and stick-slip. JJ

static oil pressure. The oil pressure in a stationary ram holding a load, when the elevator is not moving and in a standby or holding position ready to be operated. JJ

static seal. *See* seal: static.

station: car-top inspection. Control panel situated on the top of the car which allows the elevator to be removed from service and controlled from the car top. AS14

station: mechanics. A control panel, very often plugged in, situated in the ends of an escalator allowing the step band to be rotated under controlled conditions by a mechanic. CO

stationary switch. *See* switch: stationary.

steel tape. *See* tape: steel.

step. The moving platform on which an escalator passenger rides. NE139

step axle. A shaft connecting the escalator step chains on each side and fastened to the step at the front end of the step frame and on which the chain wheels are installed. NE27/32

step band. The mobile assembly of steps and two loops of step chains within the escalator. LO27/32

step chain. Heavy section steel roller chain, through which step axles pass, linking the main drive at the top of the escalator and the lower (tension) carriage at the bottom of the escalator and comprising two chains to each escalator handed for each side of the steps. LO27/32

step chain wheel. The wheel mounted on either side of the escalator step on the chain wheel axle used to support the weight of the step band and passenger loading. LO9/32

step demarcation lighting. *See* lighting: step demarcation.

step frame. The escalator steel framework upon which axles, wheels, riser and treads are mounted to form the step assembly. LO27/32

step journey time. *See* time: escalator flight time.

step nose line. The theoretical line that intersects the nose of each step on the useable part of an escalator or in a stairway. LO27/32

step plan. The pressed steel escalator frame that forms the tread and the riser which combined with the step yokes forms the step frame. LO27/32

step riser. *See* riser: step.

step roller. *See* roller: step.

step tracks. *See* tracks: step.

step tread. The cleated surface of the escalator step assembly that meshes with the comb. LO27/32

step upthrust switch. *See* switch: step upthrust.

step wheels. The wheels of an escalator step which are secured to and driven by the step chain. NE139

step yoke. The side of the escalator step frame that may be integral with the frame or a separate steel forging or pressing. LO27/32

step: die cast. A type of escalator step thus called due to its manufacturing process. CO

step: rated load. The load which the escalator step must be designed to support. CO

stick-slip. A phenomenon caused when rams are operating through the gland packing, particularly at slow speed, when the difference between the static friction and the sliding friction causes a gripping and then a release effect on the ram movement. JJ

stile. Vertical member of the car frame. AS23

stop diamond. A design of passenger emergency stop device used principally on London Underground escalators. CO

stop push. A latching push button and switch used to interrupt the safety circuit, and stop the escalator. LO27/32

stop push button. *See* push button: stop.

stop switch. Switch: stop.

stop: car call. *See* stop: car.

stop: car. A stop by an elevator car at a floor resulting from a car call. BA

stop: cushioned. A stop fitted to the end of ram stroke inside the cylinder, which prevents the ram stop hitting the end of the cylinder. JJ

stop: down. A stop by an elevator car whilst travelling in the down direction. BA

stop: hall call. *See* stop: landing call.

stop: landing call. A stop by an elevator car resulting from a landing call. BA

stop: plunger. A fixed stop fitted at the end of the plunger inside the cylinder of hydraulic elevators thus preventing the plunger being forced out of the gland and packing. JJ

stop: ram. The internal or external stop on a ram to prevent the ram being pushed out of a cylinder at the end of its stroke. JJ

stop: up. A stop by an elevator car whilst travelling in the up direction. BA

stops: probable. The average number of stops an elevator car makes, during a round trip under up peak traffic conditions, calculated using statistical methods. BE18

stretcher gear. The pair of wheels and system of weights used to tension the handrails on some escalators. LO27/32

strike jamb. *See* jamb: strike.

stroke: oil buffer. Distance the buffer piston or plunger moves, excluding the travel of the buffer plunger accelerating device. AS3

stroke: spring buffer. Distance the contact end of the spring moves, before all the coils are in contact or a fixed stop is reached. AS3

submersible electric motor. *See* under oil motor.

suction intake. The common term for the oil being sucked into the pump. JJ

suction line. The pipe line that is used to supply the pump with sufficient oil. JJ

supervisory control. *See* control: supervisory.

supervisory panel. *See* panel: despatcher.

supply distribution. A system comprising busbar trunking and a cable end box used to feed individual switch boards. CO

supply switch gear. The group of switchboards electrically connected to the supply distribution systems and to individual escalator controllers. LO27/32

suspension rope. *See* rope: suspension.

sweep track. *See* track: curved.

switch. A device which makes, breaks or changed connections in an electrical circuit. LO28/32

switch: auxiliary isolating. A switch located in the vicinity of the escalator machine, or in the return station, or in the vicinity of the control devices, which interrupts the supply to the motor without cutting the supply to the socket outlets needed for maintenance and inspection purposes. BS78p2

switch: brake cooling. The switch which causes a reduction in the brake coil current to

prevent overheating of electromagnetic brakes. LO p7/32

switch: broken drive chain. A switch provided to detect the failure of the escalator drive chain being also activated under slack chain or sudden impact conditions. CO

switch: broken handrail. A switch in the safety circuit that opens when a break in the escalator handrail is detected. LO7/32

switch: broken step chain safety. A switch in the safety circuit that opens when a break in the escalator step chain is detected. NE14

switch: buffer. A mechanically operated switch, which removes power from the elevator drive system, whenever the oil buffer is compressed. AS14

switch: car. An attendant operated switch mounted in the elevator car used to control the motion (starting and stopping) of the car. P249

switch: carriage. One of a pair of switches in the safety circuit which open when the escalator tension carriage moves beyond set limits. LO8/32

switch: chain anchor. The switch in the safety circuit which detects that the chain anchors have been removed prior to the starting of an escalator. CO

switch: chain stretch. A switch provided to detect the stretch of an escalator chain or chains. CO

switch: collision. *See* switch: displacement.

switch: comb plate. A switch in the safety circuit that opens when excessive force or deflection is detected on the escalator comb or combplate. LO9/32

switch: cooling. The switch that causes a reduction in brake coil current to prevent over heating on electromagnetic brakes. LO10/32

switch: countershaft drive chain. A switch in the safety circuit that opens when a break in the countershaft drive chain is detected. LO10/32

switch: derailment. *See* switch: displacement.

switch: directional start. A key operated switch located generally in the newel bases at both upper and lower landings, which allows the designated authority to select the movement of the stairs for up and down direction and is sometimes located in the adjacent walls or columns. CO

switch: displacement. Switch actuated by the displacement of the counterweight used to signal to the control system that a collision is possible. AS499

switch: door. Switch operated by the movement of a door. BOpt9

switch: door limit. Switch which limits the travel of a door. AS16

switch: dropped step. A switch provided to detect a dropped escalator step situation. CO

switch: emergency stop (1). Switch located in the elevator car which when operated causes the

power to be removed from drive machine and brake. AS6

switch: emergency stop (2). A separate stop button usually located in adjacent walls, columns or within the balustrading providing the facility for a passenger or observer to stop the escalator, in the event of an emergency. CO

switch: fault condition. A solid state/electro mechanical device used to detect faults in an escalator and to provide either protection or warning. CO

switch: final limit. Emergency switch used to stop an elevator automatically, in the event that the car travels a predetermined distance past the terminal landing. BOpt9

switch: final terminal stopping. A mechanically operated switch, which automatically causes the power to be removed from the elevator drive machine and brake, independent of the normal terminal stopping switch, car switch, push button or any other control device. AS182

switch: fire shutter. A switch fitted to detect the release of a fire shutter and to stop the escalator. CO

switch: fireman's. Switch which when operated brings the designated elevator car under the control of the fire fighting service. BSpt6

switch: float. The combined arrangement of a float that moves with the change in oil level in the tank, and operates a switch at pre-adjusted levels. JJ

switch: floor stopping. Switch or switches used to bring a elevator car to rest at or near a designated floor. BOpt9

switch: governor. A mechanically operated switch mounted on the governor that removes power from the escalator motor and brake when an escalator overspeed condition occurs. NEp60

switch: governor drive chain. A switch on the safety circuit that opens when a break in the governor drive chain is detected. LO16/32

switch: governor overspeed. Mechanically operated switch located on the governor, which removes the power from the elevator drive machine and brake, whenever an overspeed condition occurs. AS18

switch: handrail entry. A switch provided at the newel entry aperture where the handrail passes through and designed to trip and cut off power to the main motor in the event of an obstruction being detected. CO

switch: key. Switch which can only be operated by means of a key. BA

switch: limit. Switch placed in the hoistway to indicate to the control system that a specified limit has been passed. BA

switch: low pressure. An electrical switch actuated by hydraulic pressure and used to signal a reduction in pressure in the hydraulic system. JJ

switch: low step. The switches in the safety circuit, that open when a low escalator step is

detected approaching or leaving either comb. LO19/32

switch: lubrication float. The switch that detects a low level of lubricant on an escalator and provides either alarm, or protection. CO

switch: manual control. A manually operated switch used to select a single escalator control option. CO

switch: newel entry. A switch provided at the newel entry space to stop the escalator or passenger conveyor should a passengers fingers enter this space. CO

switch: normal terminal stopping. Switch of any type which causes the elevator automatically to slow down and stop at or near the terminal landing, independent of the car switch, push button or any other control device. AS182

switch: oil buffer. Switch used to indicate the level of oil in an oil buffer is below a specified level and prevent operation of the elevator. AS14

switch: pit. Emergency stop switch located in the elevator or escalator pit, which when operated causes power to be removed from the drive machine and brake. AS188

switch: rotary selector. A device that makes, breaks or changes connections in an electrical circuit. CO

switch: seismic. Switch activated by ground movement to signal the possibility of an earthquake. AS499

switch: service. Key operated switch which is not operative whilst the elevator car is in motion, used to take the elevator out of service. BOpt9

switch: slack rope. Switch or switches arranged to stop the elevator should the suspension ropes slacken by a predetermined amount. BOpt9

switch: slow down. Hoistway mounted switch used to control the slow down sequence of a elevator car to a landing. BA

switch: stationary. A switch in the safety circuit forming part of some governors that opens as the escalator step band speed decreases to zero. CO

switch: step upthrust. A switch designed to shut down an escalator in the event of a step being forced upwards off its intended plane of travel. CO

switch: stopping. Switch actuated by the movement of the elevator car, at predetermined points in the hoistway, and which causes power to be removed from the drive machine. BOpt9

switch: terminal slow down. A limit switch located at a terminal landing, which initiates a slow down sequence in the event the normal slow down system fails to function. AS24

switch: terminal stopping. *See* switch: normal terminal stopping and switch: final terminal stopping.

switch: underspeed. A switch in the safety circuit forming part of some governors that

opens when the step band speed falls below a set limit. LO30/32

switch: wedge breaker roller. A switch that monitors the resetting of an escalator brake prior to restart. CO

switchboard. An enclosure containing the main circuit breaker, main isolator, and in some cases the mechanical locking system used to switch on and off, isolate (and lock off) the electric supply to each escalator. CO

switches: safety circuit. Electrical circuit switches located at various points within the unit which will cause the escalator to shut down in order to prevent accidents to passengers or damage to the escalator itself. CO

switches: skirt. Safety switches located immediately behind the escalator skirt panels at the lower landing, which are activated if a wedging action occurs between the steps and skirt panels. CO

synchronised rams. *See* telescopic rams.

synchronising valve. *See* valve: synchronising.

system response time. *See* time: system response.

system: alarm. *See* alarm system.

system: automatic remote monitoring. A system of remote monitor units on each machine, central processor, software and video display units that send, read, interpret and display operating and fault information from the monitored machines. LO6/32

system: signalling. Means of indicating landing calls to the supervisory control system using a common riser of landing push buttons. BA

tail rope. *See* rope: safety.

tail shaft. The driven shaft in the tension carriage carrying two sprockets that tension and reverse the direction of the escalator step chains. LO17/32

tandem operation. Escalators used in series with common intermediate landings. CO

tangent track. *See* track: adjustable.

tank discharge. *See* exhaust flow.

tank return. Either the exhaust line from the main valve or, the pilot valves discharging oil back to the tank. JI

tape: steel. Tape, usually toothed, used to drive tachometers, position sensors and governors. BA

teagle. Early form of British lift (c.1845) driven by a belt from line shafting in industrial premises and controlled by a hand rope. S6/8

telescopic ram and cylinder. An arrangement of rams and cylinders, which may be of different diameters, working in synchronism, where the synchronism may be hydraulically or mechanically arranged for constant speed. JI

temperature compensated. Electrical or thermal devices fitted to a hydraulic elevator

control system, in order to change the valve settings, and compensate for any change in oil temperature and bring the performance back to an acceptable level. JI

tension carriage. *See* carriage: tension.

tension pulley. *See* pulley: tension.

tension sheave. *See* sheave: tension.

terminal final stopping switch. *See* switch: final terminal stopping.

terminal floor. *See* floor: terminal.

terminal landing. *See* floor: terminal.

terminal normal stopping switch. *See* switch: normal terminal stopping.

terminal slow down switch. *See* switch: terminal slow down.

terminal stopping switch. *See* switch: terminal stopping.

terminal: express zone. *See* floor: express zone terminal.

test: acceptance. Inspection and test of new or altered equipment to check for code/standard and contract conformance. AS7

test: periodic. Detailed examination and tests carried out periodically to ensure continued compliance to relevant codes/standards. AS7

test: safety. Procedure whereby all parts of the elevator car safety gear and governor are subjected to a rigorous visual inspection and then tested under controlled operating conditions. N124

theoretical escalator handling capacity. *See* capacity: theoretical escalator handling.

thread seal. A compound or plastic material painted on or wrapped around threads to form a fluid seal between two threaded parts; for example, a pipe being screwed into a valve housing. JI

threshold comb. The toothed portion of a threshold plate on a moving walkway designed to mesh with the grooved treadway surface of an escalator or moving walkway. NEp146

threshold: moving walkway. The portion of the landing adjacent to the treadway consisting of one or more stationary or slightly moveable plates. CO

through car. *See* car: through.

thyristor. A three terminal semiconductor rectifier, which can be controlled to turn on at a point during the positive half cycle of the ac waveform. BA

time. The interval between two successive events, or the period through which an action, condition, or state continues. O2308

time delay relay. *See* relay: time delay.

time: boarding. *See* time: passenger loading.

time: car call dwell. The time that the elevator doors are held open at a landing, after the door opening sequence has been completed, in response to a stop resulting from a car call. BE16

time: cycle. The time for an elevator to move from one floor to the next adjacent floor, measured from the instant that the doors start to close at the departure floor to the instant the doors start to close at the arrival floor, provided that no passengers have entered or left the car. ET267

time: despatch interval. The period of time between successive car departures from a terminal floor for a group of elevators controlled by a scheduling supervisory control system. BE37

time: door closed. The period of time which elevator doors remain closed. BA

time: door closing. The period of time measured from the instant that the elevator door close push button is pressed (or the first visible door movement) until the door interlocks are made up. BE16

time: door hold(ing). *See* time: car call dwell and time: landing call dwell time.

time: door open. The period of time that the elevator doors remain open. BA

time: door opening. The period of time measured from the instant of the elevator car being level at a floor and when the doors are open 800 mm. BE16

time: entry. *See* time: passenger loading.

time: escalator flight time. The time taken for an escalator step to travel between floor levels. CO

time: flight. *See* time: single floor flight and time: multiple floor flight.

time: floor to floor. *See* time: single floor flight or multiple floor flight.

time: interfloor. The period of time for an elevator car travelling at rated speed to pass between two adjacent floors. BE16

time: journey. *See* time: passenger journey.

time: landing call dwell. The time that the elevator doors are held open at a landing, after the door opening sequence has been completed, in response to a stop resulting from a landing call. BE16

time: loading. *See* time: passenger loading.

time: loading interval. The period of time that a car may be held at the main terminal after the first passenger has registered a car call. BE37

time: multiple floor flight. The period of time measured from the instant when the door interlocks are made up at the departure floor until the instant that the elevator car is level at the next stopping floor, which can be more than two floors distant. BE16

time: passenger average to destination. The average time that a passenger takes to reach the

mid point of travel, including average waiting time. BA

time: passenger journey. The period of time that a passenger spends travelling to a destination floor measured from the instant that the passenger registers a landing call at the departure floor until the instant the passenger alights at the destination floor. BE165

time: passenger loading. The average period of time required for a single passenger to enter an elevator car. BE16

time: passenger transfer. The average period of time required for a single passenger to enter or leave an elevator car. BE16

time: passenger transit. *See* time: transit.

time: passenger unloading. The average period of time required for a single passenger to leave an elevator car. BE16

time: passenger waiting. The period of time that a passenger spends waiting for an elevator car measured from the instant that the passenger registers a landing call until the instant the passenger enters the car. BE165

time: performance. The time for an elevator to move from one floor to the next adjacent floor, measured from the instant that the doors start to close at the departure floor to the instant the doors are open 800 mm at the arrival floor. BA

time: round trip. The average period of time for a single elevator car trip around a building, usually during up peak traffic conditions, measured from the time the car doors open at the main terminal, until the car doors reopen at the main terminal, when the car returns to the main terminal, after its trip around the building. BE13

time: running. The total period of time during a round trip, when the elevator is moving. S66

time: single floor flight. The period of time measured from the instant when the door interlocks are made up at the departure floor until the instant that the elevator car is level at the next adjacent landing. BE16

time: standing. The total period of time during a round trip, when the elevator is not moving. S70

time: stop. A composite time period which represents the 'penalty' time introduced by the elevator car stopping at a floor and which comprises the sum of door opening, door closing and single floor flight times minus the transit time to pass between two floors at rated speed (interfloor time). BE16

time: system response. The period of time that it takes an elevator group to respond to the first registered landing call at a floor. BE273

time: transfer. *See* time: passenger transfer.

time: transit. The period of time that a passenger spends travelling in an elevator car measured, from the instant that the passenger boards the car, until the instant that the passenger alights at the destination floor. BE4

time: unloading. *See* time: passenger unloading.

time: waiting. *See* time: passenger waiting.

toe guard. *See* guard: sill.

top runby. *See* runby: top — direct plunger hydraulic elevator.

top terminal floor. *See* floor: top terminal.

top terminal landing. *See* floor: top terminal.

track bracket. A bracket used to fix the position and secure the track to the trusswork. LO28/32

track insert. Replaceable steel track that is secured into cast track. LO28/32

track section. A length of track. LO28/32

track supports. Brackets fastened to the vertical stanchion members. CO

track: adjustable. The horizontal track section that leads onto and off of the escalator main drive and idler sprockets (also known as the tangent track). LO5/32

track: curved. The curved track that guides the escalator step band between the horizontal and the incline. LO11/32

track: dee. The semicircular track that guides the trailer wheels around the main drive and idler sprockets, and where the upthrust changes to running track and vice versa. CO

track: door. A rail on which the door hanger rolls and which allows the horizontal sliding movement of the doors. AS16

track: door hanger. An assembly, which is fastened to the top of a door panel and which allows the horizontal sliding movement of the door. AS16

track: half. The half width track section that forms part of the slide track on the tension carriage side. LO16/32

track: handrail. The track that guides the handrail on the passenger side between the newel wheels at each end. LO16/32

track: hanger. *See* track: door.

track: tangent. *See* track: adjustable.

track: upper line. The track between the main drive and idler sprockets on the passenger side of the escalator. LO30/32

track: upthrust. The track that ensures that the possible lifting of wheels from the running track is restricted. LO30/32

track: variable. The track section that is of special length for different escalator rises, fitted at the head of the incline. LO31/32

tracks: step. A series of tracks which support and guide the escalator steps through both the exposed and return portions of step travel, where the chain leading wheels and the trailing wheels have separate track systems and where changes in the vertical height between the chain wheel track and the trailing wheel track cause the step profile to change. CO

traction machine. *See* machine: traction.

traffic analysis. Determination of the statistical characteristics of passenger movements (average passenger waiting and journey times, percentiles, etc) in an elevator and escalator systems. BA

traffic controller. *See* control: group supervisory.

traffic: (balanced) interfloor. A traffic condition where there is no discernable pattern of calls and a random traffic pattern can be said to exist. BE9

traffic: down peak. A down peak traffic condition exists when the dominant or only traffic flow is in a downward direction with all or the majority of passengers leaving the lift system at the main terminal of the building. BE7

traffic: four way. A four way traffic condition exists when the dominant traffic flows to and from two specific floors, one of which may be the main floor. BE8

traffic: heavy duty. *See* traffic: intensive duty.

traffic: intensive duty. Where an individual lift car is expected to undertake more than 180 starts per hour. PcpVI

traffic: light duty. Where an individual lift car is expected to undertake 90 or less starts per hour. PcpVI

traffic: medium duty. Where an individual lift car is expected to undertake between 90 and 180 starts per hour. PcpVI

traffic: two way. A two way traffic condition exists when the dominant traffic flow is to and from one specific floor, which is not the main floor. BE8

traffic: up peak. An up peak traffic condition exists when the dominant or only traffic flow is in the upward direction with all or the majority of the passengers entering the lift system at the main floor of the building. BE6

trailer wheel. The wheel mounted on either side of the escalator step on the trailer wheel axle used to set the inclination of the step. LO29/32

trailer wheel axle. The common axle that links the escalator step frame with the trailer wheels mounted at either end. LO29/32

trailer wheel track. The escalator trailer wheel running and upthrust track. LO29/32

trailing cable. *See* cable: travelling.

trailing wheel. Idler wheels which support the riser end of an escalator step. NE148

transformer. An electrical device which by electro magnetic induction transfers ac voltage and current between two or more windings at the same frequency and at different values of voltage and current. LO9/32

transportation: horizontal. Where the movement of people and materials is in the horizontal plane. BA

transportation: vertical. Where the movement of people and materials is in the vertical plane. BA

travel (1). The vertical distance an elevator can move, measured between the bottom terminal floor and the top terminal floor of building zone. AS11

travel (2). The vertical distance an escalator serves between two levels. CO

travelling cable. *See* cable: travelling.

tread board. The wooden board onto which slats are mounted to form the escalator step tread. LO29

tread former. A roller assembly (or skid) placed on both sides in the escalator comb region to ensure that the step treads align with the comb in the event of lateral step movement. LO29/32

tread section. The aluminium cleated die casting that when mounted together in the step frame form the escalator step tread. LO29/32

treadplate. The moveable steel plate that forms a wearing surface and interfaces between the comb level and finished floor level. LO29/32

treadway. The passenger carrying member of a moving walkway. CO

trip counter. *See* counter: journey.

trip: express (run). The distance an elevator travels without stopping during a movement between terminal floors or when crossing an unserved building zone. BA

triplex. Three interconnected cars, sharing a common signalling system, controlled under a simple group control system operating under directional collective principles. BE88

trouser leg shim. *See* shim: trouser leg.

truss. An assembly of structural steel or tubular steel shapes which forms the supporting structure for the escalator. NE150

truss module. A section of the truss manufactured as one assembly and joined to adjacent modules on site. LO29/32

truss supports. Concrete walls, steel structures or a combination of both used to support the truss work. LO29/32

truss work. The steelwork forming part of the escalator truss. LO29/32

truss: high chord. A design where most of the truss steel structure is located above the escalator step line. CO

truss: rated load. The load which the truss of an escalator must be designed to support. CO

turbulent flow. Where the particles within the fluid cannot negotiate the pipe and valve configuration at an increased velocity, causing the flow to change from laminar to turbulent flow. HH

twin rams. Two rams arranged to support the load, where both can be under the elevator car or one ram can be on either side of the car in order to avoid deep excavation work. JJ

two-point suspension. Relates to an escalator unit in which the total load is supported at two points: the upper head and the lower head. CO

two-speed door. *See* door two speed.

two-speed drive. A switching system used for the speed control and star/delta starting of alternating current motors. CO

two-to-one roping. *See* roping: two-to-one.

two-way traffic. *See* traffic: two way.

‘U’-groove. *See* groove: ‘U’.

under oil motor. A squirrel cage motor, in open frame construction, fully immersed in the oil and directly coupled to a pump, where the oil is in contact with the windings and in the space between the stator and rotor. JJ

under step lighting. *See* lighting: under step.

undercut groove. *See* groove: undercut.

underspeed switch. *See* switch: underspeed.

unloaded start. *See* no load start.

unloading ramp. The ramp with low friction insert that acts on the step chains to reduce the load on the chain wheels as they move round the upper curves of the escalator. LO18/32

up peak. *See* traffic: up peak.

up peak interval. *See* interval: up peak.

up peak passenger arrival rate. *See* arrival-rate: up peak passenger.

up peak traffic. *See* traffic: up peak.

up arrow. *See* arrow: up.

up call. *See* call: up.

up contactor. A contactor with its contacts arranged so as to provide power to the main motor to rotate in an up direction. CO

up stop. *See* stop: up.

uplighting. Luminaries that reflects light upward, where used on some escalators they consist of bowl shaped lamp fitting/reflector mounted upon a pole protruding from the balustrade decking. LO30/32

upper head. The horizontal portion of the truss at the upper end of the escalator where the drive unit, connecting sprockets and controller are normally mounted. CO

upper line track. *See* track: upper line.

upper machine room. The compartment beneath the upper landing passenger concourse, forming the upper section of the machine room, which contains the escalator control, and drive machinery. LO30/32

upper terminal floor. *See* floor: top terminal.

upper zone. *See* zone: high rise.

upside down cylinder. An arrangement for hydraulic elevators where the cylinder assembly

can be inverted, so the piston is extended from or retracted into the bottom of the cylinder, so that the piston rods are in tension. Sometimes referred to as ‘boot strap’ type. JJ

upthrust angle. The angle track that ensures that the possible lifting of wheels from the incline and curved running tracks is restricted by means of the upthrust pin. LO30/32

upthrust pin. The lug or pin integral with the escalator step, located either on both or one side only and positioned to engage with the upthrust angle and restrict the upward movement of the step. LO30/32

upthrust system. The upthrust track, upthrust angle and other methods that combine and ensure that the possible lifting of wheels from the running track is restricted on all areas of the escalator. LO30/32

upthrust track. *See* track: upthrust.

vacuum. Strictly zero pressure, but used loosely to denote a pressure, which is negative compared to atmospheric pressure. *See also* cavitation. JJ

valve coil. *See* valve solenoid.

valve solenoid. A valve that has its pilot system operated by solenoids. JJ

valve: ball. Where the moving part of the valve is spherical shaped and has a hole through its centre. The ball is held in between seals, and by rotating the ball the flow can be controlled. JJ

valve: bypass. Valve, which is used to divert fluid into an alternative path, for example: the pump output from the fluid power line to the fluid storage tank, of a hydraulic elevator. BOpt9

valve: check. A one way valve that is installed to prevent the reverse flow of oil back to the pump, or to prevent a reverse flow in a hydraulic circuit. JJ

valve: closed pilot. A pilot valve system that is normally closed with the power to the solenoid turned off. JJ

valve: differential pressure. A valve, where the spool, or piston, is moved by fluid pressure (for example a pipe rupture valve), where the valve closes, when there is a loss of pressure on one side of the valve due to line failure. JJ

valve: electronic. Typically the electronic circuit that monitors the temperature and/or pressure and which in turn varies the flow rate of the valve in accordance with the design parameters. JJ

valve: integrated rupture. A pipe rupture valve mounted inside the cylinder base of a telescopic ram and cylinder. JJ

valve: needle. A type of valve usually fitted in the pilot lines of hydraulic valve systems for controlling small oil flow, which can be either manually or solenoid operated. JJ

valve: open pilot. A pilot valve that is normally open when the power to the solenoid is turned off. JJ

valve: pipe rupture. A valve designed to close in the event of the pressure line from a cylinder failing or bursting by detecting the sudden increase in differential pressure across the valve and where in the case of high inertia systems the valve may have a cushioned closure to avoid high pressure peaks. JI

valve: poppet. A cylindrical piston approximately the same length as its diameter, where the movement of the poppet longitudinally, controls the fluid flow at its end, where the seal is made. JI

valve: pressure compensated. A valve which has in-built controls or components, that detect pressure changes and vary the valve operation either directly or indirectly to compensate for the change in pressure. JI

valve: relief. A valve that opens, when a set pressure is reached, or to maintain a constant pressure in a system. JI

valve: shut off. A valve that can be either electrically or manually operated to close off the fluid flow in a system. JI

valve: spool. A long cylindrical plunger inside a valve assembly, that moves longitudinally and controls fluid flow by ports and seals positioned along its length. JI

valve: synchronising. A small valve located at the bottom of each stage of a telescopic cylinder of the hydraulically synchronised type, which allows oil to be transferred from one stage to another in cases where the synchronisation needs correction. JI

vane pump. *See* pump: vane.

vane. A thin piece of metal, positioned in the hoistway, which operates as the actuating part of a magnetically operated switch. AS24

vane: door. A mechanism mounted on a car door transmitting operating power to the hoistway doors. AS24

variable flow. A hydraulic pump, whose displacement can be changed for any constant drive speed. JI

variable track. *See* track: variable.

variable resistance drive. A drive system used to control the starting current of direct current motor by varying the series resistance of the motor armature. Typically incorporates a bank of switched fixed resistors housed in a separate enclosure. CO

vee groove. *See* groove: 'V'-cut.

vee packing seal. The name given to a seal, which when viewed in cross section is vee shaped, sometimes called chevron seal. JI

velocity fuse. *See* pipe rupture valve.

velocity valve. *See* valve: pipe rupture.

ventilation: car. Means of removal of heat, generated inside the car, by natural or mechanical means, via suitable vents placed in the car enclosure. AS147

vertical transportation. *See* transportation: vertical.

vibration. Vibration in a hydraulic system caused by pressure pulses from pumps and relief valve flutter, which may cause damage to the more vulnerable parts of a system. HH

viscosity. The internal friction or resistance to the relative motion of parts of a fluid. JI

vision panel. *See* panel: vision.

wainscot. The walls of an elevator car extending from the floor to (usually) the ceiling. AS24

waiting interval. *See* interval: waiting.

waterhammer. A term used in conjunction with a pressure surge in any liquid, which is caused by sudden interruption of flow, whose magnitude depends on the amount of liquid, its velocity and the speed of the interruption. HH

Watford starter. An accelerating rheostat unit that shorts out resistance in a stepped operation by means of solenoid operated actuation. CO

wedge breaker roller switch. *See* switch: wedge breaker roller.

weighing: load. A means of determining the weight (but not the number) of passengers being carried in an elevator car. BE277

well. The space bounded by the bottom of the pit and the walls and roof of the hoistway in which the car and counterweight travel. BSpt5

wellway. The portion of the building which receives and supports the escalator truss. NE158

wellway railing. A balustrade located around the escalator wellway opening to prevent people falling into it. CO

wellway railing capping. The capping member of the wellway railing to match the capping member with the escalator decking. CO

wheel newel. *See* newel wheel.

wheel: worm. Part of a worm gear. J75

wheelchair lift. *See* elevator: wheelchair.

width. The normal dimension measured between the escalator balustrade panels. CO

winding. *See* handwinding.

winding drum machine. *See* machine: winding drum.

wiper ring. Ring arranged so that they grip a piston rod and scrape off any foreign matter. HH

wire rope. *See* rope: wire.

wiper seal. *See* wiper ring.

wiring diagram. A drawing that shows the connections between the controller and all switches, contacts etc. NE159

wiring loom. A group of wires cut to predetermined lengths and running parallel to each other. CO

working point. A point used by escalator manufacturers to determine the relationship of

the unit to the building structure to assure proper erection. CO

working pressure. The pressure measured at the cylinder entry of an hydraulic lift, when lifting the car and its rated load at rated speed. JI

worm gear. *See* gear: worm.

worm reduction gear. *See* gear.

worm wheel. *See* wheel: worm.

wrap angle. *See* angle of wrap.

wrap: single (1:1). A roping arrangement where the rope joining the car and the counterweight passes over the sheave once. J44

wrap: double. A roping arrangement where, in order to increase the traction, the rope joining the car and the counterweight passes over the drive sheave twice. J44

yoke attachment. A fixing arrangement on the cylinder head of an intermediate ram stage on a telescopic ram of a hydraulic elevator. JI

yokes. *See* cylinder head guide yoke.

zig zag arrangement. *See* arrangement: zig zag.

zone. A number of floors, usually adjacent, in a building served by a group or groups of cars. BE91

zone: door. A distance (about 200 mm) measured from the landing floor, in both directions, in which it is permitted for the car doors to be opened, when a car is levelling at a floor. BA

zone: express. *See* zone: high rise.

zone: high rise. A building zone situated in the middle or top of the building. BE92

zone: landing. *See* zone: door.

zone: levelling. A distance near to each landing floor in which an elevator car slows and 'inches' towards the floor level. BA

zone: local. A building zone adjacent to and including the main floor. BE91

zone: parking. An area designated for the parking of cars when they have served their last car call. BA

zone: upper. *See* zone: high rise.

Appendix A2: Lift kinematics

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A2.1 Fundamentals

Lift kinematics is the study of the motion of a lift in a shaft without reference to mass or force. This motion is described in terms of velocity (speed), acceleration and jerk (rate of change of acceleration). The maximum values of these parameters is limited by what passengers perceive as a comfortable ride. Speed has no influence on comfort and can be any practical value. However, the maximum values of acceleration and jerk are typically limited to 1.2–1.5 m/s² and 1.5–1.8 m/s³ respectively to meet passenger expectations.

Modern drives kinematics can be controlled precisely to match speed reference profiles. An example of a speed reference curve is shown in Figure A2.1. Curves similar to these are often presented in manufacturers' literature as a demonstration of a fast, comfortable and efficient drive system.

Most major lift companies can provide the values calculated in this appendix for their equipment using computer programs. Independent industry design programs calculating kinematics are also available.

The analysis of lift kinematics cannot be made using the three familiar equations:

$$s = ut + \frac{1}{2}at^2 \quad v = u + at \quad v^2 = u^2 + 2as \quad (\text{A2.1})$$

These equation assume, for simplicity, that the stated value of acceleration (a) is reached instantaneously. This is not true, which makes the mathematical analysis more complex. Figure A2.2 illustrates the complex nature of ideal lift motion.

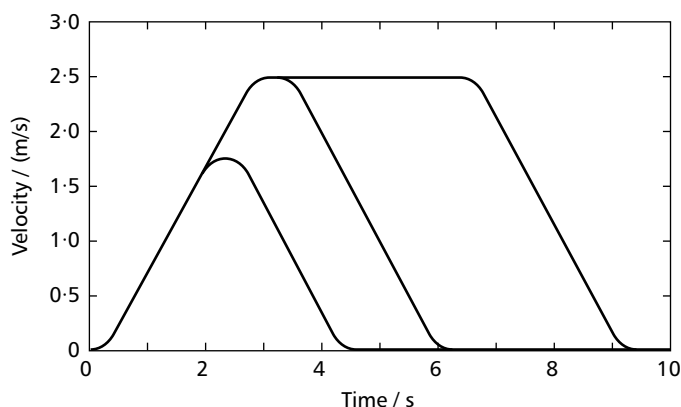
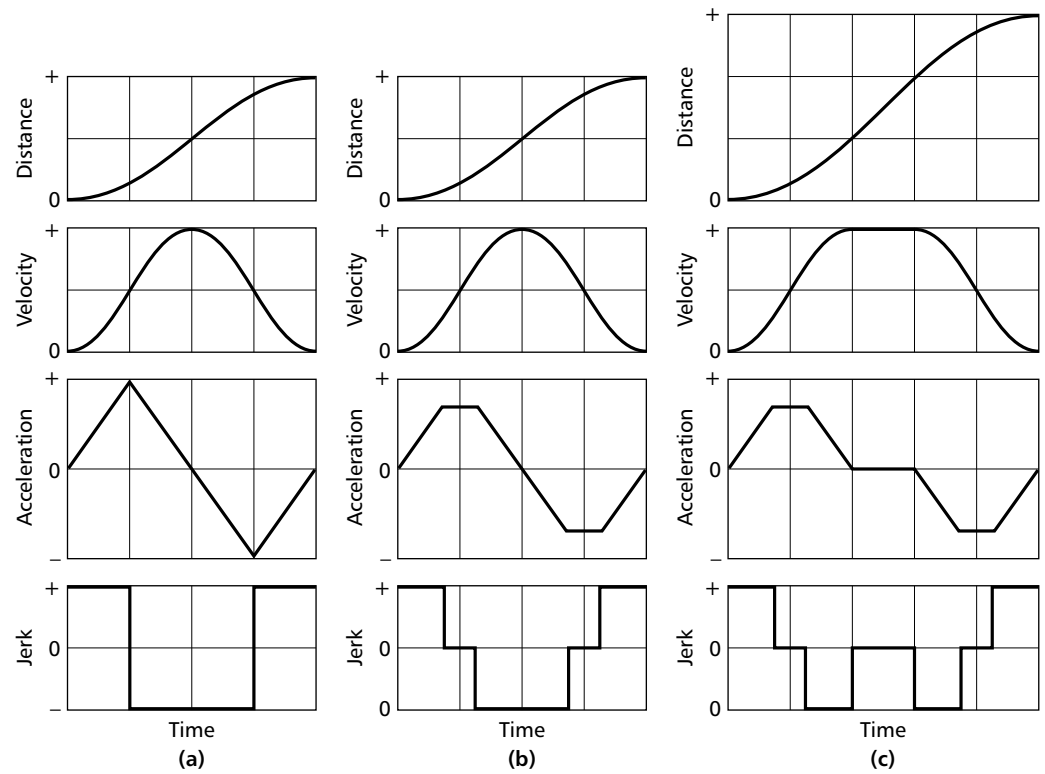


Figure A2.1 Example of a speed reference curve

Figure A2.2 Lift dynamics; (a) rated speed reached before rated acceleration, (b) rated acceleration reached, rated speed not reached, (c) both rated acceleration and rated speed reached



A2.2 Ideal kinematics of a lift system

Motz (1976, 1991) published an exact analysis of the ideal kinematics of lifts in 1976. The equations most relevant to the motion of practical lift systems are presented below.

Distance (s_a) to reach rated acceleration (a):

$$s_a = \frac{a^3}{6j^2} \quad (\text{A2.2})$$

where j is jerk (m/s^3).

Time (t_a) to reach rated acceleration:

$$t_a = \frac{a}{j} \quad (\text{A2.3})$$

Speed (v_a) at rated acceleration:

$$v_a = \frac{a^2}{2j} \quad (\text{A2.4})$$

Distance (s_{vm}) to reach rated speed (v_m):

$$s_{vm} = \frac{v_m^2}{2a} + \frac{a \times v_m}{2j} \quad (\text{A2.5})$$

Time (t_{vm}) to reach rated speed:

$$t_{vm} = \frac{v_m}{a} + \frac{a}{j} \quad (\text{A2.6})$$

Maximum speed (v) reached for a single floor jump of (d_f) if full speed cannot be reached, or is reached for an instant only:

$$v = -\frac{a^2}{2j} + \sqrt{\left(a \times d_f\right) + \left(\frac{a^2}{j}\right)^2} \quad (\text{A2.7})$$

Flight time ($t_f(1)$) for a single floor jump if rated speed v_m is reached instantaneously:

$$t_f(1) = \frac{d_f}{v_m} + \frac{a}{j} + \frac{v_m}{a} \quad (\text{A2.8})$$

Flight time ($t_f(1)$) for a single floor jump of d_f if speed (v) is less than rated speed v_m :

$$t_f(1) = \frac{a}{j} + \sqrt{\frac{4d_f}{a} + \left(\frac{a}{2j}\right)^2} \quad (\text{A2.9})$$

The flight times given by equations A2.8 and A2.9 are most important times when carrying out traffic calculations.

A2.3 Example

Using the equations above consider a gearless system with the following parameters:

$$v_m = 5.0 \text{ m/s}; a = 1.0 \text{ m/s}^2; j = 1.5 \text{ m/s}^3; d_f = 5.0 \text{ m}$$

Distance (s_a) to reach rated acceleration (a), using equation A2.2:

$$s_a = \frac{1.0^3}{6 \times 1.52} = 0.074 \text{ m}$$

Time (t_a) to reach rated acceleration using equation A2.3:

$$t_a = 1.0/1.5 = 0.67 \text{ s}$$

Speed (v_a) at rated acceleration using equation A2.4:

$$v_a = \frac{1.0^2}{2 \times 1.5} = 0.33 \text{ m/s}$$

Distance (s_{vm}) to reach rated speed (v_m) using equation A2.5:

$$s_{vm} = \frac{5.02}{2 \times 1.0} + \frac{1.0 \times 5.0}{2 \times 1.5} = 14.17 \text{ m}$$

Time (t_{vm}) to reach rated speed using equation A2.6:

$$t_{vm} = \frac{5.0}{1.0} + \frac{1.0}{1.5} = 5.67 \text{ s}$$

Maximum speed (v) reached for a single floor jump of d_f using equation A2.7:

$$v = -\frac{1.0^2}{2 \times 1.5} + \sqrt{\left(1.0 \times 5.0\right) + \left(\frac{1.0^2}{2 \times 1.5}\right)^2} = 1.93 \text{ m/s}$$

Flight time ($t_f(1)$) for a single floor jump if v is less than v_m using equation A2.9:

$$t_f(1) = \frac{1.0}{1.5} + \sqrt{\frac{4 \times 5.0}{1.0} + \left(\frac{1.0}{1.5}\right)^2} = 5.19 \text{ s}$$

A2.4 Comparison three typical lift systems

Table A2.1 gives the results for three systems. The first is typical of a geared system, the second is typical of a high-speed gearless system (examined in section A2.3 above) and the third is for a super-fast system. All the results are for ideal kinematics and do not include any start delays or levelling times, which must be added.

Table A2.1 Data and results for three lift systems

Parameter	Geared	Gearless	Super-fast
d_f Trip distance (m)	5.0	5.0	400
v_m Speed (m/s)	1.6	5.0	16.8
a Acceleration (m/s^2)	0.6	1.0	1.2
j Jerk (m/s^3)	0.8	1.5	1.8
$t_f(1)$ Flight time for trip distance (s)	6.57	5.19	38.5
v Maximum speed reached during trip (m/s)	1.52	1.93	16.8
s_a Distance to reach rated acceleration (m)	0.06	0.07	0.09
t_a Time to reach rated acceleration (s)	0.75	0.67	0.67
v_a Speed at rated acceleration (m/s)	0.22	0.33	0.40
s_{vm} Distance to reach rated speed (m)	2.73	14.17	123.20
t_{vm} Time to reach rated speed (s)	3.42	5.67	14.67

The geared and gearless systems do not reach the rated speed over a trip distance of 5.0 m. To achieve this the geared system requires a minimum distance of 5.46 m (2×2.73) and the gearless system requires a minimum distance of 28.34 m (2×14.17), i.e. a 5-floor jump.

The super-fast system requires a trip of some 250 m, in order to reach its rated speed mid-flight and will take at least 30 s for the trip.

A2.5 Measurement

Ideal and measured performance can be compared using an accelerometer combined with software that plots the ideal kinematics curves (Peters, 1996; Anderson, 2007). Figure A2.3 shows idealised and measured acceleration/deceleration plotted together for comparison. A best-fit algorithm can be used to establish the nominal velocity, acceleration and jerk for a particular installation.

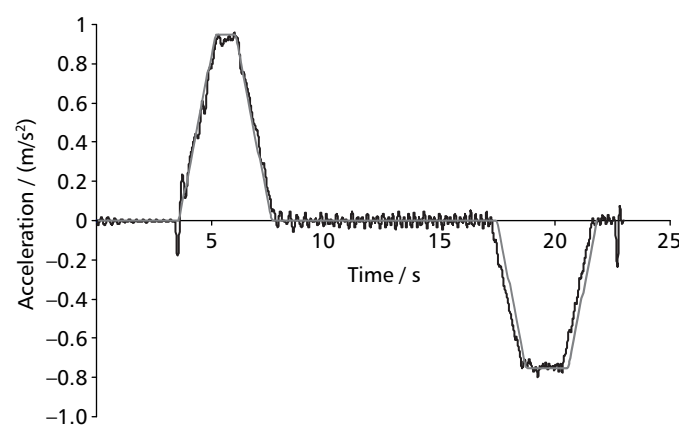


Figure A2.3 Plot of idealised acceleration curve with superimposed measured acceleration for a given rated velocity, rated acceleration/deceleration and rated jerk

Motor start delay and levelling times can be examined in detail. Figure A2.4 shows measurements from an installation with advanced door opening. The advanced door opening is operating correctly, but only overcomes the lost time due to the lift's levelling

operation. A drive system not needing a levelling operation could equal the performance without advance door opening. Performance could be improved by having no levelling operation while maintaining the advanced door opening function.

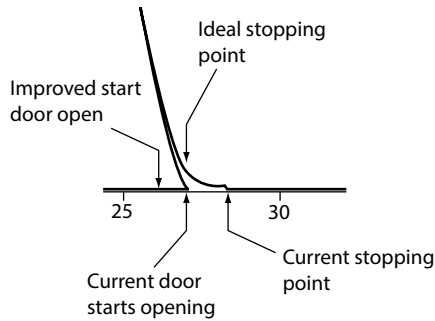


Figure A2.4 Plot of ideal and measured velocity for the stopping phase of a lift with a levelling operation and advanced door opening

A2.6 Advanced modelling of performance time

In traffic planning calculations, it is common for a start delay of 0.5 s and a levelling delay of 0 s to be assumed. A study of major premium office buildings in London (Peters, 2012) found that start delay varied from 0 to 3.5 s and levelling delay between 0 s and 4 s. These delays can have a significant impact on quality of service. Thus it is essential to pay close attention to the lift kinematics if high performance is required.

To model advanced kinematics in simulation requires the definition of performance time presented in chapter 3 to be extended. Peters (2012) has proposed the following extended equation:

$$T(d) = t_f(d) + t_{sd} + t_{ld} + t_c + t_o - t_a \quad (\text{A2.10})$$

where $T(d)$ is the performance time (s) for flight distance d (m), $t_f(d)$ is the flight time (s) for travel distance d (m), t_{sd} is the start delay time (s), t_{ld} is the levelling delay time (s), t_c is the door closing time (s), t_o is the door opening time (s) and t_a is the advanced door opening time (s).

The travel time function $t_f(d)$ is known from kinematics research (Peters, 1996), see chapter 4, equations 4.9, 4.10 and 4.11.

References

- Anderson AM (2007) 'Ideal lift kinematics: equations of motion of a lift with separate acceleration and deceleration' *Int. J. of Elevator Engineers* 7 9–14
- Motz HD (1976) 'On the kinematics of the ideal motion of lifts' *Foerden und haben* 26(1) (in German)
- Motz HD (1991) 'On the kinematics of the ideal motion of lifts' *Elevatori* (January 1991) (in English and Italian)
- Peters RD (1996) 'Ideal lift kinematics: derivation of formulae for the equations of motion of a lift' *Int. J. of Elevator Engineers* 1(1)
- Peters RD (2012) 'Lift performance time' *Proc. 2nd. Symp. on Lift and Escalator Technologies, Northampton, September 2012* 53–64

Appendix A3: Legislation, standards etc. related to lifts, escalators and moving walks

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Warning: the six sections of this appendix list legislation and standards relevant to lifts, escalators and moving walks (passenger conveyors). The lists were as comprehensive and as up-to-date as possible at the time of their preparation (10 May 2015). Some entries indicate 'under review' at the time of publication and readers are advised to seek the latest version. The entries are arranged in numerical and date order. They include entries that are not now current. These may be useful when dealing with equipment not installed to the current requirements. For the latest information readers should consult government web sites regarding current legislation and BSI on-line (<http://bsonline.techindex.co.uk>) regarding current standards.

The European Commission's 'Enterprise and Industry' website (http://ec.europa.eu/enterprise/sectors/mechanical/lifts/index_en.htm) has additional information.

A3.1 Legislation related to lifts, escalators and moving walks

A3.1.1 Relevant European Directives and related documents

86/312/EEG 86/312/EEC 86/312/CEE Commission Directive of 18 June 1986 adapting to technical progress Council Directive 84/529/EEC on the approximation of the laws of the Member States relating to electrically operated lifts.

89/392/EEC Council Directive of 14 June 1989 on the approximation of the laws of Member States relating to machinery.

90/486/EEG 90/486/EEC 90/486/CEE Council Directive of 17 September 1990 amending Directive 84/529/EEC on the approximation of the laws of the Member States relating to electrically operated lifts (90/486/EEC).

95/16/EG 95/16/EC 95/16/CE European Parliament and Council Directive 95/16/EC of 29 June 1995 on the approximation of the laws of the Member States relating to lifts.

95/16/EGVerz 2000 95/16/ECVerz 2000 95/16/CEVerz 2000 00/C292/01 List of notified bodies designated by the

Member States and the EFTA countries (EEA Members) under the new approach Directives.

2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) became applicable on 29 December 2009.

2014/33/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to lifts and safety components for lifts (recast) (Text with EEA relevance) came into force 18 April 2014 and will be applicable on 20 April 2016

A3.1.2 Relevant UK legislation

The Supply of Machinery (Safety) Regulations 1992 Statutory Instruments 1992 No. 3073, as amended by the Supply of Machinery (Safety) (Amendment) Regulations Statutory Instruments 1994 No. 2063 and Supply of Machinery (Safety) (Amendment) Regulations Statutory Instruments 2005 No. 831.

The Supply of Machinery (Safety) Regulations 2008 Statutory Instruments 2008 No.1587.

The Lifts Regulations 1997 Statutory Instruments 1997 No. 831.

The Lifts Regulations 2016 (to be enacted).

The Construction (Design and Management) Regulations 2007 Statutory Instruments 2007 No. 320.

The Construction (Design and Management) Regulations 2015 Statutory Instruments 51 2015 (CDM 2015) came into force on 6 April 2015, replacing CDM 2007.

The Provision and Use of Work Equipment Regulations 1998, Statutory Instruments 1998 No. 2306.

The Lifting Operations and Lifting Equipment Regulations 1998 Statutory Instruments 1998 No. 2307.

A3.2 British national standards related to lifts, escalators and moving walks

PAS 32-1: 1999: *Specification for examination and test of new lifts before putting into service. Electric traction lifts*

PAS 32-2: 1999: *Specification for examination and test of new lifts before putting into service. Hydraulic lifts*

DD 176: 1988: *Data logging and remote monitoring equipment for lifts, escalators and passenger conveyors*

DD 197: 1990: *Recommendations for vandal resistant lifts*

DD 222: 1996: *Rack and pinion lifts*

DD 265: 2008: *Protocol for communications between a lift alarm system and an alarm receiving station (rescue centre). Specification*

BS 302-4: 1987: *Stranded steel wire ropes. Specification for ropes for lifts*

BS 329: 1968: *Specification for steel wire ropes for electric lifts*

CP 407: 1972: *Electric, hydraulic and hand-powered lifts*

BS 1570: 1999: *Lifting tables. Safety requirements for lifting tables*

BS 2655: *Specification for lifts, escalators, passenger conveyors and paternosters:*

- BS 2655-1: 1970: *General requirements for electric, hydraulic and hand powered lifts*
- BS 2655-2: 1959: *Single-speed poly-phase induction motors for driving lifts*
- BS 2655-3: 1971: *Arrangements of standard electric lifts*
- BS 2655-4: 1969: *General requirements for escalators and passenger conveyors*
- BS 2655-5: 1970: *General requirements for paternosters*
- BS 2655-6: 1970: *Building construction requirements*
- BS 2655-7: 1970: *Testing and inspection*
- BS 2655-8: 1971: *Modernization or reconstruction of lifts, escalators and paternosters*
- BS 2655-9: 1970: *Definitions*
- BS 2655-10: 1972: *General requirements for guarding*

BS 3810-8: 1975: *Glossary of terms used in materials handling*

BS 5266-1: 2011: *Emergency lighting. Code of practice for the emergency escape lighting of premises* (incorporating corrigendum dated June 2012)

BS 5323: 1980: *Code of practice for scissor lifts*

BS 5588: *Fire precautions in the design and construction of buildings:*

- BS 5588-5: 1986: *Code of practice for firefighting stairways and lifts*
- BS 5588-5: 1991: *Code of practice for firefighting stairs and lifts*
- BS 5588-5: 2004: *Access and facilities for firefighting*
- BS 5588-8: 1988: *Code of practice for means of escape for disabled people*
- BS 5588-8: 1999: Amd. 2004: *Code of practice for means of escape for disabled people*

BS 5655: *Lifts and service lifts:*

- BS 5655-1: ES: 1981: *Explanatory supplement to BS 5655 Lifts and service lifts Part 1 Safety rules for the construction and installation of electric lifts (EN 81:Part 1)*
- BS 5655-1: 1979, EN 81-1: 1977: *Safety rules for the construction and installation of electric lifts*
- BS 5655-1: 1986, EN 81-1: 1985: *Safety rules for the construction and installation of electric lifts*
- BS 5655-2: 1983: *Lifts and service lifts. Specification for hydraulic lifts*
- BS 5655-2: 1988, EN 81-2: 1987: *Safety rules for the construction and installation of hydraulic lifts*
- BS 5655-3: 1989: *Lifts and service lifts. Specification for electric service lifts*
- BS 5655-5: 1989: *Specification for dimensions of standard lift arrangements*
- BS 5655-6: 1985: *Lifts and service lifts. Code of practice for selection and installation*
- BS 5655-6: 1990: *Lifts and service lifts. Code of practice for selection and installation*
- BS 5655-6: 2002: *Lifts and service lifts. Code of practice for the selection and installation of new lifts*
- BS 5655-6: 2011: *Lifts and service lifts. Code of practice for the selection, installation and location of new lifts*
- BS 5655-7: 1983: *Specification for manual control devices, indicators and additional fittings*
- BS 5655-8: 1983: *Specification for eyebolts for lift suspension*
- BS 5655-9: 1985: *Specification for guide rails*
- BS 5655-10: 1986: *Specification for the testing and inspection of electric and hydraulic lifts*
- BS 5655-10.1.1: 1995: *Specification for the testing and examination of lifts and service. Electric lifts Commissioning test for new lifts*

- BS 5655-10.2.1: 1995: *Specification for the testing and examination of lifts and service. Hydraulic lifts. Commissioning tests for new lifts*
- BS 5655-10.1.2 (draft): *Specification for the testing and examination of lifts and service lifts. Electric lifts. Commissioning tests for modernised lifts*
- BS 5655-10.2.2 (draft): *Specification for the testing and examination of lifts and service lifts. Hydraulic lifts. Commissioning tests for modernised lifts*
- BS 5655-11: 1989: *Recommendations for the installation of new, and the modernization of, electric lifts in existing buildings*
- BS 5655-11: 2005: *Code of practice for the undertaking of modifications to existing electric lifts*
- BS 5655-12: 1989: *Recommendations for the installations of new, and the modernization of, hydraulic lifts in existing buildings*
- BS 5655-12: 2005: *Code of practice for the undertaking of modifications to existing hydraulic lifts*
- BS 5655-13: 1995: *Recommendations for vandal resistant lifts*
- BS 5655-14: 1995: *Specification for hand powered service lifts and platform hoists*
- BS 5656: 1983: *Safety rules for the construction and installation of escalators and passenger conveyors*
- BS 5656: *Safety rules for the construction and installation of escalators and passenger conveyors:*
 - BS 5656-1: 1997: *Safety rules for the construction and installation of escalators and passenger conveyors. Specification and proformas for test and examination of new installations*
 - BS 5656-1: 2013: *Safety rules for the construction and installation of escalators and moving walks. Examination and test of new escalators before putting into service. Specification for means of determining compliance with BS EN 115-1:2008+A1:2010*
 - BS 5656-2: 2004: *Safety rules for the construction and installation of escalators and moving walks. Code of practice for the selection, installation and location of new escalators and moving walks*
 - BS 5656-3:2014: *Safety rules for the construction and installation of escalators and moving walks. Examination and test of new moving walks before putting into service. Specification for means of determining compliance with BS EN 115-1:2008+A1:2010*
- BS 5776: 1996: *Specification for powered stairlifts*
- BS 5810: 1979: *Code of practice for access for the disabled to buildings*
- BS 5900: 1980: *Specification for powered home lifts*
- BS 5900: 1991: *Specification for powered domestic lifts*
- BS 5900: 1999: *Specification for powered domestic lifts with partially enclosed cars and no lift well enclosures*
- BS 5900: 2012: *Powered homelifts with partially enclosed carriers and no liftway enclosures. Specification*
- BS 5965: 1980: *Specification for manually driven balanced personal home lifts*
- BS 6440: 1983: *Code of practice for powered lifting platforms for use by disabled persons*
- BS 6440: 1999: *Power lifting platforms for use by disabled persons. Code of practice*
- BS 6440:2011: *Powered vertical lifting platforms having non-enclosed or partially enclosed liftways intended for use by persons with impaired mobility. Specification*
- PD 6523: 1989: *Information on access to and movement within and around buildings and on certain facilities for disabled people*
- PD 6500: 1984: *Explanatory supplement to BS 5655 'Lifts and service lifts' Part 1 'Safety rules for the construction and installation of electric lifts' (EN 81: Part 1)*
- PD 6500: 1986: *Explanatory supplement to BS 5655 'Lifts and service lifts' Part 1 'Safety rules for the construction and installation of electric lifts' (EN 81: Part 1)*
- BS 6977: 1981: *Specification for insulated flexible cables for lifts and for other flexible connections*
- BS 6977: 1991: *Specification for insulated flexible cables for lifts and for other flexible connections*
- BS 7255: 1989: *Code of practice for safe working on lifts*
- BS 7255: 2001: Amd. 2002: *Code of practice for safe working on lifts*
- BS 7255: 2012: *Code of practice for safe working on lifts*
- BS 7671: 2008: *Requirements for electrical installations. IEE Wiring Regulations. Seventeenth edition*
- BS 7671: Amendment 2: August 2013: *Requirements for Electrical Installations IET Wiring Regulations Seventeenth Edition*
- BS 7671: 2008 + A3: 2015: *Requirements for Electrical Installations IET Wiring Regulations Seventeenth Edition*
- BS 7801: 1995: *Code of practice for safe working on escalators and passenger conveyors in use*
- BS 7801: 2004: *Code of practice for safe working on escalators and moving walks*
- BS 7801: 2011: *Escalators and moving walks. Code of practice for safe working on escalators and moving walks*
- BS 8486: *Examination and test of new lifts before putting into service:*
 - BS 8486-1: 2007: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Electric lifts*
 - BS 8486-1: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Electric lifts*

- BS 8486-2: 2007: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Hydraulic lifts*
- BS 8486-2: 2007 + A1: 2011: *Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Hydraulic lifts*

BS 9102: 2014: *Code of practice for safe working on lifting platforms*

A3.3 European (CEN) standards related to lifts, escalators and moving walks

BS EN 81: *Safety rules for the construction and installation of lifts and service lifts:*

- BS EN 81-1: 1998: *Safety rules for the construction and installation of lifts and service lifts. Electric lifts*
- BS EN 81-1: 1998 + A1 + A2: Consolidated 2006: *Safety rules for the construction and installation of lifts and service lifts. Electric lifts*
- BS EN 81-1: 1998 + A3: 2009: Consolidated BS EN 81-1: 1998 + A1: 2005 + A2: 2004 + A3: 2009 + corrigendum September 1999: *Safety rules for the construction and installation of lifts and service lifts. Electric lifts*
- BS EN 81-2: 1998: *Safety rules for the construction and installation of lifts and service lifts. Hydraulic lifts*
- BS EN 81-2 + A1 + A2: Consolidated 2006: *Safety rules for the construction and installation of lifts and service lifts. Hydraulic lifts*
- BS EN 81-2: 1998 + A3: 2009: Consolidated BS EN 81-2: 1998 + A1: 2005 + A2: 2004 + A3: 2009 + corrigendum September 1999: *Safety rules for the construction and installation of lifts and service lifts. Hydraulic lifts*
- BS EN 81-3: 2000 + A1: 2008: *Safety rules for the construction and installation of lifts and service lifts. Electric and hydraulic service lifts*
- prEN 81-5: *Safety rules for the construction and installation of lifts and service lifts. Screw lifts*
- prEN 81-6: *Safety rules for the construction and installation of lifts and service lifts. Guided chain lifts*
- prEN 81-7: 2002: *Safety rules for the construction and installation of lifts and service lifts. Rack and pinion lifts*
- prEN 81-7: 2009: *Safety rules for the construction and installation of lifts and service lifts. Rack and pinion lifts (under review)*
- PD CEN/TR81-10: 2004: *Safety rules for the construction and installation of lifts. Basics. System of the EN 81 series of standards*
- PD CEN/TR81-10: 2008: *Safety rules for the construction and installation of lifts. Basics and interpretations. System of the EN 81 series of standards*
- DD CEN/TS81-11: 2009: *Safety rules for the construction and installation of lifts. Basics and interpretations. Interpretations related to EN 81 family of standards*
- DD CEN/TS 81-11: 2011: *Safety rules for the construction and installation of lifts. Basics and interpretations. Interpretations related to EN 81 family of standards*
- PD CEN/TR 81-12: 2014: *Safety rules for the construction and installation of lifts Basics and interpretations. Use of EN 81-20 and EN 81-50 in specific markets*
- BS EN 81-20: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts*
- BS EN 81-21: 2009: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. New passenger and goods passenger lifts in existing building*
- BS EN 81-21: 2009 + A1: 2012: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. New passenger and goods passenger lifts in existing building*
- BS EN 81-22: 2014: *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Electric lifts with inclined path*
- BS EN 81-28: 2003: *Safety rules for the construction and installation of lifts. Remote alarms on passenger and goods passenger lifts*
- DD CEN/TS 81-29: 2004: *Safety rules for the construction and installation of lifts. Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Interpretations related to EN 81-20 up to EN 81-28 (includes EN 81-1:1998 and EN 81-2:1998)*
- BS EN 81-31: 2010: *Safety rules for the construction and installation of lifts. Lifts for the transport of goods only. Accessible goods only lifts*
- BS EN 81-40: 2008: *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Stairlifts and inclined lifting platforms intended for persons with impaired mobility (formerly EN 81-32)*
- BS EN 81-41: 2010: *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Vertical lifting platforms intended for use by persons with impaired mobility (formerly EN81-31)*
- BS EN 81-43: 2009: *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Lifts for cranes*
- BS EN 81-50: 2014: *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components*
- BS EN 81-58: 2003: *Safety rules for the construction and installation of lifts. Examination and tests. Landing doors fire resistance test (formerly EN 81-8)*
- BS EN 81-70: 2003: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Accessibility to lifts for persons including persons with disability*

- BS EN 81-71: 2005: *Safety rules for the construction and installation of lifts. Particular applications to passenger lifts and goods passenger lifts. Vandal resistant lifts*
- BS EN 81-72: 2003: *Rules for lifts which remain in use in case of fire (Firefighters lifts)*
- BS EN 81-72: 2015: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Firefighters lifts*
- BS EN 81-73: 2005: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Behaviour of lifts in the event of fire*
- BS EN 81-73 Amd 1: 2009: 09/30201228 DC: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Part 73. Behaviour of lifts in the event of fire*
- prEN 81-73: 2013: *Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Part 73: Behaviour of lifts in the event of fire*
- DD CEN/TS 81-76: 2011: *Safety rules for the construction and installation of lifts. Particular applications for passengers and goods passenger lifts. Part 76: Evacuation of disabled persons using lifts*
- BS EN 81-77: 2013: *Safety rules for the construction and installations of lifts. Particular applications for passenger and goods passenger lifts. Lifts subject to seismic conditions*
- BS EN 81-80: 2003: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of safety of existing passenger and goods passenger lifts*
- DD CEN/TS 81-82: 2008: *Safety rules for the construction and installation of lifts. Existing lifts. Improvement of the accessibility of existing lifts for persons including persons with disability*
- BS EN 81-82: 2013: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of the accessibility of existing lifts for persons including persons with disability*
- DD CEN/TS 81-83: 2009: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of the resistance against vandalism*
- BS EN 115: 1995: *Safety rules for the construction and installation of escalators and passenger conveyors*
- BS EN 115 + prA1: 1998: *Safety rules for the construction and installation of escalators and passenger conveyors; Amendment A1*
- BS EN 115 + A1 + A2: 2006: Consolidated 2006: *Safety rules for the construction and installation of escalators and passenger conveyors; Amendment A1*
- BS EN 115-1: 2008: *Safety of escalators and moving walks. Construction and installation*
- BS EN 115-1: 2008 + A1: 2010: *Safety of escalators and moving walks. Construction and installation*
- prEN 115-1: 2014: *Safety of escalators and moving walks. Construction and installation*
- BS EN 115-2: 2010: *Safety of escalators and moving walks. Rules for the improvement of safety of existing escalators and moving walks*
- PD CEN/TR 115-3: 2009: *Safety of escalators and moving walks. Correlation between EN 115:1995 and its amendments and EN 115-1:2008*
- PD CEN/TS 115-4: 2014: *Safety of escalators and moving walks. Interpretations related to EN 115 family of standards*
- BS EN 292-1: 1991: *Safety of machinery. Basic concepts, general principles for design. Basic terminology, methodology*
- BS EN 292-2: 1991: *Safety of machinery. Basic concepts, general principles for design. Technical principles and specifications*
- BS EN 627: 1996: *Specification for data logging and monitoring of lifts, escalators and passenger conveyors*
- BS EN 1050: 1997: *Safety of machinery. Principles for risk assessment*
- BS EN 1570-1: 2011 + A1: 2014: *Safety requirements for lifting tables. Lifting tables serving up to two fixed landings*
- BS EN ISO 10535: 1998: *Hoists for the transfer of disabled persons. Requirements and test methods*
- BS EN 12015: 1998: *Electromagnetic compatibility Product family standard for lifts, escalators and passenger conveyors. Emission*
- BS EN 12015: 2004: *Electromagnetic compatibility Product family standard for lifts, escalators and passenger conveyors. Emission*
- BS EN 12015: 2014: *Electromagnetic compatibility. Product family standard for lifts, escalators and moving walks. Emission*
- BS EN 12016: 1998: *Electromagnetic compatibility. Product family standard for lifts, escalators and passenger conveyors. Immunity*
- BS EN 12016: 2004: *Electromagnetic compatibility. Product family standard for lifts, escalators and passenger conveyors. Immunity*
- BS EN 12016: 2004 + A1: 2008: *Electromagnetic compatibility. Product family standard for lifts, escalators and moving walks. Immunity*
- BS EN 12016: 2013: *Electromagnetic compatibility. Product family standard for lifts, escalators and moving walks. Immunity*
- BS EN ISO 12100-1: 2003: *Safety of machinery. Basic concepts, general principles for design*
- BS EN 12158: 2000: *Builders hoists for goods:*
 - BS EN 12158-1: 2000: *Builders hoists for goods. Hoists with accessible platforms*
 - BS EN 12158-2: 2000: *Builders hoists for goods. Inclined hoists with non-accessible load carrying devices*

BS EN 12183: 1999: *Manually propelled wheelchairs Requirements and test methods*

BS EN 12184: 1999: *Electrically powered wheelchairs, scooters and their chargers. Requirements and test methods*

EN 12385-5: 2002: *Steel wire ropes. Safety. Stranded ropes for lifts*

BS EN 13015: 2001: *Maintenance for lifts and escalators. Rules for maintenance instructions*

BS EN 13015: 2001 + A1: 2008: *Maintenance for lifts and escalators. Rules for maintenance instructions*

BS EN 50214: 1998: *Flexible cables for lifts*

BS EN ISO 14798: 2013: *Lifts (elevators), escalators and moving walks. Risk assessment and reduction methodology*

BS EN 61508: *Functional safety of electrical/electronic/programmable electronic safety-related systems:*

- BS EN 61508-1: 2002 (IEC 61508-1: 1998 + Corrigendum 1999): *Functional safety of electrical/electronic/programmable electronic safety-related systems. General requirements*
- BS EN 61508-1: 2010 (IEC 61508-1: 2010): *Functional safety of electrical/electronic/programmable electronic safety-related systems. General requirements*
- BS EN 61508-2: 2002 (IEC 61508-2: 2000): *Functional safety of electrical/electronic/programmable electronic safety-related systems. Requirements for electrical/electronic/programmable electronic safety-related systems*
- BS EN 61508-2: 2010 (IEC 61508-2: 2010): *Functional safety of electrical/electronic/programmable electronic safety-related systems. Requirements for electrical/electronic/programmable electronic safety-related systems*
- BS EN 61508-3: 2002 (IEC 61508-3: 1998 + Corrigendum 1999): *Functional safety of electrical/electronic/programmable electronic safety-related systems. Software requirements*
- BS EN 61508-3: 2010 (IEC 61508-2: 2010): *Functional safety of electrical/electronic/programmable electronic safety-related systems. Software requirements*
- BS EN 61508-4: 2002 (IEC 61508-4: 1998 + Corrigendum 1999): *Functional safety of electrical/electronic/programmable electronic safety-related systems. Definitions and abbreviations*
- BS EN 61508-4: 2010 (IEC 61508-4: 2010): *Functional safety of electrical/electronic/programmable electronic safety related systems. Definitions and abbreviations*
- BS EN 61508-5: 2002 (IEC 61508-5: 1998 + Corrigendum 1999): *Functional safety of electrical/electronic/programmable electronic safety-related systems. Examples of methods for the determination of safety integrity levels*
- BS EN 61508-5: 2010 (IEC 61508-5: 2010): *Functional safety of electrical/electronic/programmable electronic safety related systems. Examples of methods for the determination of safety integrity levels*

— BS EN 61508-7: 2002 (IEC 61508-7: 2000): *Functional safety of electrical/electronic/programmable electronic safety-related systems. Overview of techniques and measures*

— BS EN 61508-7: 2010 (IEC 61508-7: 2010): *Functional safety of electrical/electronic/programmable electronic safety related systems. Overview of techniques and measures*

BS EN 62305: *Protection against lightning:*

— BS EN 62305-3: 2006: *Protection against lightning. Physical damage to structures*

— BS EN 62305-4: 2006: *Protection against lightning. Electrical and electronic systems within structures*

A3.4 International standards related to lifts, escalators and moving walks

BS ISO 4190-1: 1999: *Lift (US: Elevator) installation. Class I, II, III and VI lifts*

BS ISO 4190-1: 2010: *Lift (Elevator) installation. Class I, II, III and VI lifts*

BS ISO 4190-2: 2001: *Lift (US: Elevator) installation. Class IV lifts*

ISO 4190-3: 1982: *Passenger lift installations. Service lifts class V*

ISO 4190-5: 1987: *Lifts and service lifts (USA: Elevators and dumbwaiters). Control devices, signals and additional fittings*

BS ISO 4190-5: 2006: *Lift (elevator) installation. Control devices, signals and additional fittings*

ISO 4190-6: 1984: *Lifts and service lifts (USA : elevators and dumbwaiters). Passenger lifts to be installed in residential buildings. Planning and selection (under review)*

ISO 4344: 2004: *Steel wire ropes for lifts. Minimum requirements*

ISO 7193: 1985: *Wheelchairs. Maximum overall dimensions*

ISO 7465: 2001: *Passenger lifts and service lifts. Guide rails for lift cars and counterweights. T-type*

ISO 7465 : 2007: *Passenger lifts and service lifts. Guide rails for lift cars and counterweights. T-type*

ISO/DIS 7465: 2005: *Passenger lifts and service lifts. Guide rails for lift cars and counterweights. T-type*

ISO 8383: 1985: *Lifts on ships. Specific requirements*

ISO 9386: *Power-operated lifting platforms for persons with impaired mobility:*

— ISO 9386-1: 2000: *Power-operated lifting platforms for persons with impaired mobility. Rules for safety, dimensions and functional operation. Vertical lifting platforms*

- ISO 9386-2: 2000: *Power-operated lifting platforms for persons with impaired mobility. Rules for safety, dimensions and functional operation. Powered stairlifts for seated, standing and wheelchair users moving in an inclined plane*
- ISO 9589: 1994: *Escalators. Building dimensions*
- ISO/TR 11071-1: 1990: *Comparison of worldwide lift safety standards. Electric lifts (elevators)*
- ISO/TR 11071-1: 1990: Amd 1: 1999: *References to Japanese standards*
- ISO/TR 11071-1: 1990: Amd 2: 2001: *References to Australian standards*
- ISO/TR 11071-2: 1996: *Comparison of worldwide lift safety standards. Hydraulic lifts (elevators)*
- ISO/TR 11071-2: 1996: Amd 1: 1999: *References to Japanese and Australian standards*
- PD ISO/TR 11071-1: 2004: *Comparison of worldwide lift safety standards. Electric lifts (elevators)*
- ISO/TR 11071-2: 1996: *Comparison of worldwide lift safety standards. Hydraulic lifts (elevators)*
- ISO/TR 11071-2: 1996: Amd 1: 1999: *References to Japanese and Australian standards*
- ISO/TS 14798: 2000: *Lifts (elevators), escalators and passenger conveyors. Risk analysis methodology*
- DD ISO/TS 14798: 2006: *Lifts (elevators), escalators and moving walks. Risk assessment and reduction methodology*
- BS ISO 14798: 2009: *Lifts (elevators), escalators and moving walks. Risk assessment and reduction methodology*
- ISO/TR 16764: 2003: *Lifts, escalators and passenger conveyors. Comparison of worldwide standards on electromagnetic interference/electromagnetic compatibility*
- ISO/TR 16765: 2003: *Comparison of worldwide safety standards on lifts for firefighters*
- BS ISO 18738: 2003: *Lifts (elevators). Measurement of lift ride quality*
- prBS ISO 18738-1: 2010: *Measurement of lift ride quality. Lifts (elevators)*
- BS ISO 18738-2: 2012: *Measurement of ride quality. Escalators and moving walks*
- PD ISO/TS 18870: 2014: *Lifts (elevators). Requirements for lifts used to assist in building evacuation*
- BS ISO 22199: 2009: *Electromagnetic compatibility. Product family standard for lifts, escalators and moving walks. Emission*
- BS ISO 22200: 2009: *Electromagnetic compatibility. Product family standard for lifts, escalators and moving walks. Immunity*
- BS ISO 22201: 2009: *Lifts (elevators). Design and development of programmable electronic systems in safety-related applications for lifts (PESSRAL)*
- BS ISO 22201-2: 2013: *Lifts (elevators), escalators and moving walks. Programmable electronic systems in safety related applications. Escalators and moving walks (PESSRAE)*
- PD ISO/TR 22201-3: 2013: *Lifts (elevators), escalators and moving walks. Programmable electronic systems in safety related applications. Life cycle guideline for programmable electronic systems related to PESSRAL and PESSRAE*
- DD ISO/TS 22559-1: 2004: *Safety requirements for lifts (elevators). Global safety requirements (GESRs) for lifts (elevators)*
- BS ISO 22559-1: 2014: *Safety requirements for lifts (elevators). Global essential safety requirements (GESRs)*
- DD ISO/TS 22559-2: 2010: *Safety requirements for lifts (elevators). Safety parameters meeting the global essential safety requirements (GESRs)*
- DD ISO/TS 22559-3: 2011: *Safety requirements for lifts (elevators). Global conformity assessment procedures (GCAP). Prerequisites for certification of conformity of lift systems, lift components and lift functions*
- DD ISO/TS 22559-4: 2011: *Safety requirements for lifts (elevators). Global conformity assessment procedures (GCAP). Certification and accreditation requirements*
- ISO/DTS 25740-1: 2007: *Safety requirements for escalators and moving walks. Global essential safety requirements (GESRs)*
- DD ISO/TS 25740-1: 2011: *Safety requirements for escalators and moving walks. Global essential safety requirements (GESR)*
- ISO/TR 25741: 2008: *Lifts and escalators subject to seismic conditions. Compilation report*
- ISO/DTR 25743: 2009: *Lifts (elevators). Study into the use of lifts for evacuation during an emergency*
- PD ISO/TR 25743: 2010: *Lifts (elevators). Study of the use of lifts for evacuation during an emergency*
- ISO/CD 25744: 2007: *Escalators and moving walks. Measurement of ride quality*
- BS EN ISO 25745-1: 2012: *Energy performance of lifts, escalators and moving walks. Energy measurement and verification*
- BS EN ISO 25745-2: 2015: *Energy performance of lifts, escalators and moving walks. Energy calculation and classification for lifts (elevators)*
- BS EN ISO 25745-3: 2015: *Energy performance of lifts, escalators and moving walks. Energy calculation and classification of escalators and moving walks*

A3.5 Standards relating to access and movement of people with disabilities in buildings

BS EN 81-40: 2008: *Stairlifts and inclined lifting platforms intended for persons with impaired mobility*

prEN 81-41: 2008 (ISO/FDIS 9386-1): *Vertical lifting platforms*

BS EN 81-41: 2010: *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Vertical lifting platforms intended for use by persons with impaired mobility (formerly EN81-31)*

BS EN 81-70: 2003: *Rules for accessibility of disabled people to lifts*

prCEN/TR 81-76: 2006: *Evacuation of disabled persons using lifts*

DD CEN/TS 81-82: 2008: *Safety rules for the construction and installation of lifts. Existing lifts. Improvement of the accessibility of existing lifts for persons including persons with disability*

BS EN 81-82: 2013: *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of the accessibility of existing lifts for persons including persons with disability*

EP 230: 2001: *BSI Electronic Book. Disability Access (BS 8300:2001)* (CD-ROM)

BS 5588-8: 1999: *Fire precautions in the design, construction and use of buildings. Code of practice for means of escape for disabled people*

BS 5588-8: 1999: Amd 2004: *Code of practice for means of escape for disabled people*

BS 5776: 1996: *Specification for powered stairlifts*

BS 5900: 1999: *Specification for powered domestic lifts with partially enclosed cars and no lift well enclosures*

BS 5900: 2012: *Powered homelifts with partially enclosed carriers and no liftway enclosures. Specification*

BS 5965: 1980: *Specification for manually driven balanced personal home lifts*

BS 6440: 1999: *Power lifting platforms for use by disabled persons. Code of practice*

BS 6440:2011: *Powered vertical lifting platforms having non-enclosed or partially enclosed liftways intended for use by persons with impaired mobility. Specification*

PD 6523: 1989: *Information on access to and movement within and around buildings and on certain facilities for disabled people*

BS 8300: 2001: *Design of buildings and their approaches to meet the needs of disabled people. Code of practice*

BS 8300: 2009 + A1: 2010: *Design of buildings and their approaches to meet the needs of disabled people. Code of practice*

Draft BS 9266: *Design of accessible and adaptable general needs housing. Code of practice*

BS 9991: 2011: *Fire safety in the design, management and use of residential buildings. Code of practice*

BS 9999: 2008: *Code of practice for fire safety in the design, management and use of buildings*

BS EN ISO 10535: 1998: *Hoists for the transfer of disabled persons. Requirements and test methods*

BS EN 12182: 1999: *Technical aids for disabled persons. General requirements and test methods*

ISO/DTR 25743: 2010: *Lifts (elevators). Study into the use of lifts for evacuation during an emergency*

A3.6 Interpretations to EN 81

Safety standards are very necessary, but the documents that describe them often require detailed study to obtain a full understanding. Sometimes the meaning is still unclear and hence the use of requests for interpretations. It is very important that designers, manufacturers, installers, maintainers, owners, inspectors and consultants keep up-to-date with such interpretations.

BSI publishes EN 81-11: *Safety rules for the construction and installation of lifts. Basics and interpretations. Interpretations related to the EN 81 family of standards* as DD CEN/TS 81-11: 2011.

EN 81-11 contains a listing and description of interpretations to the current 1998 versions of EN 81-1/2 (series number greater than 500) and a cross-reference to those interpretations still relevant made to the earlier EN 81-1/2 standards (series up to 272). These latter interpretations were published by BSI in HB 10105: 2000: *Lifts handbook. An explanatory supplement to BS 5655: Parts 1 and 2*. This has been withdrawn from the BSI catalogue. These interpretations may apply to BS EN 81-20: 2014 and BS EN 81-50: 2014.

Table A3.1 gives the interpretation number on a clause-by-clause basis with a X in the column of the standards relevant to the clause. Only a brief description is given, so it will necessary to examine the actual text to understand the full meaning.

New interpretations are issued on an *ad hoc* timescale. Eventually these are collected together and published. This does mean a practitioner's knowledge can become out-of-date. *Elevatori*, the European lift magazine (<http://www.elevatori.it>), publishes the basic text of each new interpretation shortly after it becomes agreed. Table A3.2 provides further interpretations to BS EN 81-1/2 not listed in DD CEN/TS 81-29: 2004.

Tables A3.3 to A3.7 list interpretations to BS EN 81-28: 2003, BS EN 81-58: 2003, BS EN 81-70: 2003, BS EN 81-72: 2003 and BS EN 81-73:2005.



Warning: interpretations do not have the same status as the standards to which they are related. However the application of interpretations should give to the interested parties confidence that the relevant standard has not been wrongly applied.

Table A3.1 List of interpretations to BS EN 81-1/2

Clause	No.	Brief description	EN 81-1			EN 81-2	
			1978	1985	1998	1987	1998
0.1.2.1	249	Diverter pulleys made of plastic		X	X	X	X
1.2	532	Maximum allowable pressure					X
1.3	532	Maximum allowable pressure					X
1.3(g)	524	Speeds less than 1 m/s					X
3	140	Clear height of car	X	X	X	X	X
3	166	Definition of permanent lifting equipment	X	X	X	X	X
3	553	Electric safety chain			X		X
5.2.2.1.1	58	Signs on inspection traps	X	X	X	X	X
5.2.2.1.2	216	Requirement of emergency doors		X	X	X	X
5.3.1.2	518	Use of glass in partially enclosed wells				X	X
5.3.1.2	567	Glass walls, floor and ceiling of well				X	X
5.3.2.2	517	Strength of floor under buffers				X	X
5.3.2.3	517	Strength of floor under buffers				X	X
5.4.3.2.1(a)	156	Distances to walls (entrance sides)	X	X	X	X	X
5.4.3.2.2	25	Prevention of misuse of car door locking mechanism	X	X	X	X	X
5.6.1	501	Protection in well				X	X
5.6.1	568	Counterweight screen			X		X
5.6.2	568	Counterweight screen			X		X
5.7	565	Clearances in the headroom and the pit				X	X
5.7.1.1	251	Distance between the guides of yoke and car at the same guide rail				X	X
5.7.1.1(c)	212	Free vertical distance above diverter pulleys on the car		X	X	X	X
5.7.1.1(d)	122	Standing area, location on car roof		X	X	X	X
5.7.2.1	229	Distance between counterweight and bottom of the pit				X	X
5.7.2.2	539	Accessibility of pit				X	X
5.7.2.3(b)(2)	157	Clearances in pit				X	X
5.7.2.3	229	Distance between counterweight and bottom of the pit				X	X
5.7.2.5(a)	121	Types of stop switch				X	X
5.7.3.2	539	Accessibility of pit				X	X
5.7.3.3(b)(2)	157	Clearances in pit	X	X	X		
5.7.3.4	121	Types of stop switch	X	X	X		
5.8	22	Use of sprinkler systems	X	X	X	X	X
5.8	231	Main earth cables inside the well	X	X	X	X	X
5.9	516	50 lux well lighting			X		X
5.9	551	Well lighting				X	X
5.10	534	Alarm devices in pit				X	X
6.1.2	566	Diverter pulleys in the headroom				X	X
6.1.2	272	Diverter pulleys in the well, location at the pedestal of the jack				X	X
6.1.2.1.1	73	Pulleys at top of well		X	X	X	X
6.1.2.1.1	239	Protection of diverter pulleys in the pit		X	X		
6.1.2.1.1	248	Maintenance on rope terminations		X	X	X	X
6.1.2.1.2(b)	113	Dimensioning of openings between machine room and well	X	X	X		
6.1.2.1.4(c)	271	Protection at pulleys, introduction of objects, dimension of objects		X	X		
6.1.2.3	234	Maintenance of air conditioners inside machine room		X	X	X	X
6.2.2(b)	536	Access to the interior of machine room		X	X		
6.3.2.1	3	Machine room, maintenance areas	X	X	X	X	X
6.3.3.2	105	Protective measures on trapdoors	X	X	X	X	X
6.3	569	Machine rooms and overhead pulleys				X	X
6.3.5.2	234	Maintenance of air conditioners inside the machine room		X	X	X	X
6.3.6	550	Machine room lighting				X	X
6.3.7	220	Installation for heavy equipment hoisting		X	X	X	X
6.4	569	Machine rooms and overhead pulleys				X	
6.4.3.1	105	Protective measures on trapdoors	X	X	X	X	X
6.7.3.3(b)(2)	547	Pit depth			X		
6.7.2.3(b)(2)	547	Pit depth					X
7	269	Additional means for security locking at landing doors		X	X	X	X
7.1.1	50	Handles on sliding doors	X	X	X	X	X
7.1.1	170	Design of edges of doors	X	X	X	X	X
7.1.1	192 A	Design of closing edges of doors	X	X	X	X	X
7.4.3.1	132	Suspension for vertically sliding doors	X	X	X	X	X

Table continues

Table A3.1 List of interpretations to BS EN 81-1/2 — *continued*

Clause	No.	Brief description	EN 81-1			EN 81-2	
			1978	1985	1998	1987	1998
7.5.1	192 A	Design of closing edges of doors	X	X	X	X	X
7.5.2	171	Design of large landing and car doors		X	X	X	X
7.5.2.1.1.1	49A	Closing force limiter	X	X	X	X	X
7.5.2.1.1.1	187	Solutions of closing-force limitations	X	X	X	X	X
7.5.2.1.1.1	197	Measurement of the closing force		X	X	X	X
7.5.2.1.1.3	49A	Closing force limiter	X	X	X	X	X
7.5.2.1.1.3	106	Protective devices on doors	X	X	X	X	X
7.5.2.1.1.3	128	Protective device arrangement on centre opening doors	X	X	X	X	X
7.5.2.1.1.3	158	Actuating force for door protective devices	X	X	X	X	X
7.5.2.1.1.3	187	Solutions of closing-force limitations	X	X	X	X	X
7.5.2.1.2	171	Design of large car doors and landing doors		X	X	X	X
7.5.2.2	23	Requirements for vertically-sliding doors	X	X	X	X	X
7.5.2.2	172	Design of vertically sliding car and landing doors		X	X	X	X
7.7.2.1	196	Energising the brake		X	X	X	X
7.7.2.1	207	Preliminary operations				X	X
7.7.2.2	196	Energising the brake		X	X	X	X
7.7.3	222	Type examination of door locking devices		X	X	X	X
7.7.3	227	Power operated opening of car door		X	X	X	X
7.7.3.2	50	Handles on sliding doors	X	X	X	X	X
7.7.3.2	171	Design of large landing and car doors		X	X	X	X
7.7.4.1	222	Type examination of door locking devices		X	X	X	X
7.7.5.1	222	Type examination of door locking devices		X	X	X	X
7.7.6	99	Linkage of door panels (strength)	X	X	X	X	X
7.7.6.1	100	Linkage of door panels (fire resistance)	X	X	X	X	X
8.1.1	140	Clear height of car	X	X	X	X	X
8.2.1	544	Available car area				X	X
8.2.1	131	Recesses in lift car	X	X	X	X	X
8.2.1	191	Available car area	X	X	X	X	X
8.2.2	63	Loading devices and rated load	X	X	X		
8.2.2	191	Available car area				X	X
8.2.2	206	Use of handling devices, calculation		X	X		
8.2.2.3	226	Calculation of the jack				X	X
8.2.2.4	523	Good lift rated load					X
8.2.3	63	Loading devices and rated load				X	X
8.2.3	206	Use of handling devices, calculation				X	X
8.3	202	Cars made of wood		X	X	X	X
8.3	211	Advertising message in the car		X	X	X	X
8.3	261	Mirrors at the walls of the car		X	X	X	X
8.3.2.1	24	Defined area for door strength calculations	X	X	X	X	X
8.4.1	193	Reduction of the distance between car sill and landing door sill	X	X	X	X	X
8.6.1	32	Mesh width of mesh panel doors	X	X	X	X	X
8.6.1	172	Design of vertically sliding car- and landing doors		X	X	X	X
8.6.6	132	Suspension for vertically sliding doors	X	X	X	X	X
8.7.2.1.1.1	187	Solutions of closing-force limitations	X	X	X	X	X
8.7.2.1.1.1	197	Measurement of the closing force		X	X	X	X
8.7.2.1.1.3	158	Actuating force for door protective devices	X	X	X	X	X
8.7.2.1.1.3	180	Protective device on car folding doors	X	X	X	X	X
8.7.2.1.1.3	187	Solutions of closing-force limitations	X	X	X	X	X
8.12.4	31	Emergency car doors	X	X	X	X	X
8.13	571	Balustrade height, etc.			X		X
8.13.3	572	Balustrade height, etc.					X
8.17.1	260	Switching off the car lighting		X	X	X	X
8.17.3	130	Emergency lighting in lift car		X	X	X	X
8.17.4	549	Car lighting				X	X
8.18.2(a)	141	Rope restraint on counterweight pulleys	X	X	X		
8.18.3	164	Emergency machine for traction drive lifts	X	X	X		
9.1.2	561	Suspension ropes			X		X
9.3	33	Traction sheave with groove inserts	X	X	X		
9.3.1	165	Traction examination	X	X	X		
9.3.1(a)	270	Traction, lifting of the empty car, duration of the test		X	X		
9.3.3	70	Safety switch for suspension ropes				X	X

Table continues

Table A3.1 List of interpretations to BS EN 81-1/2 — *continued*

Clause	No.	Brief description	EN 81-1			EN 81-2	
			1978	1985	1998	1987	1998
9.4.1	56	Guards for chain pulleys				X	X
9.4.4	264	Fleet angle of suspension ropes		X	X		
9.5.3	70	Safety switch for suspension ropes	X	X	X		
9.6	561	Suspension ropes			X		
9.6.2	537	Anti rebound device operation				X	
9.7	56	Guards for chain pulleys	X	X	X		
9.8.2.1(d)	525	Instantaneous safety gear 0.63–1.00 m/s					X
9.8.3.1	520	Safety gear operation activation				X	X
9.8.3.1	235	Tripping of the safety gear of the car		X	X		
9.8.5.1	230	Release of a tripped safety gear				X	X
9.8.5.3	230	Release of a tripped safety gear		X	X		
9.8.7	48	Car floor inclination	X	X	X	X	X
9.8.8	230	Release of a tripped safety gear		X	X	X	X
9.8.8	237	Slack rope/chain and safety gear contract				X	X
9.8.8	252	Electric safety device at the safety gear				X	X
9.9	148	Overspeed governor in pit	X	X	X		
9.9.1	149	Indication of rated speeds for overspeed	X	X	X		
9.9.1	160	Governor tripping speed check	X	X	X		
9.9.2	559	Limit switches heavy rated loads, low speeds				X	
9.9.2.1	526	Text revised for clamping device					X
9.9.5.1	527	Release of clamping device					X
9.9.5.2	527	Release of clamping device					X
9.9.6	561	Suspension ropes			X		
9.9.6.1	71	Overspeed governor drive	X	X	X		
9.9.6.5	159	Tensioning of governor rope	X	X	X		
9.9.7	228	Response time		X	X		
9.9.9	72	Manual checking of safety gear	X	X	X		
9.9.11	177	Electric safety device at the overspeed governor	X	X	X		
9.9.11.1	266	Operation of the electric safety device at the overspeed governor		X	X		
9.9.11.2	241	Electric safety device on overspeed governor		X	X		
9.10.1	555	Safety gear			X		
9.10.2	160	Governor tripping speed check				X	X
9.10.2.1	149	Indication of rated speeds for overspeed governor				X	X
9.10.2.2	559	Limit switches heavy rated loads, low speeds					X
9.10.2.5.1	71	Overspeed governor drive				X	X
9.10.2.5.2	148	Overspeed governor in pit				X	X
9.10.2.5.2	159	Tensioning of governor rope				X	X
9.10.2.6	228	Response time				X	X
9.10.2.8	72	Manual checking of safety gear				X	X
9.10.2.10.2	177	Electric safety device at the overspeed governor				X	X
9.10.2.10.2	241	Electric safety device on overspeed governor				X	X
9.10.3	535	Ascending car retardation				X	
9.10.3.2	256	Tripping the safety gear by suspension failure				X	X
9.10.4	555	Safety gear			X		
9.10.5	555	Safety gear			X		
9.10.6	561	Suspension ropes					X
9.11.7	210	Buffering system in pawl devices				X	X
10.1.2	94	Fixing of guide rails	X	X	X	X	X
10.1.2.1	542	Guide rails, yield point, tensile strength				X	X
10.3	127	Impact speed on buffers	X	X	X	X	X
10.3.1	103	Buffer arrangements	X	X	X	X	X
10.3.1	111	Possible design of instantaneous safety gear with buffered effect	X	X	X		
10.3.1	521	Moving buffers				X	X
10.3.2	111	Possible design of instantaneous safety gear with buffered effect				X	X
10.3.3	557	Car buffer requirements					X
10.3.3	194	Buffers underneath the car				X	X
10.3.4	236	Touch between the ram and the bottom of the cylinder				X	X
10.4.1.2.2	564	Energy accumulation buffers				X	X
10.4.2.1	560	Electromechanical brake				X	
10.4.3.2	533	Striking speed on buffers				X	
10.5.2.3(a)	134	Final limit switch	X	X	X	X	X

Table continues

Table A3.1 List of interpretations to BS EN 81-1/2 — *continued*

Clause	No.	Brief description	EN 81-1			EN 81-2	
			1978	1985	1998	1987	1998
10.5.2.3(a)	224	Tripping of the final limit switch				X	X
10.5.3	201	Effects after operation of the final limit switch				X	X
10.5.3.1	545	Limit switches				X	
10.5.3.1	512	Final limit switch usage					X
10.5.3.1	513	Final limit switch usage					X
10.5.3.1(a)	219	Final limit switches for drum drive lifts		X	X		
10.5.3.2	512	Final limit switch usage					X
10.5.3.2	513	Final limit switch usage					X
10.5.3.2	238	Return to normal service from operation of the final limit switch				X	X
10.5.3.2	245	Realisation of non response to calls				X	X
10.6	182	Combination of slack-rope switch and safety gear switch				X	X
10.6	237	Slack rope/chain and safety gear contact				X	X
11	250	Distances between car and installation inside the well		X	X	X	X
11.4	217	Distance between car and counterweight		X	X	X	X
12.2.1(b)	164	Emergency machine for traction drive lifts	X	X	X		
12.4.1(a)	108	Interruption of motor power supply				X	X
12.4.1(b)	207	Preliminary operations				X	X
12.4.2.1	244	Minimum retardation of the brake		X	X		
12.4.2.3	196	Energising the brake		X	X		
12.5	147	Removable hand wheel	X	X	X		
12.5.5.2	538	Accessibility of rupture valve					X
12.5.6.2	538	Accessibility of rupture valve					X
12.5.7	502	Hydraulic control					X
12.5.7	178	Filter				X	X
12.7.1	552	Monitoring device, main contactors				X	
12.7.1	108	Interruption of motor power supply	X	X	X		
12.7.3(a)	552	Monitoring device, main contactors				X	
12.7.3	259	Combination of control and monitoring device		X	X		
12.8	533	Striking speed on buffers				X	
12.9	118	Protective measures in machine room	X	X	X		
12.9.1.5	175	Design of the manually operated emergency lowering valve				X	X
12.9.1.5	225	Safety against slack rope/chain at the manual emergency lowering valve				X	X
12.11	118	Protective measures in machine room				X	X
12.12.4	554	Motor run time limiter					X
12.13	268	Operation of the temperature detecting device				X	X
13	18	Printed circuits	X	X	X	X	X
13.1.1.2	541	Electric installations, wiring, method				X	X
13.1.2	519	Degree of protection — IP codes				X	X
13.1.2	263	IP-degree in the well		X	X	X	X
13.1.4	255	Power supply of automatic doors		X	X	X	X
13.1.4	257	Application of BS EN 60204		X	X	X	X
13.3.2	505	Door motor protection				X	X
13.3.2	186	Motor protection		X	X	X	X
13.3.3	186	Motor protection		X	X	X	X
13.4.2	506	Main switch — multiple				X	X
13.5.1.3	541	Electric installations, wiring, method				X	X
13.5.3.3	119	Light switch	X	X	X	X	X
13.5.3.6	541	Electric installations, wiring, method				X	X
13.6.1	563	Electric supply of the lift				X	X
13.6.2	173	Socket outlets and switches for lighting	X	X	X	X	X
14.1.1	213	Failure analysis for inspection operation		X	X	X	X
14.1.1.3	240	Position of contacts of contactors		X	X	X	X
14.1.2.1.2	123	Electric safety devices in neutral conductor		X	X	X	X
14.1.2.1.3	510	Electrical safety circuit monitoring				X	X
14.1.2.1.3	515	Bypass of landing/car door contacts				X	X
14.1.2.1.3	548	Safety circuits				X	X
14.1.2.1.3	540	Inspection controls in relation to glass lifts				X	X
14.1.2.1.4	507	Emergency electrical operation				X	
14.1.2.4	196	Energising the brake		X	X	X	X

Table continues

Table A3.1 List of interpretations to BS EN 81-1/2 — *continued*

Clause	No.	Brief description	EN 81-1			EN 81-2	
			1978	1985	1998	1987	1998
14.1.2.4	553	Electric safety chain			X		X
14.2	267	Use of emergency electrical operation				X	X
14.2	558	Emergency electrical control					X
14.2.1.2	196	Energising the brake		X	X	X	X
14.2.1.2	263	IP-degree in the well		X	X	X	X
14.2.1.3	101A	Inspection control station arrangements	X	X	X	X	X
14.2.1.3	120	Inspection control	X	X	X	X	X
14.2.1.3	133	Timer in inspection operation circuit	X	X	X	X	X
14.2.1.3	183	Inspection controls and door movements	X	X	X	X	X
14.2.1.3	265	Inspection control and door movements		X	X	X	X
14.2.1.3	570	Inspection control			X		X
14.2.1.4	136	Emergency electrical arrangements	X	X	X		
14.2.1.4	267	Use of emergency electrical operation		X	X		
14.2.1.5	200	Protection against phase reversal				X	X
14.2.1.5.1	258	Activation of the re-levelling device				X	X
14.2.2	223	Failure analysis for inspection operation		X	X	X	X
14.2.2.1	98	Car stop switch in docking operation	X	X	X	X	X
14.2.2.2	531	In car stopping device				X	X
14.2.2.3(a)	101A	Inspection control station arrangements	X	X	X	X	X
14.2.3.3	514	Duplex voice operation				X	X
14.2.4.3	126	Car direction indicators	X	X	X	X	X
14.2.4.3	215	Signal indicating the direction of the car		X	X	X	X
15	511	Type certificates, safety devices				X	X
15	522	Marking electronic components				X	X
15.2	211	Advertising message in the car		X	X	X	X
15.2.3.1	125	Push button for alarm signal	X	X	X	X	X
15.2.3.2	198	Identification of controls in the car		X	X	X	X
15.9	218	Indication of the level of car stop		X	X	X	X
16.1.3	543	Type examination certificate				X	X
16.2(a)(6)	519	Degree of protection — IP codes				X	X
Annex A	137	Combination of electric safety devices	X	X	X	X	X
Annex D	242	Verification: phase reversal, motor run time limiter, speed control device		X	X	X	X
Annex D2	556	Safety gear test, suspension failure					X
Annex D2	560	Electro mechanical brake				X	
Annex D2(g)(1)	160	Governor tripping speed check				X	X
Annex D2(h)(2)	138	Traction tests	X	X	X		
Annex D2(h)(2)	165	Traction examination	X	X	X		
Annex D2(i)(1)	160	Governor tripping speed check	X	X	X		
Annex D2(n)(1)	528	Check rope slackening					X
Annex E	242	Verification: phase reversal, motor run time limiter, speed control device		X	X	X	X
Annex F0.2	543	Type examination certificate				X	X
Annex F1.1.2	154	Extent of type tests on door locks	X	X	X	X	X
Annex F4.3.2	149	Indication of rated speeds for overspeed governor	X	X	X	X	X
Annex F6	508	Tests — safety chain				X	X
Annex F6	548	Safety circuits				X	X
Annex H1	509	PCB safety circuits				X	X
Annex H1	510	Electrical safety circuit monitoring				X	X
Annex J1	504	Dimensions of glass				X	
Annex J7	530	Hinged glass doors				X	X
Annex J7	529	Delete reference to national regulations				X	X
Annex J7	503	Fixing glass				X	X
Annex N	546	Sheave equivalent number evaluation				X	

Table A3.2 Supplementary list of interpretations to EN 81-1 and EN 81-2 (additional to Table A3.2)

Clause	No.	Brief description	EN 81-1: 1998	EN 81-2: 1998
5.7.2.3b)2)	587	Pit horizontal distance		X
5.10	593	Emergency alarm device	X	X
6.5.5	583	Lighting and socket outlets	X	X
7.2.3.1	573	Mechanical strength of car/landing doors and car walls	X	X
7.2.3.1	574	Mechanical strength of car/landing doors and car walls	X	X
7.5.2.1.1/2	575	Kinetic energy of closing doors	X	X
7.7.3.2	576	Automatic closing and locking of landing doors	X	X
8.3.2.1	573	Mechanical strength of car/landing doors and car walls	X	X
8.3.2.1	574	Mechanical strength of car/landing doors and car walls	X	X
8.6.7.1	573	Mechanical strength of car/landing doors and car walls	X	X
8.6.7.1	574	Mechanical strength of car/landing doors and car walls	X	X
8.7.2.1.1/2	575	Kinetic energy of closing doors	X	X
8.7.2.1.1.3	577	Car door re-opening device	X	X
8.17.1	582	Lift car lighting intensity	X	X
8.17.4	586	Emergency escape lighting	X	X
8.17.5	593	Emergency alarm device	X	X
9.2.2	585	Calculation of rope safety factor	X	
9.7 Table 2	594	Protection of traction sheaves	X	
9.9.7	592	Overspeed governor, instantaneous safety gear	X	X
10.3.4	580	Energy accumulation buffers with non linear characteristics	X	X
10.3.6	580	Energy accumulation buffers with non linear characteristics	X	X
12.1	578	Levelling and stopping accuracy	X	X
13.4.1f	593	Emergency alarm device	X	X
14.2.3	579	Emergency alarm device	X	X
14.2.3	593	Emergency alarm device	X	X
14.2.3	593	Emergency alarm device	X	X
14.2.3.3	562	Two-way voice communication	X	X
15.2.3.1	593	Emergency alarm device	X	X
15.12	593	Emergency alarm device	X	X
16.3	581	Maintenance instructions	X	X
Annex D.2.i)1)	588	Test of overspeed governor	X	
Annex D.2,m)	593	Emergency alarm device	X	
Annex D.2,z)	593	Emergency alarm device		X
Annex F.3.2.4.1	592	Overspeed governor, instantaneous safety gear	X	X
Annex N	585	Calculation of rope safety factor	X	

Table A3.3 List of interpretations to EN 81-28

Clause	No.	Brief description
4.1.4	001	Visual and audible signals

Table A3.4 List of interpretations to EN 81-58

Clause	No.	Brief description
11.5.2.2	001	Thermocouples
11.5.3.2	001	Thermocouples

Table A3.5 List of interpretations to EN 81-70

Clause	No.	Brief description
5.2.4	004	Passenger protective device
5.3 Table B.1	005	Minimum car dimensions
5.3.2.3	008	Mirror, safety glass
5.4 Table 2g)	001	Control buttons feedback
5.4.2 Table 2	007	Landing call buttons, arrows
5.4.2.2	006	Extra large (xl) control devices
5.4.2.3	009	Car operating panel, two entrance lift
5.4.2.3	010	Car operating panel, two entrance lift
5.4.3	002	Control devices signals
7.5.2.1.1.3	003	Passenger protection device
Annex G.1	006	Extra large (xl) control devices

Table A3.6 List of interpretations to EN 81-72

Clause	No.	Brief description
1.2	015	Dual entry car
5.1.1	011	Fire resistance — well
5.1.1	014	Protection of equipment
5.1.1, para 2	012	Machine room — fire resistance
5.1.2	001	Protection of control electronics
5.1.4	013	Temperature
5.2.3	015	Dual entry car
5.4	010	Rescue
5.4.3a)	005	Rescue ladder
5.4.7	006	Rescue ladder
5.8.2	004	Firefighters switch — triangle key
5.8.2	008	Firefighter switch
5.8.5	003	Firefighters lift switch
5.8.5	014	Protection of equipment
5.8.8	009	Hidden car operating panel
5.8.8d)	007	Call registration — re-opening of the door
5.8.8.9	002	Landing control — malfunction
5.8.9	015	Dual entry car
5.11.3	009	Hidden car operating panel

Table A3.7 List of interpretations to EN 81-73

Clause	No.	Brief description
3.11	001	Manual recall device; authorised person
5.3.1	001	Manual recall device; authorised person
5.3.7	001	Manual recall device; authorised person

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