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ISO 8100-2

Lifts for the transport of persons and goods —

Part 2: Design rules, calculations, verifications and tests of lift components

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 178, *Lifts, escalators and moving walks,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 10, *Lifts, escalators and moving walks,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 8100-2:2019), which has been technically revised.

The main changes are as follows:

— mechanical tests and temperature tests of safety circuits and SIL-rated circuits have been updated;

— errors in the formulae for traction calculation have been corrected;

— verification methods for suspension and compensation means other than steel wire ropes have been added;

— discard criteria for suspension means and sheaves have been added;

— requirements for SIL-rated circuits (previously called PESSRAL) have been revised;

— the document structure has been revised as per the ISO/IEC Directives, Part 2.

ISO/TS 8100-3:2019 provides information on the differences between this document and local standards (ASME A17.1/CSA B44 and JIS A 4307 1/JIS A 4307 2) not included in this document.

This document is intended to be used in conjunction with documents calling for the use of this document (e.g. ISO 8100-1:2026).

A list of all parts in the ISO 8100 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a type-C standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organizations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e.g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate in the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations and hazardous events are covered are indicated in the scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Lifts for the transport of persons and goods —

Part 2: **Design rules, calculations, verifications and tests of lift components**

1 Scope

This document specifies for passenger lifts and goods passenger lifts:

— the verification of door locking devices;

— the verification of safety gears;

— the verification of overspeed governors;

— the verification of buffers;

— the verification of safety circuits and SIL-rated circuits;

— the verification of ascending car overspeed protection means;

— the verification of unintended car movement protection means;

— the verification of rupture valves and one-way restrictors;

— the verification of suspension and compensation means;

— the discard criteria for suspension means and sheaves;

— the calculation of guide rails;

— the calculation of rams, cylinders, rigid pipes and fittings;

— the evaluation of the traction;

— the evaluation of the safety factor on suspension means;

— the pendulum shock tests;

— the fault exclusion for electric and electronic components;

— the design rules for SIL-rated circuits.

This document is not applicable to passenger lifts, goods passenger lifts or lift components, which are installed or manufactured before the date of its publication.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1:2016, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 3108:2017, *Steel wire ropes — Test method — Determination of measured breaking force*

ISO 4344:2022, *Steel wire ropes for lifts — Minimum requirements*

ISO 7500-1:2018, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 8100-1:2026, *Lifts for the transport of persons and goods — Part 1: Safety rules for the construction and installation of passenger and goods passenger lifts*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 17638:2016, *Non-destructive testing of welds — Magnetic particle testing*

ISO 23277:2015, *Non-destructive testing of welds — Penetrant testing — Acceptance levels*

ISO 29584:2015, *Glass in building — Pendulum impact testing and classification of safety glass*

IEC 60068-2-6:2007, *Environmental testing — Part 2-6: Tests — Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14:2023, *Environmental testing — Part 2-14: Tests — Test N: Change of temperature*

IEC 60068-2-27:2008, *Environmental testing — Part 2-27: Tests — Test Ea and guidance: Shock*

IEC 60947-5-1:2024, *Low-voltage switchgear and control gear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices*

IEC 61508-1:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General requirements*

IEC 61508-2:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems*

IEC 61508-3:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 3: Software requirements*

IEC 61709:2017, *Electric components — Reliability — Reference conditions for failure rates and stress models for conversion*

EN 10025-2:2019, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100:2010 and ISO 8100-1:2026 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Design rules, calculations, verifications and tests

4.1 General

Passenger and goods passenger lifts shall be in accordance with the safety requirements and/or protective measures of the following clauses. In addition, the passenger and goods passenger lifts shall be designed in accordance with the principles of ISO 12100:2010 for hazards relevant but not significant that are not dealt with by this document.

The precision of the instruments shall allow measurements to be made within the following accuracy:

a) ±1 % for masses, forces, distances, speeds;

b) ±2 % for accelerations, retardations;

c) ±5 % for voltages, currents;

d) ±5 °C for temperatures;

e) ±2,5 % for flow rate;

f) ±1 % for pressure, p, below 200 kPa;

g) ±5 % for pressure, p, above 200 kPa.

Recording equipment shall be capable of detecting signals, which vary in time of 0,01 s.

4.2 Verification of landing and car door locking devices

4.2.1 Verifications and tests

4.2.1.1 Verification of operation

It shall be verified that the electric safety device is not activated unless the locking element is engaged as specified by the standard calling for the use of this document (e.g. 7 mm as per ISO 8100-1:2026, 4.3.9.1.2).

4.2.1.2 Mechanical tests

4.2.1.2.1 General

The mechanical tests shall be performed in the following sequence:

a) endurance test as per 4.2.1.2.2;

b) static test as per 4.2.1.2.3;

c) dynamic test as per 4.2.1.2.4.

The static test and the dynamic test shall be carried out with the same test sample used in the endurance test.

4.2.1.2.2 Endurance test

The locking device shall be submitted to 1 000 000 (±1 %) complete cycles; one cycle comprises one forward and return movement over the full travel possible in both directions.

During the endurance test, the electrical safety device of the lock shall close a resistive circuit under the rated voltage and at a current value double that of the rated current of the locking device.

If the locking device is provided with a mechanical checking device for the locking pin or the position of the locking element, this mechanical checking device shall additionally be submitted to an endurance test of 100 000 (±1 %) cycles with the counterpart (means allowing the positive operation of the means used to prove the position of a locking element) not in place and the mechanical locking and the safety contact being not made.

The driving of the device shall be at a rate of 60 (±10 %) cycles per minute.

The number of operations of the locking element and the mechanical checking device shall be recorded by mechanical or electrical counters.

4.2.1.2.3 Static test

The test shall be made consisting of the application of a force, applied at the level of the lock, increasing to the value laid down in the standard calling for the use of this document [e.g. ISO 8100-1:2026, 4.3.9.1.6 a)] between 30 s to 60 s. The force shall be applied for a period of 300 s.

4.2.1.2.4 Dynamic test

The test shall be made consisting of the shock laid down in the standard calling for the use of this document [e.g. ISO 8100-1:2026, 4.3.9.1.6 b)] at the height of the locking device.

4.2.1.3 Criteria for the mechanical tests

After the endurance test (see 4.2.1.2.2), the static test (see 4.2.1.2.3) and the dynamic test (see 4.2.1.2.4), carried out on the locking device, there shall not be:

— wear reducing the minimum engagement of the locking element(s) as specified in the standard calling for the use of this document (e.g. ISO 8100-1:2026, 4.3.9.1.2); or

— permanent deformation; or

— breakage of parts of the locking device or of the mechanical linkage.

4.2.1.4 Electrical test

4.2.1.4.1 Endurance test of safety contacts

This test is included in the endurance test laid down in 4.2.1.2.2.

4.2.1.4.2 Test of ability to break circuit

4.2.1.4.2.1 This test shall be carried out after the endurance test to check the ability to break a live circuit. This test shall be made in accordance with the procedure in IEC 60947-5-1:2024. The values of current and rated voltage serving as a basis for the tests shall be those specified for the locking device.

The capacity to break circuit shall be verified for both AC and DC conditions.

The tests shall be carried out with the locking device in all assembly positions specified in the instructions (see 4.2.3).

The sample tested shall be provided with covers and electric wiring.

4.2.1.4.2.2 Locking devices for AC current shall open and close an electric circuit under a voltage equal to 110 % of the specified rated voltage of the safety contact 50 times at intervals of 5 s to 10 s. The contact shall remain closed for at least 0,5 s.

The testing circuit shall comprise of an inductor and a resistor in series. Its power factor shall be 0,7 ± 0,05 and the test current shall be 11 times the specified rated current of the locking device.

4.2.1.4.2.3 Locking devices for DC current shall open and close an electric circuit under a voltage equal to 110 % of the specified rated voltage of the safety contact 20 times at intervals of 5 s to 10 s. The contact shall remain closed for at least 0,5 s.

The testing circuit shall comprise of an inductor and a resistor in series, having values such that the current reaches 95 % of the steady-state value of the test current in 300 ms.

The test current shall be 110 % of the specified rated current of the locking device.

4.2.1.4.2.4 The tests are considered satisfactory if the safety contact has the ability to break a live circuit.

4.2.1.4.3 Verification of clearances and creepage distances

The clearances in air and creepage distances shall be in accordance with the requirements laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.11.2.2.4).

4.2.1.4.4 Verification of the protection against direct contact

In case of access to hazardous voltage this verification shall be made taking into account the mounting position, the orientation and the layout of the locking device (e.g. ISO 8100-1:2026, 4.10.1.2).

4.2.2 Test particular to certain types of locking devices

4.2.2.1 Locking device for horizontally or vertically sliding doors with several panels

Devices providing direct mechanical linkage between panels shall be included in the tests mentioned in 4.2.1.2.2.

4.2.2.2 Flap type locking device for hinged door

For the flap type locking device the following shall be verified:

— the specified minimum overlap-dimensions as required by the standard calling for this device [e.g. ISO 8100-1:2026, 4.3.9.1.12 b) and 4.3.9.1.12 c)];

— the locking device cannot engage when the landing door is not fully in the closed position as required by the standard calling for this device [e.g. ISO 8100-1:2026, 4.3.9.1.12 d)];

— the locking force limiter as in the standard calling for the use of this document [e.g. ISO 8100-1:2026, 4.3.9.1.12 f)] shall be tested on an operationally constructed door by pushing open the door panels with a steadily increasing force until the locking force limiter releases the flap. The force shall be applied as required by the standard calling for this device [e.g. ISO 8100-1:2026, 4.3.9.1.12 f)]. The flap shall not release before the force exceeds the force required by the standard calling for this device [e.g. ISO 8100-1:2026, 4.3.9.1.12 f)].

  The test shall be carried out on a door with the largest width.

  In the case of elements to limit the load on the flap that are triggered via a predetermined breaking point, the locked door shall be force-opened three times, each time with renewed trigger elements. In the case of non-destructive release elements, a limited endurance test with 50 force openings is required.

  There shall be no permanent deformation or breakage on the locking device after the test.

4.2.3 Instructions

In addition to the information for assembly, connection, adjustment and maintenance, the instructions of the locking device shall contain the following information based on the verification:

a) type and application of locking device;

b) type (AC and/or DC) and values of the rated voltage and rated current of the locking device safety contact;

c) in the case of flap type door locking devices: the necessary force to actuate the locking force limiter.

4.3 Verification of safety gear

4.3.1 General provisions

Safety gears shall be verified as described in 4.3.2, 4.3.3 and 4.3.4.

4.3.2 Instantaneous safety gear

4.3.2.1 Test samples

Two gripping assemblies with wedges or clamps and two lengths of guide rail shall be provided.

The arrangement and the fixing details for the samples shall be determined in accordance with the equipment that it uses.

If the same gripping assemblies can be used with different types of guide rails, a new test shall not be required if the thickness of the guide rails, the width of the grip needed for the safety gear, and the surface state (drawn, milled, ground) are the same.

4.3.2.2 Testing

4.3.2.2.1 Method of test

The test shall be made using a press or similar device, which moves continuously. Measurements shall be made of:

a) the distance travelled as a function of the force;

b) the deformation of the safety gear block as a function of the force or as a function of the distance travelled.

4.3.2.2.2 Test procedure

The guide rail shall be moved through the safety gear until the minimum required force is reached or rupture has occured.

4.3.2.2.3 Documents

4.3.2.2.3.1 Two charts shall be drawn up as follows:

a) the first one shall show the distance travelled as a function of the force;

b) the second one shall show the deformation of the block. It shall be done in such a way that it can be related to the first chart.

4.3.2.2.3.2 The capacity of the safety gears shall be established by integration of the area of the distance-force chart.

The area of the chart to be taken into consideration shall be:

a) the total area, if there is no permanent deformation;

b) if permanent deformation or rupture has occurred, either:

   1) the area up to the value at which the elastic limit has been reached; or

   2) the area up to the value corresponding to the maximum force.

4.3.2.3 Determination of the permissible mass

4.3.2.3.1 Energy absorbed by the safety gear

The distance of free fall in metres, h, shall be taken as Formula (1):

$$h=\left(\frac{v_1^2}{2\cdot g_n}\right)+0{,}1+0{,}03 \quad (1)$$

where

g_n	is the standard acceleration of free fall in metres per square second;
v_1	is the maximum tripping speed of the safety gear expressed in metres per second;
0,1	corresponds to the distance travelled during the response time, in metres;
0,03	corresponds to the travel during take-up of clearance between the gripping elements and the guide rails, in metres.

The total energy the safety gear is capable of absorbing is calculated with Formulae (2) and (3):

$$2\cdot K=(P+Q)_1\cdot g_n\cdot h \quad (2)$$

from which: $$(P+Q)_1=\frac{2\cdot K}{g_n\cdot h} \quad (3)$$

where

K	is the energy absorbed by one safety gear block, in joules (calculated in accordance with the chart);
P	are the masses of the empty car and components supported by the car, i.e. part of the travelling cable, compensation means (if any), etc., in kilograms;
Q	is the rated load, in kilograms;
$(P+Q)_1$	is the permissible mass, in kilograms.

4.3.2.3.2 Permissible mass

a) If the elastic limit has not been exceeded, the permissible mass in kilograms, $(P + Q)_1$, is calculated with Formula (4):

$$(P+Q)_1=\frac{2\cdot K}{2\cdot g_n\cdot h} \quad (4)$$

where

K	is calculated by the integration of the area defined in 4.3.2.2.3.2 a);
2	is taken as the dividing safety coefficient;
h	is the distance of free fall, in metres.

b) If the elastic limit has been exceeded, Formulae (5) and (6) shall be used and the higher permissible mass may be selected.

$$(P+Q)_1=\frac{2\cdot K_1}{2\cdot g_n\cdot h} \quad (5)$$

where

K_1	is calculated by the integration of the area defined in 4.3.2.2.3.2 b) 1);
2	is taken as the dividing safety coefficient;
h	is the distance of free fall, in metres.

$$(P+Q)_1 = \frac{2 \cdot K_2}{3{,}5 \cdot g_n \cdot h} \quad (6)$$

where

K_2	is calculated by the integration of the area defined in 4.3.2.2.3.2 b) 2);
3,5	is taken as the dividing safety coefficient;
h	is the distance of free fall, in metres.

4.3.3 Progressive safety gear

4.3.3.1 Testing

4.3.3.1.1 Method of test

4.3.3.1.1.1 The test shall be carried out in free fall. Direct or indirect measurements shall be made of:

a) the total height of the fall;

b) the braking distance on the guide rails;

c) the sliding distance of the overspeed governor rope, or that of the device used in its place;

d) the total travel of the elements forming the spring.

Measurements a) and b) shall be recorded as a function of the time.

4.3.3.1.1.2 The following shall be determined:

a) the average braking force;

b) the greatest instantaneous braking force;

c) the smallest instantaneous braking force.

4.3.3.1.2 Test procedure

4.3.3.1.2.1 Safety gear for a single mass

Four tests with the mass $(P + Q)_1$ shall be carried out. Between each test, the friction parts shall be allowed to return to the ambient temperature.

If during the tests, the friction parts are replaced, each set shall be capable of:

a) three tests, if the rated speed does not exceed 4 m/s;

b) two tests, if the rated speed exceeds 4 m/s.

The height of free fall shall be calculated to correspond to the maximum tripping speed of the safety gear.

The engagements of the safety gear shall be achieved by a means allowing the tripping speed to be fixed precisely.

4.3.3.1.2.2 Safety gear for different masses

Where adjustment is in stages or continuous, two series of tests in accordance with 4.3.3.1.2.1 shall be carried out for:

a) the maximum; and

b) the minimum values applied for.

A formula or a chart shall be provided showing the variation of the braking force as a function of a given parameter.

The validity of the supplied formula or chart shall be verified by one series of tests for a linear chart or two series of tests for a nonlinear chart.

The series of tests shall be performed with an intermediate value adjustment.

4.3.3.1.3 Determination of the braking force of the safety gear

4.3.3.1.3.1 Safety gear for a single mass

The braking force that the safety gear is capable of for the given adjustment and the type of guide rail, is taken as equal to the average of the average braking forces determined during the tests. Each test shall be made on an unused section of guide rail.

A check shall be made that the average values determined during the tests lie within a range of ±25 % in relation to the value of the braking force defined above.

NOTE Tests have shown that the coefficient of friction can be considerably reduced if several successive tests are carried out on the same area of a machined guide rail. This is attributed to a modification in the surface condition during successive safety gear operations.

4.3.3.1.3.2 Safety gear for different masses

Adjustment in stages or continuous adjustment.

The braking force that the safety gear is capable of, shall be calculated as laid down in 4.3.3.1.3.1 for the maximum and minimum values applied for.

4.3.3.1.4 Checking after the tests

After the test, the safety gear shall be operational.

4.3.3.2 Calculation of the permissible mass

4.3.3.2.1 Safety gear for a single mass

The permissible mass shall be calculated using Formula (7):

$$(P+Q)_1 = \frac{F_B}{16} \tag{7}$$

where

F_B	is the braking force in newtons, determined in accordance with 4.3.3.1.3;
P	is the masses of the empty car and components supported by the car, i.e. part of the travelling cable, compensation means (if any), etc., in kilograms;
Q	is the rated load, in kilograms;
$(P + Q)_1$	is the permissible mass, in kilograms.

If the calculated permissible mass is larger than the tested mass, the tested mass may be taken as permissible mass, provided that the average retardation of each test did not exceed 1,0 g_n.

4.3.3.2.2 Safety gear for different masses

4.3.3.2.2.1 Adjustment in stages

The permissible mass shall be calculated for each adjustment as laid down in 4.3.3.2.1.

4.3.3.2.2.2 Continuous adjustment

The permissible mass shall be calculated as laid down in 4.3.3.2.1 for the maximum and minimum values applied for, and in accordance with the formula supplied for the intermediate adjustments.

4.3.4 Additional verifications

The applicable mass used for a lift shall not exceed the permissible mass for instantaneous safety gear.

In the case of progressive safety gear, the mass stated may differ from the applicable mass stated in 4.3.3.2 by ±7,5 %.

A check shall be made that the possible stroke of the gripping elements covers the accumulation of design tolerances.

4.3.5 Instructions

In addition to the information for assembly, connection, adjustment and maintenance, the instructions of the safety gear shall contain the following information based on the verification:

a) the type and the application of the safety gear;

b) the limits of the permissible masses [see 4.3.4 a)];

c) the maximum tripping speed of the safety gear;

d) the type of guide rails (see ISO 8100-33:2022);

e) the permissible thickness of the guide rail blade;

f) the minimum width of the gripping areas;

g) actuation force of the safety gear if it exceeds 150 N;

and, for progressive safety gear only:

h) the surface condition of the guide rails (drawn, milled, ground);

i) the state of lubrication of the guide rails. If they are lubricated, the category and specification of the lubricant.

4.4 Verification of overspeed governors

4.4.1 General provisions

Overspeed governors shall be verified as described in 4.4.2.

4.4.2 Check on the characteristics of the overspeed governor

4.4.2.1 Test samples

The following shall be provided:

a) one overspeed governor;

b) one rope of the type used for the overspeed governor;

c) a tensioning pulley assembly of the type used for the overspeed governor.

4.4.2.2 Testing

4.4.2.2.1 Method of test

The following shall be tested:

a) the tripping speed of the overspeed governor;

b) the operation of the electric safety device(s) checking the speed, up and down [e.g. ISO 8100-1:2026, 4.6.2.2.1.6 a)], if mounted on the overspeed governor;

c) the operation of the electric safety device checking the reset position of the overspeed governor if the overspeed governor does not automatically reset itself after release;

d) the tensile force produced in the rope by the overspeed governor when tripped;

e) the maximum tripping speed of the overspeed governor in a free fall situation.

4.4.2.2.2 Test procedure

Twenty tests shall be made in the speed range for tripping, corresponding to the range of rated speeds (see e.g. ISO 8100-1:2026, 4.6.2.2.1.1), indicated in 4.4.3 b).

Six tests shall be made for the minimum and six tests shall be made for the maximum values of the range. The remaining tests shall be made evenly distributed in the speed range for tripping of the overspeed governor.

The acceleration to reach the tripping speed of the overspeed governor shall not exceed 0,1 m/s^2.

In addition to the twenty tests, two tests shall be made, simulating a free fall situation, starting from standstill with an acceleration between 0,9 g_n and 1,0 g_n.

For overspeed governors designed to trip in two directions these tests series shall be performed in both directions.

4.4.2.2.3 Assessment of the test results

In the twenty tests, the tripping speeds shall lie within the speed range as specified in 4.4.2.2.2.

In the twenty tests, the devices shall operate as specified in 4.4.2.2.1 b) and c).

The tensile force in the rope produced by the overspeed governor when tripped shall be at least 300 N or the value specified in 4.4.3 e).

When the overspeed governor operates by gripping the rope, it shall be verified that the gripping mechanism has not permanently deformed the rope.

In the two tests simulating a free fall situation there shall be no deterioration which affects the operation of the overspeed governor.

4.4.3 Instructions

In addition to the information for assembly, connection, adjustment and maintenance the instructions of the overspeed governor shall contain the following information based on the verification:

a) the type(s) of safety gear which will be operated by the overspeed governor;

b) the maximum and minimum rated speeds of the lift for which the overspeed governor may be used;

c) the diameter of the rope to be used and its construction;

d) in the case of an overspeed governor with traction pulley, the minimum tensioning force;

e) the tensile force in the rope which can be produced by the overspeed governor when tripped;

f) the maximum tripping speed reached of the overspeed governor in a free fall situation.

4.5 Verification of buffers

4.5.1 General provisions

Buffers shall be verified as described in 4.5.3.

4.5.2 Samples subject to test

The following shall be provided:

a) one buffer;

b) liquid, in the case of hydraulic buffers.

4.5.3 Testing

4.5.3.1 Energy dissipation buffers

4.5.3.1.1 Test procedure

The buffer shall be tested with the aid of weights, corresponding to the minimum and maximum masses, falling in free fall to reach the maximum speed called for at the moment of impact.

The speed shall be recorded throughout the travel of the weights. The acceleration and the retardation shall be determined as a function of time throughout the movement of the weights.

4.5.3.1.2 Equipment to be used

4.5.3.1.2.1 Weights falling in free fall

The weights shall correspond, with the tolerances of 4.1, to the maximum and minimum masses. They shall be guided vertically ensuring acceleration in free fall condition of at least 0,9 g_n.

4.5.3.1.2.2 Recording equipment

The recording equipment shall be able to detect signals with the tolerances of 4.1. The measuring chain, including the recording device for the recording of measured values as a function of time, shall be designed for a sampling frequency of at least 200 Hz for each time-varying signal recorded.

4.5.3.1.2.3 Measurement of speed

The speed shall be measured with the tolerances of 4.1.

4.5.3.1.2.4 Measurement of the retardation

If there is a device for measuring retardation (see 4.5.3.1.1), it shall be placed in line with the axis of the buffer and shall be capable of measurement with the tolerances of 4.1.

4.5.3.1.2.5 Measurement of time

Time pulses of duration of 0,01 s shall be recorded and measured with the tolerances of 4.1.

4.5.3.1.3 Ambient temperature

The ambient temperature shall be between +15 °C and +25 °C.

The temperature of the liquid shall be measured with the tolerances of 4.1.

4.5.3.1.4 Mounting of the buffer

The buffer shall be placed and fixed in accordance with its installation instructions.

4.5.3.1.5 Filling of the buffer

The buffer shall be filled up in accordance with its instructions.

4.5.3.1.6 Checks

4.5.3.1.6.1 Checking of retardation

The height of free fall of the weights shall be chosen in such a way that the speed at the moment of impact corresponds to the maximum impact speed that is considered in the application.

The retardation shall conform to the requirements of the standard calling for this device (e.g. ISO 8100-1:2026, 4.8.2.2.2).

The creeping at the end of the buffer stroke for calculation of the average retardation shall be ignored where the retardation is below 0,5 m/s^2.

A first test shall be made with maximum mass, with a check on the retardation.

A second test shall be made with minimum mass, with a check on the retardation.

4.5.3.1.6.2 Checking of the return of the buffer to the normal position

After each test, the buffer shall be held in the completely compressed position for 5 min. The buffer shall then be freed to permit return to its normal extended position.

When the buffer is of a type with spring or gravity return, the position of complete return shall be reached in a maximum period of 120 s.

Before proceeding to another retardation test, there shall be a delay of 30 min to allow the liquid to return to the tank and for air bubbles to escape.

4.5.3.1.6.3 Checking of the liquid losses

The level of liquid shall be checked after having made the two retardation tests required in 4.5.3.1.6.1. After an interval of 30 min, the level of liquid shall again be sufficient to ensure normal operation of the buffer.

4.5.3.1.6.4 Checking of the condition of the buffer after tests

After the tests as per 4.5.3.1.6.1, the buffer shall be operational.

4.5.3.2 Energy accumulation buffers with non-linear characteristics

4.5.3.2.1 Test method

The buffer shall be tested with the aid of weights falling in free fall from a height to reach the maximum speed called for at the moment of impact, but not less than 0,8 m/s.

The falling distance, speed, acceleration and retardation shall be recorded from the moment of release of the weight to complete standstill.

The weights shall correspond to the maximum and minimum masses called for. They shall be guided vertically ensuring acceleration in free fall condition of at least 0,9 g_n.

4.5.3.2.2 Equipment to be used

The equipment shall correspond to 4.5.3.1.2.

4.5.3.2.3 Ambient temperature

The ambient temperature shall be between +15 °C and +25 °C.

4.5.3.2.4 Mounting of the buffer

The buffer shall be placed and fixed in accordance with its instructions.

4.5.3.2.5 Test procedure

Within 30 min before the test, the buffer shall be once loaded, either statically or dynamically, in order to prevent further settlement and deviations during the test.

Three tests shall be made with the maximum mass called for, and three tests shall be made with the minimum mass called for.

The time delay between two consecutive tests shall be between 5 min and 30 min.

In the three tests with maximum mass, the reference value of the buffer force at a stroke given by its instructions, equal to 50 % of the real height of the buffer, shall not vary by more than 5 %.

4.5.3.2.6 Checks

4.5.3.2.6.1 Checking of retardation

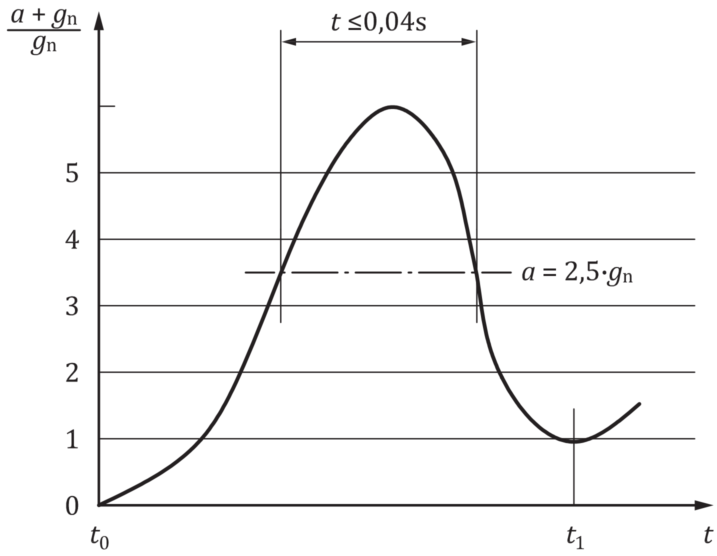
The retardation "*a*", shall conform to the following requirements.

a) The retardation will be evaluated taking into account the time between the first two absolute minima of the retardation (see Figure 1). The retardation shall not exceed the maximum as required by the standard calling for this device. [e.g. ISO 8100-1:2026, 4.8.2.1.2.1 a)].

b) Peaks duration of retardation above a value specified by the standard calling for this device shall not exceed the maximum duration of these peaks as required by the standard calling for this device [e.g. ISO 8100-1:2026, 4.8.2.1.2.1 b)].

c) The maximum peak retardation shall not exceed the maximum as required by the standard calling for this device [e.g. ISO 8100-1:2026, 4.8.2.1.2.1 e)].

d) The return speed shall not exceed the maximum as required by the standard calling for this device. [e.g. ISO 8100-1:2026, 4.8.2.1.2.1 c)].



Key

a	retardation in metres per square second
g_n	standard acceleration of free fall in metres per square second
t	time in seconds
t_0	moment of hitting the buffer (first absolute minimum)
t_1	second absolute minimum

Figure 1 — Retardation graph — Example using ISO 8100-1 requirements

4.5.3.2.6.2 Checking of the condition of the buffer after tests

After the test with the maximum mass, there shall be no cracks in the buffer.

4.5.4 Instructions

In addition to the information for assembly, connection, adjustment and maintenance the instructions of the buffer shall contain the following information based on the verification:

a) the type and application of buffer;

b) the dimensions of the buffer;

c) the maximum impact speed;

d) the maximum mass;

e) the minimum mass;

f) the kind of fixation;

g) the specification of the liquid in the case of hydraulic buffers;

h) the environmental conditions for use of buffer (temperature, humidity, pollution, etc.).

4.6 Verification of safety circuits and SIL-rated circuits

4.6.1 General provisions

4.6.1.1 General

In the following subclauses, reference is made to printed circuit board. If a safety circuit is not assembled in such a manner, then the equivalent assembly shall be assumed.

4.6.1.2 Information for verification

The following shall be verified to demonstrate that the safety circuit or SIL-rated circuit perform the specified safety functions as required and to demonstrate that instructions specified in 4.6.4 are complete:

a) identification on the printed circuit board;

b) environmental working conditions;

c) list of components used;

d) layout of the printed circuit board;

e) layout of the hybrids and marks of the tracks used in safety circuits;

f) function description;

g) electrical wiring diagram, including input and output definitions of the printed circuit board;

h) method of failure analysis employed and documented results;

i) description of safe state.

4.6.1.3 Documentation for SIL-rated circuits

In addition to 4.6.1.2, the following documentation shall be provided:

a) documents and descriptions relating to the measures referenced in 4.18;

b) general description of the software used (e.g. programming rules, language, compiler, modules);

c) function description, including software architecture and hardware/software interaction;

d) description of blocks, modules, data, variables and interfaces;

e) software listings.

4.6.2 Samples subject to test

The following shall be provided:

a) one printed circuit board;

b) one bare printed circuit board (without components).

4.6.3 Tests

4.6.3.1 Mechanical tests

4.6.3.1.1 General

During the tests, the equipment shall be kept under operation in its safe state. During and after the tests the equipment shall not leave its safe state, no unsafe operation and condition shall appear within the safety-related circuit.

After the test the safety-related circuit shall operate as intended.

4.6.3.1.2 Vibration and shocks

Equipment shall be tested in accordance with:

a) IEC 60068-2-6:2007, Vibration test:
   1) 20 sweep cycles in each axis;
   2) amplitude 0,35 mm;
   3) frequency range 10 Hz to 55 Hz;
b) IEC 60068-2-27:2008, with the following test parameters for non-repetitive shocks:
   1) peak acceleration 300 m/s^2 or 30 g_n;
   2) duration of pulse 11 ms;
   3) pulse shape: half sine;
   4) number of shocks per each axis and direction: 3;
   5) three axis and two directions;
c) IEC 60068-2-27:2008, with the following test parameters for repetitive shocks:
   1) peak acceleration: 100 m/s^2 or 10 g_n;
   2) duration of pulse: 16 ms;
   3) pulse shape: half sine;
   4) number of shocks per each axis and direction: 1 000 ± 10;
   5) repetition rate: 2/s;
   6) three axis and two directions.

NOTE Where shock absorbers are fitted, they are considered as part of the equipment.

After tests, clearances and creepage distances shall not become smaller than the minimum required.

4.6.3.2 Temperature tests

Equipment shall be tested in accordance with IEC 60068-2-14:2023, Test Nb with following severity parameters:

— lower temperature T_A: 0 °C;

— higher temperature T_B: +65 °C;

— temperature change rate: (1 ± 0,2) °C /min;

— exposure time to each of the two temperatures: 4 h;

— number of cycles: 2

Test conditions:

— the lower and higher temperatures are to be understood as the ambient temperature of the equipment;

— the printed circuit board shall be in operational position;

— the printed circuit board shall be supplied with rated operational voltage;

— during and after the test, the safety device shall operate correctly when demanded. Demand rate minimum once in 10 min;

— if the printed circuit board includes components other than safety circuits, they also shall operate during the test (their failure is not considered);

— if the equipment is designed to operate within wider temperature limits, it shall be tested for these values.

4.6.3.3 Failure analysis of electric safety circuits

The failure analysis as required by the relevant standard calling for the use of this document shall be validated (e.g. ISO 8100-1:2026, 4.11.2.3).

4.6.3.4 Functional and safety test of SIL-rated circuit

In addition to the verification of the measures selected as per 4.18, the following shall be validated:

a) software design and coding: inspect all code statements using methods such as formal design reviews, FAGAN, test cases, etc.;

b) software and hardware inspection: verify selected measures by using, for example, fault insertion testing;

c) both PFD_{avg} and PFH calculations.

4.6.4 Instructions

In addition to the information for assembly, connection adjustment and maintenance the instructions of the safety circuits and the SIL-rated circuits shall contain the following information based on the verification:

a) the type and application of the circuitry;

b) the conditions for safe use;

c) the operating voltages;

d) identification of the hardware, including its version;

e) for SIL-rated circuits, identification of the software, including its version.

4.7 Verification of ascending car overspeed protection means

4.7.1 General provisions

4.7.2 Statement and test sample

4.7.2.1 It shall be stated for what mass (in kilograms) and tripping speed (in metres per second) the test will be carried out. If the device shall be verified for various masses, it shall be stated and indicated whether the adjustment for various masses is by stages or continuous.

4.7.2.2 The test shall be performed with:

— a complete assembly consisting of both elements, speed reducing element and speed monitoring element; or

— only that device which was not subject to verifications as per 4.3 or 4.4.

The number of sets of gripping elements necessary for all the tests shall be attached. The type of part on which the device acts, shall also be provided.

4.7.3 Testing

4.7.3.1 Test method

The following shall be measured:

a) the acceleration and speed;

b) the braking distance;

c) the retardation.

Measurements shall be recorded.

4.7.3.2 Test procedure

4.7.3.2.1 General

The acceleration of the mass to reach the tripping speed shall not exceed 0,1 m/s^2.

4.7.3.2.2 Speed reducing element

4.7.3.2.2.1 General

Twenty tests shall be made with the speed monitoring element in the speed range for tripping indicated in 4.7.4 c).

4.7.3.2.2.2 Verification for a single mass

The tests shall be carried out with the system mass representing an empty car.

Between each test, the friction parts shall be allowed to return to their ambient temperature.

If during the test the friction parts are replaced, each set shall be capable of:

a) three tests, if the rated speed does not exceed 4 m/s;

b) two tests, if the rated speed exceeds 4 m/s.

The tests shall be made at the maximum tripping speed for which the device is specified.

4.7.3.2.2.3 Verification for different masses

At least a series of tests in accordance with 4.7.3.2.2.2 shall be carried out for the maximum value specified, and for the minimum value. A formula, or a chart shall be provided, showing the variation of the braking force as a function of a given parameter.

The validity of the supplied formula or chart shall be verified.

4.7.3.2.2.4 Assessment of the test results

In the twenty tests, the retardation shall not exceed 1,0 g_n.

4.7.3.2.3 Speed monitoring element

4.7.3.2.3.1 Test procedure

Twenty tests shall be made in the speed range for tripping without applying the braking device.

Six tests shall be made for the minimum and six tests shall be made for the maximum values of the range.

The remaining tests shall be made evenly distributed in the speed range for tripping of the ascending car overspeed protection means.

4.7.3.2.3.2 Assessment of the test results

In the twenty tests, the tripping speeds shall lie within the specification.

4.7.3.2.4 Test procedure for self-monitoring

Ten tests shall be made to verify the operation of the device. All tests shall be positive to verify correct operation.

4.7.3.3 Checking after the tests

After the test, the ascending car overspeed protection means shall be operational.

4.7.4 Instructions

In addition to the information for assembly, connection, adjustment and maintenance, the instructions of the ascending car overspeed protection means shall contain the following information based on the verification:

a) the type and application of ascending car overspeed protection means;

b) the limits of the permissible masses or torque;

c) the tripping speed range of the speed monitoring element and the speed reducing element;

d) detailed information on the materials used, the type of part on which the ascending car overspeed protection means acts, and its surface condition (drawn, milled, ground, etc.).

4.8 Verification of unintended car movement protection means

4.8.1 General provisions

The unintended car movement protection means shall be verified as a complete system. Alternatively, the subsystems for detection, activation and stopping shall be verified individually. The verification of subsystems shall define interface conditions and the relevant parameters of each subsystem if integrated in a complete system.

In case of electric failure, it can be assumed that, for traction lifts due to internal control means, the acceleration which can be achieved is not greater than 2,5 m/s^2.

The distance the car is permitted to move during unintended movement is defined in the requirements laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.6.7.5).

4.8.2 Statement and test sample

4.8.2.1 The intended duty of the means shall be stated.

4.8.2.2 Test samples shall be provided as complete assembly of unintended car movement detection device, control circuit (actuator), stopping elements and any monitoring device(s) if applicable.

The number of sets of gripping elements necessary for all the tests shall be attached.

The type of part on which the device acts, shall also be provided.

4.8.3 Testing

4.8.3.1 Test method

The test method shall be defined depending on the device and its function.

Measurements shall be made of:

— the stopping distance;

— the retardation;

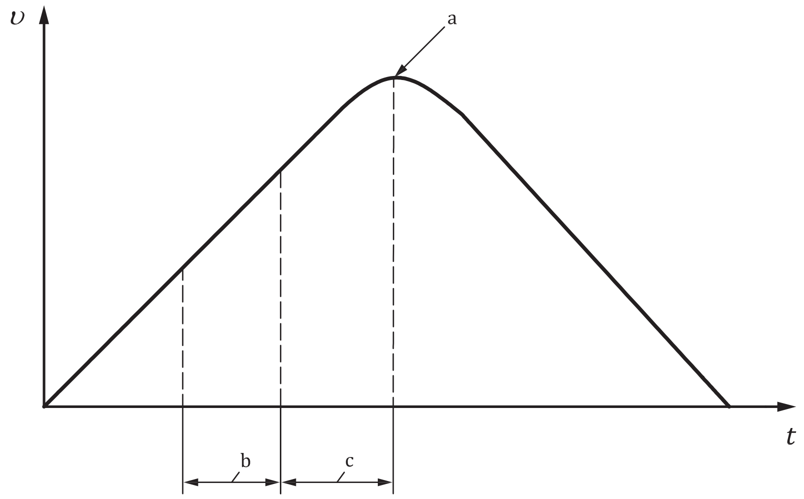
— the response time of the detection, actuation, stopping element and control circuits (see Figure 2);

— the total distance travelled (sum of acceleration and stopping distances).

The test shall also include:

— the operation of the unintended car movement detection device; and

— any automatic monitoring system, if applicable.



Key

υ	speed in metres per second
t	time in seconds
a	Point at which stopping elements start to cause a reduction in speed.
b	Response time of unintended car movement detection and any control circuits.
c	Response time of actuation circuits and stopping elements.

Figure 2 — Response times

4.8.3.2 Test procedure

4.8.3.2.1 General

Twenty tests shall be made on the stopping element with:

— no result outside the specification;

— each result within ±20 % of the average value.

4.8.3.2.2 Device verified for a single mass or torque or fluid pressure

The following tests shall be carried out:

— ten tests with the system mass or torque or fluid pressure representing an empty car in the upward direction; and

— ten tests with the system mass or torque or fluid pressure representing a car carrying the rated load in the downward direction.

Between each test, the friction parts shall be allowed to return to ambient temperature.

If during the test the friction parts are replaced, each set shall be capable of minimum five tests.

4.8.3.2.3 Device verified for different masses or torques or fluid pressures

A series of tests in accordance with 4.8.3.2.2 shall be carried out for the maximum value specified for and a series for the minimum value.

A formula or a chart shall be provided, showing the variation of the braking force or torque or fluid pressure as a function of a given adjustment. The results shall be expressed in distance travelled.

The validity of the supplied formula or chart shall be verified.

4.8.3.2.4 Test procedure for unintended movement detection means

Ten tests shall be made to verify the operation of the device. All tests shall be positive to verify correct operation.

4.8.3.2.5 Test procedure for self-monitoring

Ten tests shall be made to verify the operation of the device. All tests shall be positive to verify correct operation.

In addition, the capability of the self-monitoring to detect loss of redundancy of the stopping element before a critical situation occurs, shall be verified.

4.8.3.3 Checks after the test

After the test, unintended car movement protection means shall be operational.

4.8.4 Instructions

In addition to the information for assembly, connection, adjustment and maintenance, the instructions of the unintended car movement protection means shall contain the following information based on the verification:

a) the type and application of the unintended car movement protection system/subsystem;

b) the limits of the key parameters;

c) the test speed with relevant parameters for final inspection use;

d) the type of parts on which the stopping elements act;

e) the combination of "detecting" device and "stopping" element of the means in the case of complete systems;

f) the interface conditions in case of subsystems;

g) detailed information of the materials used, the type of part on which the means acts, and its surface condition, if relevant (drawn, milled, ground, etc.);

h) the environmental conditions for use (temperature, humidity, pollution, etc.).

NOTE 1 As an example and indication, for traction lifts, where the natural acceleration is 1,5 m/s^2 and without any torque contribution from the motor, the maximum speed attainable would be in the magnitude of 2,0 m/s. This is based on the speed attained at start of deceleration, e.g. being the result of a "natural" acceleration of 1,5 m/s^2 through the response times of the unintended car movement protection device, control circuit and stopping elements, assuming that the movement detector operates when the car reaches the limit of the unlocking zone.

NOTE 2 Test speed(s): is any speed(s) used on site to establish a distance moved by the lift (verification distance) so that the unintended movement system is verified for correct operation during verifications and tests before putting into service at site. This can be the inspection speed or any other speed.

4.9 Verification of rupture valve/one-way restrictor

4.9.1 General provisions

In the following, the term "rupture valve" means "rupture valve/one-way restrictor with mechanical moving parts".

The following shall be provided:

a) one rupture valve;

b) a list of liquids which shall be used together with the rupture valve, or a sufficient amount of special liquid to be used.

4.9.2 Testing

4.9.2.1 Test installation

The rupture valve, mounted in its intended method, shall be tested in a hydraulic system, where:

a) the required testing pressure is dependent on the mass;

b) the flow is controlled by adjustable valves;

c) the pressure before and behind the rupture valve can be recorded;

NOTE "Before the rupture valve" means between the cylinder and the rupture valve.

d) means to change the ambient temperature of the rupture valve and the viscosity of the hydraulic fluid are provided.

The system shall allow recording of the flow over time. To determine the values of flow, the measurement of another figure, i.e. the speed of the ram from which the flow can be derived is permitted.

4.9.2.2 Measuring instruments

The measuring instruments shall have accuracy in accordance with 4.1.

4.9.3 Test procedure

4.9.3.1 General

The test shall:

a) simulate a total piping failure occurring at a moment when the speed of the car is zero;

b) evaluate the resistance of the rupture valve against pressure.

4.9.3.2 Simulation of a total piping failure

4.9.3.2.1 Simulating a total piping failure, the flow shall be initiated from a static situation by opening a valve, on condition that the static pressure before the rupture valve decreases to less than 10 %.

The variability of the closing operation of the rupture valve shall be verified within the stated range of:

a) flow;

b) viscosity;

c) pressure;

d) ambient temperature.

This shall be achieved by:

— ten tests with maximum pressure, maximum ambient temperature, minimum adjustable flow and minimum viscosity;

— ten tests with minimum pressure, minimum ambient temperature, maximum adjustable flow and maximum viscosity.

4.9.3.2.2 During the tests, the relation between:

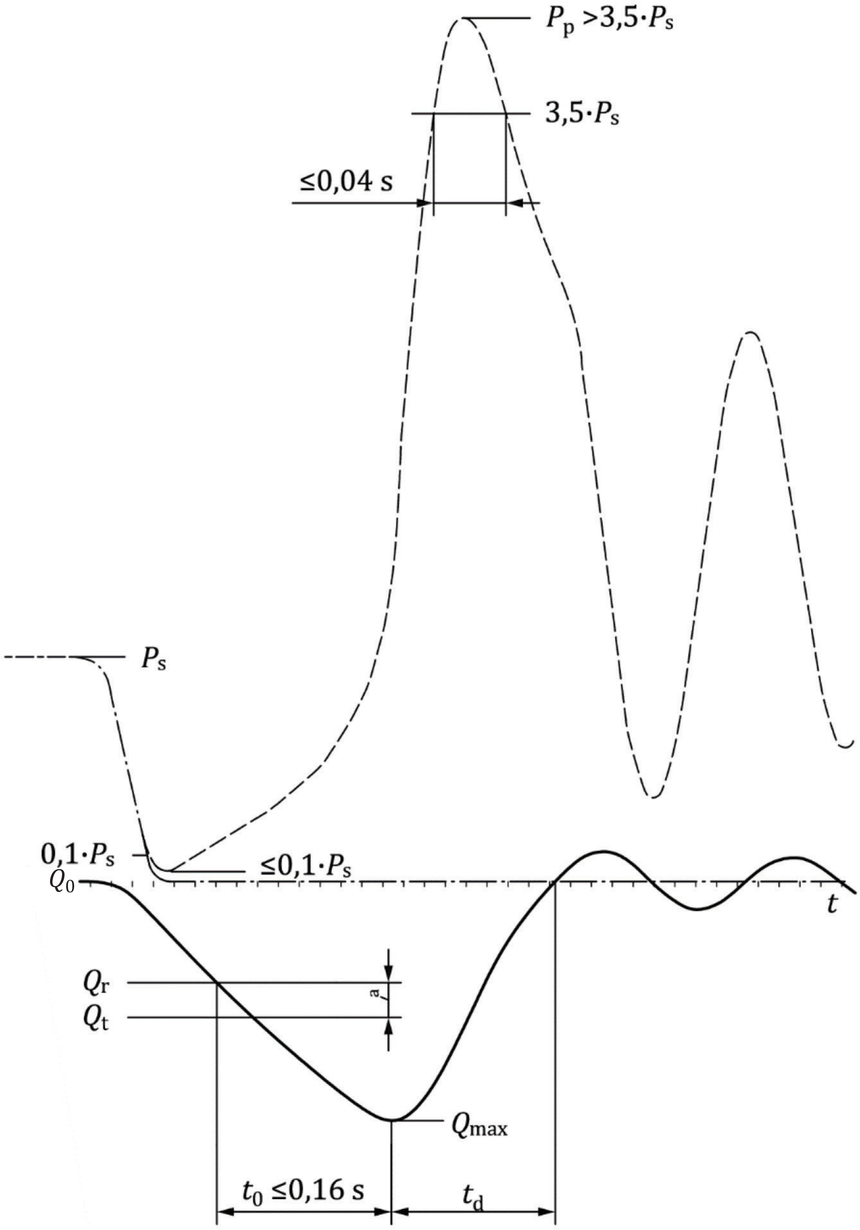
— flow and time;

— pressure before the rupture valve and time;

— pressure behind the rupture valve and time;

shall be recorded.

The typical characteristics of these curves are shown in Figure 3.



Key

P_p	pressure peak
P_s	pressure static, before test
Q_0	flow before test
Q_{max}	maximum flow
Q_r	flow at rated speed detection point
Q_t	flow at tripping point
t	time
t_0	time between detection point and maximum flow before closing
t_d	time between maximum closing flow and zero flow before any rebound
— · — ·	pressure after rupture valve

——— hydraulic fluid flow

— — — pressure before rupture valve

a The rupture valve shall be tripped before the speed is equal to rated speed +0,3 m/s.

Figure 3 — Hydraulic fluid flow through, pressure before and behind the rupture valve — Example using ISO 8100-1:2026 requirements

4.9.3.3 Resistance against pressure

The rupture valve shall be submitted to a pressure test with 5 times the maximum pressure over 2 min.

4.9.3.4 Assessment of the tests

4.9.3.4.1 Closing operation

The rupture valve fulfils the requirements laid down in the standard calling for the use of this document (e.g. ISO 8100-1:2026, 4.6.3) if the curves recorded as per 4.9.3.2.2 show that:

a) the time, t_0, between the rated flow (100 % flow) and the maximum flow, Q_{max}, does not exceed 0,16 s;

b) the time, t_d, for the decrease of the flow is as Formula (8):

$$\frac{Q_{max}}{6 \cdot A \cdot 9{,}81} \leq t_d \leq \frac{Q_{max}}{6 \cdot A \cdot 1{,}96} \quad (8)$$

where

A is the area of jack, where pressure is acting in square centimetres;

Q_{max} is the maximum flow of the hydraulic fluid in litre per minute;

t_d is the braking time in seconds;

c) a pressure of more than 3,5 · p_S, where p_S is the static pressure, shall not last longer than 0,04 s;

d) the rupture valve shall be tripped before the speed is equal to the rated speed plus 0,30 m/s.

4.9.3.4.2 Pressure resistance

The rupture valve fulfils the requirements laid down in the standard calling for the use of this document (e.g. ISO 8100-1:2026, 4.6.3) if it shows no permanent damage, after the pressure test as per 4.9.3.3.

4.9.4 Instructions

In addition to the information for assembly, connection, adjustment and maintenance, the instructions for the rupture valve shall contain the following information based on the verification:

a) the type and application of the rupture valve;

b) the range of:

1) flow of the rupture valve;

2) pressure of the rupture valve;

3) viscosity of hydraulic fluids to be used;

4) ambient temperature of the rupture valve;

c) the method of mounting.

The instructions shall be accompanied with a graph showing the relationship between the maximum flow Q_{max} (see Figure 3) and the adjustment of the device.

4.10 Guide rails calculation

4.10.1 Range of calculation

Independent of the calculation method guide rails shall be dimensioned taking into account the following stresses:

- bending stress;
- combined bending;
- buckling stress;
- compression stress/tension stress;
- combined bending and compression/tension stress;
- combined bending and buckling;
- flange bending stress.

In addition, deflections shall be analysed.

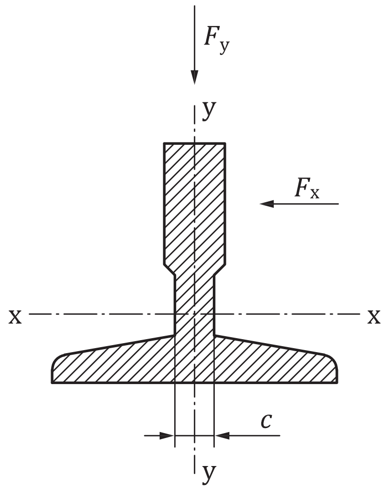
Parameters used in these calculations are described in the standards calling for the use of this document, e.g. ISO 8100-1:2026, 4.7.

NOTE An example for a calculation based on the analytical structural calculation method is given in Annex B.

4.10.2 Bending

4.10.2.1 The calculation of the bending stresses in the different axes of the guide rail (see Figure 4), shall use a model where:

- the guide rail is a continuous beam with fixing points simulating the brackets;
- the resultant of guide shoe forces causing bending stresses act in the middle between adjacent fixing points;
- the fixing points (pinned supports or roller supports) supporting the guides are rigid in X and Y directions and limit horizontal displacement of the guide and are free in rotational direction;
- bending moments act on the neutral axes of the profile of the guide rail.



Key

X	neutral axis in the x-x plane
Y	neutral axis in the y-y plane
c	width of the connecting part of the foot to the blade
F_x	force exerted to the flat of the guide blade
F_y	force exerted to the end of the guide blade

Figure 4 — Axis of the guide rail

4.10.2.2 The bending stress shall be calculated on a guide rail with four supports, spaced at the distance between brackets. The load shall be applied at the centre of the most critical span of the lift considering the applicable load cases. The first fixing point shall be a pinned support type, and the other three fixing points shall be roller support types with a degree of freedom in the vertical direction.

For analytical structural calculation method Formulae (9) and (10) shall be used for evaluating the bending stress, σ_m, from horizontal forces acting at right angles to the axis of the profile:

$$\sigma_m = \frac{M_m}{W} \tag{9}$$

$$\text{with } M_m = \frac{3 \cdot F_h \cdot l}{16} \tag{10}$$

where

F_h	is the horizontal force applied to the guide rail by the guide shoes in the different load cases in newtons;
l	is the maximum distance between guide brackets in millimetres;
M_m	is the bending moment in newtons millimetres;
σ_m	is the bending stress in newtons per square millimetre;
W	is the cross-sectional area modulus in cubic millimetres.

4.10.2.3 Bending stresses in different axes shall be combined taking into account the guide rail profile.

If, the profile section modulus, W_x and W_y, are used and the permissible stresses are not exceeded, no further proof is necessary. Otherwise, it shall be analysed at which outer edge of the guide rail profile the stresses have their maximum.

NOTE ISO 8100-33:2022 provides values of W_x and W_y for standardised guide rails.

4.10.2.4 If more than two guide rail lines are used, the forces between the guide rails shall be distributed equally, provided that their profiles are identical.

4.10.2.5 If more than one safety gear is used, acting on different guide rails, the whole braking force shall be equally distributed between the safety gears.

4.10.2.6 In the case of vertical multiplex safety gears acting on the same guide rail, the braking force of a guide rail shall be applied on one point.

4.10.3 Buckling

The buckling shall be calculated on a guide rail with two fixing points at the distance between brackets. The first fixing point shall be a pinned support type, and the other shall be roller support type with a degree of freedom in the vertical direction.

For analytical structural calculation method, the buckling stresses shall be determined by the omega method using Formulae (11) to (14):

$$\sigma_k = \frac{(F_v + F_{aux}) \cdot \omega}{A} \tag{11}$$

where

A	is the cross-sectional area of a guide rail in square millimetres;
F_{aux}	is the force in a guide rail due to auxiliary equipment and bouncing scenarios in newtons;
F_v	is the vertical force on a guide rail of the car, counterweight or balancing weight in newtons;
σ_k	is the buckling stress in newtons per square millimetre;
ω	is the omega value.

The slenderness values shall be evaluated by using Formulae (12) and (13):

$$\lambda = l_k / i \tag{12}$$

$$l_k = l \tag{13}$$

where

λ	is the slenderness;
i	is the minimum radius of gyration in millimetres;
l	is the maximum distance between guide brackets in millimetres;
l_k	is the buckling length in millimetres.

For steel with tensile strength, R_m = 370 N/mm^2:

Value of λ	Value of ω
$20 \le \lambda \le 60$	$\omega = 0{,}000\,129\,20 \cdot \lambda^{1{,}89} + 1$
$60 < \lambda \le 85$	$\omega = 0{,}000\,046\,27 \cdot \lambda^{2{,}14} + 1$
$85 < \lambda \le 115$	$\omega = 0{,}000\,017\,11 \cdot \lambda^{2{,}35} + 1{,}04$
$115 < \lambda \le 250$	$\omega = 0{,}000\,168\,87 \cdot \lambda^{2{,}00}$

For steel with tensile strength, R_m = 520 N/mm^2:

Value of λ	Value of ω
$20 \leq \lambda \leq 50$	$\omega = 0{,}000\,082\,40 \cdot \lambda^{2{,}06} + 1{,}021$
$50 < \lambda \leq 70$	$\omega = 0{,}000\,018\,95 \cdot \lambda^{2{,}41} + 1{,}05$
$70 < \lambda \leq 89$	$\omega = 0{,}000\,024\,47 \cdot \lambda^{2{,}36} + 1{,}03$
$89 < \lambda \leq 250$	$\omega = 0{,}000\,253\,30 \cdot \lambda^{2{,}00}$

The determination of omega values (ω_R) of steel with tensile strength, R_m, between 370 N/mm^2 and 520 N/mm^2 shall be carried out by using Formula (14):

$$\omega_R = \left[\frac{\omega_{520} - \omega_{370}}{520 - 370} \cdot (R_m - 370) \right] + \omega_{370} \tag{14}$$

where

ω_R is the omega value for steel with tensile strength, R_m;

ω_{370} is the omega value calculated as per the table for steel with tensile strength, 370 N/mm^2;

ω_{520} is the omega value calculated as per the table for steel with tensile strength, 520 N/mm^2.

4.10.4 Combination of bending and compression/tension or buckling stresses

For the analytical structural calculation method, the combined bending and compression/tension or buckling stresses shall be evaluated using Formulae (15) to (17):

Bending stresses:

$$\sigma = \sigma_m = \sigma_x + \sigma_y \leq \sigma_{perm} \tag{15}$$

Bending and compression/tension:

$$\sigma = \sigma_m + \frac{F_v + F_{aux}}{A} \leq \sigma_{perm} \tag{16}$$

Bending and buckling:

$$\sigma = \sigma_k + 0{,}9 \times \sigma_m \leq \sigma_{perm} \tag{17}$$

where

A is the cross-sectional area of a guide rail in square millimetres;

F_{aux} is the force in a guide rail due to auxiliary equipment and bouncing scenarios in newtons;

F_v is the vertical force on a guide rail of the car, counterweight or balancing weight in newtons;

σ is the combined stress in newtons per square millimetre;

σ_k is the buckling stress in newtons per square millimetre;

σ_m is the bending stress in newtons per square millimetre;

σ_{perm} is the permissible stress in newtons per square millimetre;

σ_x is the bending stress related to the X-axis in newtons per square millimetre;

σ_y is the bending stress related to the Y-axis in newtons per square millimetre.

4.10.5 Flange bending

The bending stress on the base of the guide rail flange produced by lateral loads shall be calculated using a model that consists of a stretch of rail fixed at its base with the following length:

a) For roller guide shoes: 3,25 times the distance from the top of the blade to the flange base (h_1-f, see Figure 5).

b) For sliding guide shoes: the length of the guide shoe plus 2 times the distance from the top of the blade to the base of the flange (h_1-f, see Figure 5).

For the analytical structural calculation method for T-shaped guide rails, Formulae (18) and (19) shall be used:

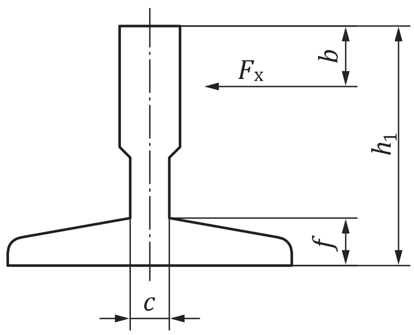
$$\sigma_F = \frac{1{,}85 \cdot F_x}{c^2} \leq \sigma_{perm} \quad \text{for roller guide shoes} \tag{18}$$

$$\sigma_F = \frac{F_x \cdot (h_1 - b - f) \cdot 6}{c^2 \cdot [l + 2 \cdot (h_1 - f)]} \leq \sigma_{perm} \quad \text{for sliding guide shoes} \tag{19}$$

where

b	is half the width of the guide shoe lining in millimetres;
c	is the width of the connecting part of the foot to the blade in millimetres;
f	is the foot depth of guide rail at its connection with the blade in millimetres;
F_x	is the force exerted by a guide shoe to the flange in newtons;
h_1	is the guide rail height in millimetres;
l	is the length of the guide shoe lining in millimetres;
σ_F	is the local flange bending stress in newtons per square millimetre;
σ_{perm}	is the permissible stress in newtons per square millimetre.

NOTE Dimensions are shown in Figure 5.



Key

b	half the width of the guide shoe lining
c	width of the connecting part of the foot to the blade
f	foot depth of guide rail at its connection with the blade
F_x	force exerted by a guide shoe to the flange
h_1	guide rail height

Figure 5 — Dimensions for flange bending calculation

4.10.6 Deflections

The deflections shall be calculated on a guide rail with four supports, spaced at the distance between brackets. The load shall be applied at the centre of the most critical span of the lift considering the applicable load cases. The first fixing point shall be a pinned support type, and the other three fixing points shall be roller support types with a degree of freedom in the vertical direction.

For the analytical structural calculation method the deflections shall be calculated by using Formulae (20) and (21):

$$\delta_x = 0{,}7 \frac{F_x \cdot l^3}{48 \cdot E \cdot I_y} + \delta_{str\text{-}x} \le \delta_{perm} \tag{20}$$

$$\delta_y = 0{,}7 \frac{F_y \cdot l^3}{48 \cdot E \cdot I_x} + \delta_{str\text{-}y} \le \delta_{perm} \tag{21}$$

where

δ_{perm}	is the maximum permissible deflection in millimetres;
δ_x	is the deflection in the X-axis in millimetres;
δ_y	is the deflection in the Y-axis in millimetres;
$\delta_{str\text{-}x}$	is the deflection of the fixings (brackets, separation beams) in the X-axis in millimetres;
$\delta_{str\text{-}y}$	is the deflection of the fixings (brackets, separation beams) in the Y-axis in millimetres;
E	is the modulus of elasticity in newtons per square millimetre;
F_x	is the supporting force in the X-axis in newtons;
F_y	is the supporting force in the Y-axis in newtons;
I_x	is the second moment of area related to the X-axis in fourth power millimetres;
I_y	is the second moment of area related to the Y-axis in fourth power millimetres;
l	is the maximum distance between guide brackets in millimetres.

4.11 Traction calculation

4.11.1 General

In the traction calculation the friction factors in accordance with Table 1 shall be applied.

Table 1 — Applicable friction factors

	Steel wire ropes with steel/cast iron traction sheave	**Elastomeric coated steel wire ropes**	**Elastomeric coated traction belts**	**Steel wire ropes: with elastomeric coated traction sheave, and with non-metallic replaceable traction sheave groove liners**
Car loading condition	f_{load}[a] shall be calculated in accordance with 4.13.6.1	f_{load}[a] shall be verified in accordance with 4.13.6.2	f_{load}[a] shall be verified in accordance with 4.13.6.2	f_{load}[a] shall be calculated in accordance with 4.13.6.1
Emergency braking condition	f_{brake}[b] shall be calculated in accordance with 4.13.6.1 or verified in accordance with 4.13.6.2	f_{brake}[b] shall be verified in accordance with 4.13.6.2	f_{brake}[b] shall be verified in accordance with 4.13.6.2	f_{brake}[b] shall be calculated in accordance with 4.13.6.1
Car/counterweight stalled condition	f_{stall}[c] shall be calculated in accordance with 4.13.6.1	f_{stall}[c] shall be verified in accordance with 4.13.6.2	f_{stall}[c] shall be verified in accordance with 4.13.6.2	f_{stall}[c] shall be verified in accordance with 4.13.6.2

[a] f_{load} friction factor for car loading condition

[b] f_{brake} friction factor for emergency braking condition

[c] f_{stall} friction factor for car/counterweight stalled condition

4.11.2 Evaluation of T_1 and T_2

4.11.2.1 Car loading condition

For car loading Formula (22) shall be applied.

$$\frac{T_1}{T_2} \leq e^{f_{\text{load}} \alpha} \tag{22}$$

where

α	is the angle of wrap of the suspension means on the traction sheave in radian;
f_{load}	is the friction factor for car loading condition;
T_1, T_2	are the forces in the portion of the suspension means situated at either side of the traction sheave.

The static ratio, T_1 / T_2, shall be evaluated for the worst case depending on the position of the car in the well with 125 % of the rated load.

4.11.2.2 Emergency braking condition

For emergency braking condition Formula (23) shall be applied.

$$\frac{T_1}{T_2} \leq e^{f_{\text{brake}} \alpha} \tag{23}$$

where

α	is the angle of wrap of the suspension means on the traction sheave in radian;
f_{brake}	is the friction factor for emergency braking condition;
T_1, T_2	are the forces in the portion of the suspension means situated at either side of the traction sheave.

The dynamic ratio, T_1 / T_2, shall be evaluated for the worst case depending on the position of the car in the well and the load conditions (empty, or with rated load).

Each moving element shall be considered with its proper rate of retardation, taking into account the reeving factor of the installation.

In no case shall the rate of retardation to consider be less than:

— 0,5 m/s^2 in normal cases;

— the minimum retardation to slow down the speed of the car and counterweight to a value not exceeding that for which the buffers are designed, in the case of reduced buffer stroke.

4.11.2.3 Car/counterweight stalled condition

For car/counterweight stalled conditions Formula (24) shall be applied.

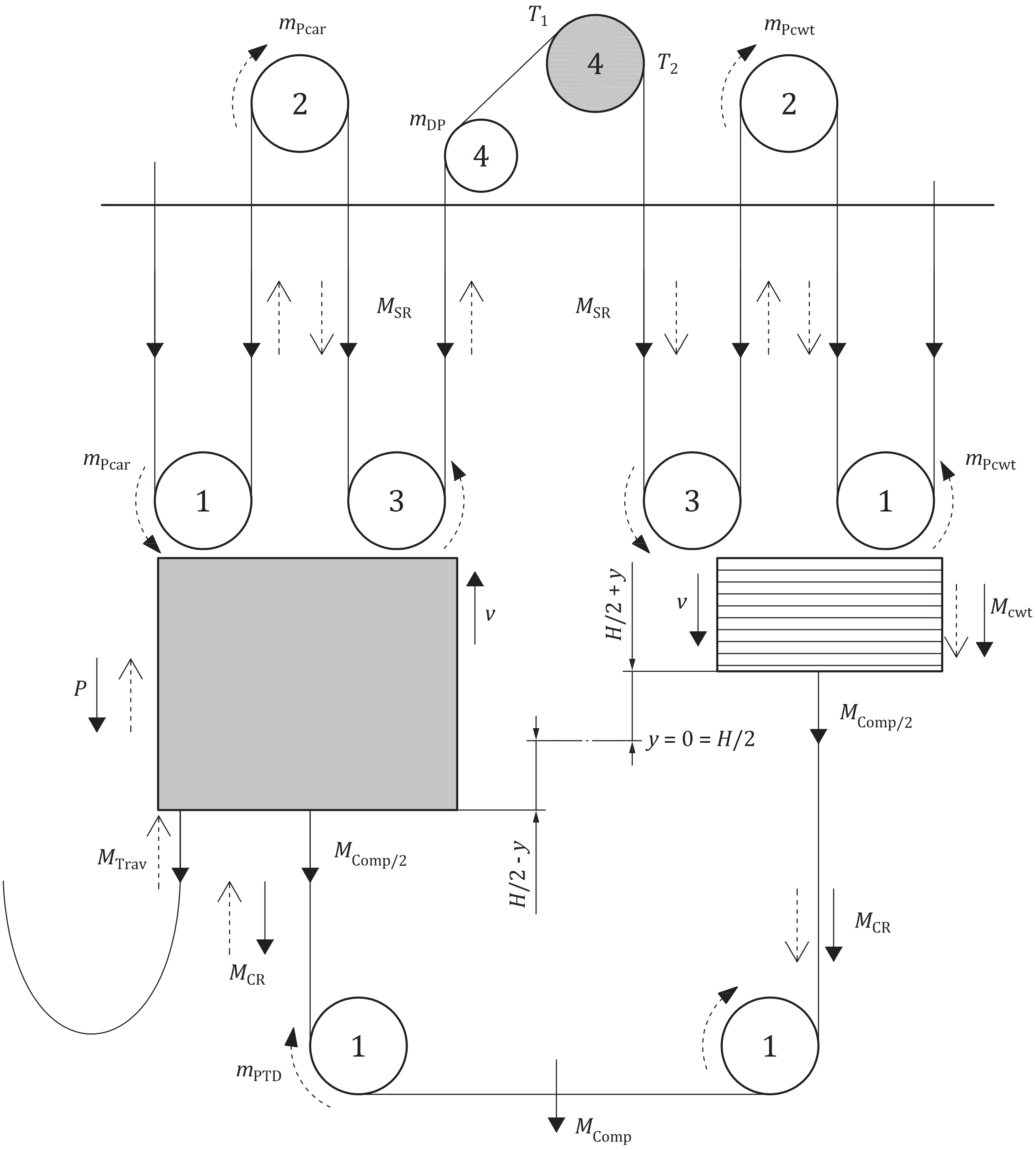
$$\frac{T_1}{T_2} \geq e^{f_{\text{stall}} \alpha} \tag{24}$$

where

α	is the angle of wrap of the suspension means on the traction sheave in radian;
f_{stall}	is the friction factor for stalled condition;
T_1, T_2	are the forces in the portion of the suspension means situated at either side of the traction sheave.

The static ratio, T_1 / T_2, shall be evaluated for the empty car at the highest and lowest position.

4.11.3 Formulae for a general case (see Figure 6)



Key

H	travel height in metres
m_{Pcar}	reduced mass (related to the car) of pulleys on car side in kilograms
m_{DP}	reduced mass (related to the car/counterweight) of deflection pulleys on car and/or counterweight side in kilograms
m_{Pcwt}	reduced mass (related to the counterweight) of pulleys on counterweight side in kilograms
m_{PTD}	reduced mass (related to car/counterweight) of one pulley on tensioning device in kilograms
M_{CR}	actual mass of compensation means in kilograms
M_{Comp}	mass of tension device including mass of pulleys in kilograms
M_{cwt}	mass of counterweight including mass of pulleys in kilograms
M_{SR}	actual mass of suspension means in kilograms

M_{Trav}	actual mass of travelling cable in kilograms
P	mass of the empty car including mass of pulleys in kilograms
v	speed of the car/counterweight in metres per second
y	level 0,5 H → y = 0 in metres
T_1, T_2	the forces exerted on suspension means in newtons
1, 2, 3, 4	speed factor of pulleys (example: 2 = 2 · v_{car})

Figure 6 — General case

Formulae (29) to (32) apply.

a) For machinery located above:

$$T_1 = \left[\frac{P+Q+M_{CRcar}+M_{Trav}}{r}\cdot(g_n \pm a)\right]+\left[\frac{M_{Comp}}{2\cdot r}\cdot g_n\right]+\left[M_{SRcar}\left(g_n \pm a\cdot\frac{r^2+2}{3}\right)\right] \pm\left[\frac{i_{PTD}\cdot m_{PTD}}{2\cdot r}\cdot a\right]\pm\left[m_{DP}\cdot a\cdot r\right]^{I} \pm\left[\sum_{i=1}^{n_P}\frac{m_{Pcar\_i}\cdot\left(\frac{v_{P\_i}}{v}\right)^2\cdot a}{r}\right]^{III} \mp\left[\frac{FR_{car}}{r}\right] \tag{29}$$

$$T_2 = \left[\frac{M_{cwt}+M_{CRcwt}}{r}\cdot(g_n \mp a)\right]+\left[\frac{M_{Comp}}{2\cdot r}\cdot g_n\right]+\left[M_{SRcwt}\left(g_n \mp a\cdot\frac{r^2+2}{3}\right)\right] \mp\left[\frac{i_{PTD}\cdot m_{PTD}}{2\cdot r}\cdot a\right]\mp\left[m_{DP}\cdot a\cdot r\right]^{II} \mp\left[\sum_{i=1}^{n_P}\frac{m_{Pcwt\_i}\cdot\left(\frac{v_{P\_i}}{v}\right)^2\cdot a}{r}\right]^{III} \pm\left[\frac{FR_{cwt}}{r}\right] \tag{30}$$

b) For machinery located below:

$$T_1 = \left[\frac{P+Q+M_{CRcar}+M_{Trav}}{r}\cdot(g_n \pm a)\right]+\left[\frac{M_{Comp}}{2\cdot r}\cdot g_n\right]+\left[M_{SR1car}\cdot(-g_n \pm a\cdot r)\right] +\left[M_{SR2car}\cdot\left(g_n \pm a\cdot\frac{r^2+2}{3}\right)\right]\pm\left[\frac{i_{PTD}\cdot m_{PTD}}{2\cdot r}\cdot a\right]\pm\left[m_{DP}\cdot a\cdot r\right]^{I} \pm\left[\sum_{i=1}^{n_P}\frac{m_{Pcar\_i}\cdot\left(\frac{v_{P\_i}}{v}\right)^2\cdot a}{r}\right]^{III} \mp\left[\frac{FR_{car}}{r}\right] \tag{31}$$

$$T_2 = \left[\frac{M_{\text{cwt}} + M_{\text{CRcwt}}}{r} \cdot (g_{\text{n}} \mp a)\right] + \left[\frac{M_{\text{Comp}}}{2 \cdot r} \cdot g_{\text{n}}\right] + \left[M_{\text{SR1cwt}} \cdot (-g_{\text{n}} \mp a \cdot r)\right]$$
$$+ \left[M_{\text{SR2cwt}}\left(g_{\text{n}} \mp a \cdot \frac{r^2+2}{3}\right)\right] \mp \left[\frac{i_{\text{PTD}} \cdot m_{\text{PTD}}}{2 \cdot r} \cdot a\right] \mp \left[m_{\text{DP}} \cdot a \cdot r\right]^{\boldsymbol{II}} \quad (32)$$
$$\mp \left[\sum_{i=1}^{n_P} \frac{m_{P\text{cwt}\_i} \cdot \left(\frac{v_{P\_i}}{v}\right)^2 \cdot a}{r}\right]^{\boldsymbol{III}} \pm \left[\frac{FR_{\text{cwt}}}{r}\right]$$

where

a	is the braking retardation (positive value) of the car in metres per square second;
FR_{car}	is the frictional force in the well (efficiency of bearings car side and friction on guide rails, etc.) in newtons;
FR_{cwt}	is the frictional force in the well (efficiency of bearings counterweight side and friction on guide rails, etc.) in newtons;
g_{n}	is the standard acceleration of free fall in metres per square second;
H	is the travel height in metres;
i_{PTD}	is the number of pulleys for tensioning device;
J_{Pcar}	is the moment of inertia of one pulley on the car side in kilograms square metre;
J_{Pcwt}	is the moment of inertia of one pulley on the counterweight side in kilograms square metre;
J_{DP}	is the moment of inertia of deflection pulleys on car and/or counterweight side in kilograms square metre;
J_{PTD}	is the moment of inertia of one pulley on tensioning device in kilograms square metre;
m_{DP}	is the reduced mass J_{DP}/R^2 (related to the car/counterweight) of deflection pulleys on car and/or counterweight side, having the same suspension means speed than the traction sheave, in kilograms;
$m_{\text{Pcar\_i}}$	is the reduced mass J_{Pcar}/R^2 (related to the car) of one pulley on the car side in kilograms;
$m_{\text{Pcwt\_i}}$	is the reduced mass J_{Pcwt}/R^2 (related to the counterweight) of one pulley on the counterweight side in kilograms;
m_{PTD}	is the reduced mass J_{PTD}/R^2 (related to car/counterweight) of one pulley on tensioning device in kilograms;
M_{Comp}	is the mass of tension device including mass of pulleys in kilograms;
M_{CR}	is the actual mass of compensation means [(0,5 $\cdot H \pm y) \cdot n_{\text{c}} \cdot$ compensation means weight per unit length], in kilograms;
M_{CRcar}	is the mass M_{CR} on the car side;
M_{CRcwt}	is the mass M_{CR} on the counterweight side;
M_{cwt}	is the mass of counterweight including mass of pulleys in kilograms;
M_{SR}	is the actual mass of suspension means [(0,5 $\cdot H \pm y) \cdot n_{\text{s}} \cdot$ *suspension means weight per unit length*], in kilograms;
M_{SRcar}	is the mass M_{SR} on car side;
M_{SR1car}	is the mass M_{SR} of the suspension means leading from the machine to the pulley(s) in the headroom in the case of machine below;
M_{SR2car}	is the mass M_{SR} of the suspension means leading from the pulley(s) in the headroom to the car in the case of machine below, (M_{SR2car} = 0 if car at upmost landing);
M_{SRcwt}	is the mass M_{SR} on counterweight side;
M_{SR1cwt}	is the mass M_{SR} of the suspension means leading from the machine to the pulley(s) in the headroom;

M_{SR2cwt}	is the mass M_{SR} of the suspension means leading from pulley(s) in the headroom to the counterweight, (M_{SR2cwt} = 0 if counterweight at upmost landing);
M_{Trav}	is the actual mass of travelling cable [(0,25H ± 0,5y) · n_t · *travelling cable weight per unit length*], in kilograms;
n_C	is the number of compensation means;
n_P	is the number of pulleys on the car/counterweight side;
n_S	is the number of suspension means;
n_t	is the number of travelling cables;
P	is the mass of the empty car including mass of pulleys in kilograms;
Q	is the rated load in kilograms;
r	is the reeving factor;
R	is the radius of related pulleys in metres;
T_1, T_2	are the forces exerted on suspension means in newtons;
v	is the speed of the car/counterweight in metres per second;
v_{P_i}	is the rotation speed of one pulley (rope speed) in metres per second;
y	is on the level $0{,}5 \cdot H \rightarrow y = 0$, in metres;
→	is the static force;
⟶	is the dynamic force.

Conditions:

I	is for any deflection pulley on car side;
II	is for any deflection pulley on counterweight side;
III	is only for reeving factor > 1;

NOTE 1 Formulae (29) to (32) can be also used for the empty car by deleting Q. In this case, T_1 becomes T_2, and T_2 becomes T_1.

In Formulae (29) to (32), the symbols ± and ∓ shall be used in such a way that:

— the upper operation is applicable in case the car is retarding in the downward direction, and

— the lower operation in case the car is retarding in the upward direction.

For cases with car loading and stalled condition, $a = 0$.

For the car loading case, Q shall be replaced by 1,25 Q.

The friction forces, FR_{car} and FR_{cwt}, shall be deleted in all conditions if a minimum friction force cannot be ensured.

NOTE 2 For calculation example, see Annex C.

4.12 Evaluation of safety factor of steel wire ropes

4.12.1 General

This subclause describes the method of evaluation of the safety factor "S_f" for the suspension means of traction drive lifts with steel/cast iron traction sheaves and non-metallic replaceable traction sheave groove liners in combination with steel wire ropes in accordance with ISO 4344:2022.

NOTE This method is based on sufficient life time of the steel wire ropes assuming a regular maintenance and inspection.

4.12.2 Equivalent number, N_{equiv}, of pulleys

4.12.2.1 General

The number of bends and the degree of severity of each bend cause deterioration of the rope. This is influenced by the type of grooves (U- or V-groove) and whether the bend is reversed or not.

The degree of severity of each bend can be equated to a number of simple bends.

A simple bend is defined by the rope travelling over a semi-circular groove, where the radius of the groove is not more than 0,53 of the nominal rope diameter.

The number of simple bends corresponds to an equivalent number of pulleys, N_{equiv}, which can be derived from Formula (33):

$$N_{equiv} = N_{equiv(t)} + N_{equiv(p)} \quad (33)$$

where

$N_{equiv(t)}$ is the equivalent number of traction sheaves;
$N_{equiv(p)}$ is the equivalent number of deflection pulleys.

4.12.2.2 Evaluation of $N_{equiv(t)}$

Values of $N_{equiv(t)}$ shall be taken from Table 2.

Table 2 — Evaluation of equivalent number of traction sheaves $N_{equiv(t)}$

V-grooves	V-angle (γ)	35°	36°	38°	40°	42°	45°	50°
	$N_{equiv(t)}$	18,5	16	12	10	8	6,5	5
U-Undercut grooves	U-angle (β)	75°	80°	85°	90°	95°	100°	105°
	$N_{equiv(t)}$	2,5	3,0	3,8	5,0	6,7	10,0	15,2

For U-grooves without undercut, $N_{equiv(t)} = 1$.

Values for angles not in Table 2 may be determined by linear interpolation.

4.12.2.3 Evaluation of $N_{equiv(p)}$

A bend is only considered to be a reverse bend if the distance from the rope contacts on two consecutive pulleys or sheaves, which have a fixed distance between their axles, is less than 200 times the rope diameter, and the bending planes are rotated through more than 120° [see Formulae (34) and (35)].

$$N_{equiv(p)} = K_p \cdot (N_{ps} + 4 \cdot N_{pr}) \quad (34)$$

where

N_{ps} is the number of pulleys with simple bends;
N_{pr} is the number of pulleys with reversed bends;
K_p is the factor of ratio between sheave and pulley diameters.

$$\text{with } K_p = \left(\frac{D_t}{D_p}\right)^4 \quad (35)$$

where

D_t is the diameter of the traction sheave, in metres;
D_p is the average diameter of all pulleys, traction sheave excluded, in metres.

NOTE Examples for evaluation of equivalent number of pulleys are given in Annex D.

4.12.3 Safety factor

For a given design of rope drive, the minimum value of safety factor can be selected from Figure 7 taking into account the correct ratio of D_t/d_r and the calculated N_{equiv} for the worst-case section of ropes.

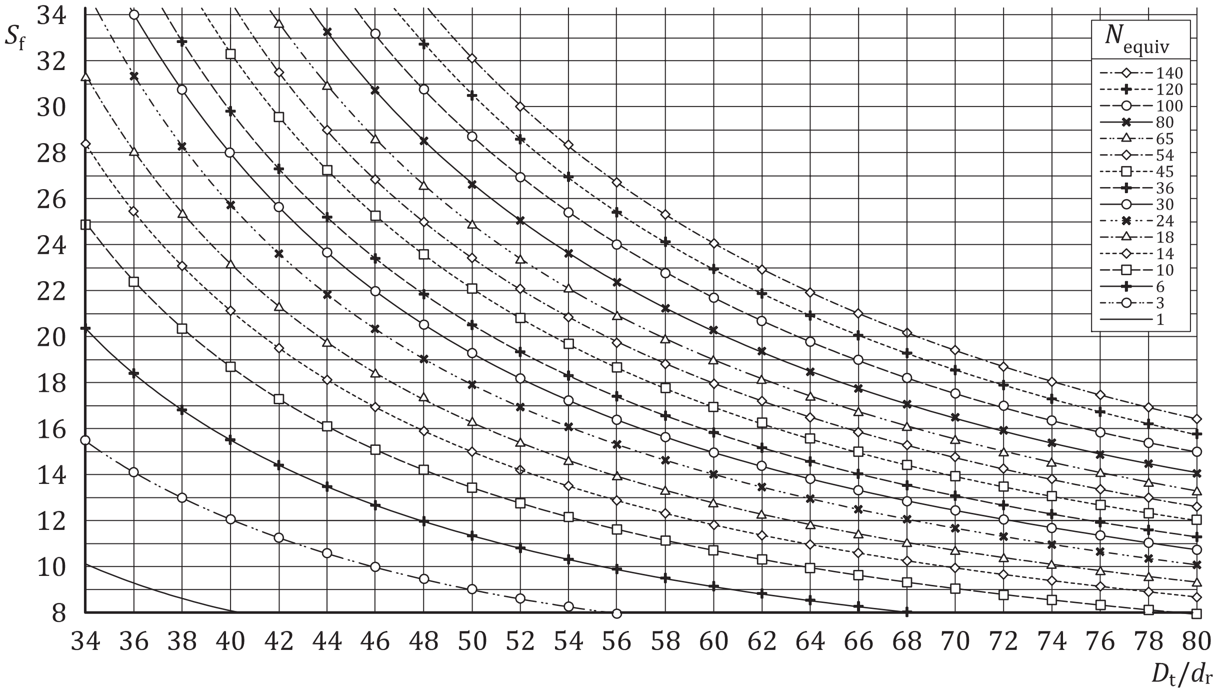


Figure 7 — Evaluation of minimum safety factor

The curves of the Figure 7 are based on Formula (36):

$$S_f = 10^{\left(2,683\,4 - \frac{\lg\left(\frac{695,85 \cdot 10^6 \cdot N_{equiv}}{\left(\frac{D_t}{d_r}\right)^{8,567}} \right)}{\lg\left(77,09 \left(\frac{D_t}{d_r}\right)^{-2,894} \right)} \right)} \qquad (36)$$

where

D_t	is the diameter of traction sheave;
d_r	is the diameter of the ropes;
N_{equiv}	is the equivalent number of pulleys;
S_f	is the safety factor.

4.13 Verification of suspension means, compensation means and their terminations

4.13.1 Material and construction verification

Conformance with material and construction requirements of the standard calling for the use of this document (e.g. ISO 8100-1:2026, 4.5.1.2) shall be verified through a visual verification of the instructions supplied with the suspension means.

The diameter of wires, strands and ropes and the dimensions of carbon fibre reinforced polymer tension members (CFRP's) shall be measured as follows:

— Measurements shall be taken on a straight section in accordance with ISO 4344:2022, 5.3.

— The minimum accuracy of the measurement instrument shall be 0,02 mm for CFRP's, belts or diameters above 2 mm, 0,01 mm for diameters below 2 mm, and 0,001 mm for diameters below 0,5 mm.

— The measurement surface of instruments used for ropes and strands shall cover at least two strands or wires in axial direction.

The width and thickness of elastomeric coated traction belts shall be measured on a straight section of the belt.

4.13.2 Verification of elastomeric coated traction sheave grooves

Wear resistance of the traction sheave coating shall be verified with a wear test.

Therefore, the traction sheave shall rotate against the one side fixed steel wire rope (see Figure 8) of the type specified to be used in the lift application. The test shall be performed with the following parameters:

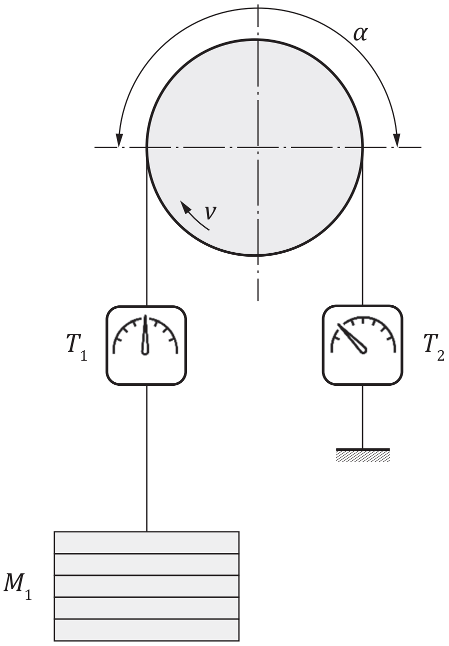
— wrapping angle of 180°;

— traction sheave shall have same design (groove geometry, material, bending diameter) as in the intended application;

— maximum load as specified for the application considering the limits as required by the standard calling for this application (e.g. ISO 8100-1:2026, 4.5.2.2);

— rotation speed during slipping test shall be limited such way that coating temperature stays below +40 °C.

— rotation direction is not requested to be reverted during the test endurance.



Key

α	is the angle of wrap of the suspension means on the traction sheave
M_1	test load
T_1, T_2	are the forces in the portion of the suspension means situated at either side of the traction sheave
v	is the traction sheave speed at rated speed of the car in meters per second

Figure 8 — Test setup example

The test slip distance shall be calculated in accordance with Formula (37) and shall not be less than 15 000 m.

$$S_T = N_{lift} \cdot C_R \cdot H \cdot r \quad (37)$$

where

C_R	is the slip percentage over two full trip distance;
H	is the travel height, in metres;
N_{lift}	is the maximum number of allowed trips for the lift application which shall be ≥ 600 000;
r	is the reeving factor;
S_T	is the total slip distance for the wear test, in metres.

The slip percentage shall be determined by a test setup with two weights corresponding to the maximum T_2 / T_1 or T_1 / T_2 ratio and heaviest mass of the intended application. The applied traction sheave shall have the same design (groove geometry, coating thickness, materials, bending diameter) as in the intended application. Slip distance shall be measured, e.g. with pen marking over the ropes and traction sheave. After running of full round trip (full trip down and full trip up to the same position) measure the slip/creeping distance of the rope on the traction sheave.

Acceptable wear depth shall be 50 % of the coating thickness and at the end of the test the coating shall be firmly in its place in the groove.

4.13.3 Terminations of suspension means

4.13.3.1 General

Each termination design, material and method of manufacture, shall be verified in accordance with 4.13.3.2 to 4.13.3.6.

The verification in accordance with 4.13.3.2 to 4.13.3.5 shall be done on assembled terminations using the highest minimum breaking force (MBF) of suspension means for which the socket is specified. Two assembled terminations shall be verified in each test.

The tests in accordance with 4.13.3.2 to 4.13.3.5 are carried out by using the same socket body, wedge and pin, they shall be conducted in the order of termination and wedge security, deformation, fatigue and tensile efficiency testing, renewing the suspension means as necessary. The testing machine shall be in accordance with ISO 7500-1:2018.

4.13.3.2 Termination and wedge security test

The test shall be carried out loading the assembled termination with a load of 20 % of the MBF of the suspension means, sustain this load for 5 s to allow settlement of the termination, then continue to sustain for a further 2 min before removing the load.

The assembled and loaded termination, after initial settlement, shall during the noted 2 min period exhibit no further movement between the suspension means and the termination, monitored either as movement of the tail of the suspension means, or as relative movement between the suspension means and the wedge.

After release of the specified load no relative movement shall occur between the wedge and socket body.

4.13.3.3 Deformation test

The termination shall be further loaded until this load reaches a value equal to 40 % of the MBF of the suspension means. The load shall then be removed, the termination dismantled and the socket body and pin checked for permanent deformation. If permanent deformation occurs, the test is failed.

4.13.3.4 Fatigue test

The test shall be carried out on an in-line tensile fatigue machine. The termination shall be prevented from rotating and the test shall consist of the application of the cycle force from 15 % to 30 % of the MBF of the suspension means along the suspension means axis for 75 000 cycles.

The frequency of the force shall not exceed 5 Hz.

The component parts shall be subject to dye penetrant in accordance with ISO 23277:2015 or magnetic particle inspection in accordance with ISO 17638:2016, both before and after the fatigue test to enable any crack propagation as a result of fatigue to be readily identified.

NOTE More than one suspension means can be required to enable the socket body to achieve 75 000 cycles.

For non-welded enclosures, the test as per ISO 17638:2016 is preferred.

After the test the socket body shall not exhibit any indications of cracks. If a pin is part of the component design, the pin and pin eye holes in the socket shall exhibit no sign of local permanent deformation.

4.13.3.5 Tensile efficiency test

The test shall be carried out loading the assembled termination with an initial load of 60 % of the MBF of the suspension means, then increasing this load at a rate of not more than 0,5 % of the MBF per second. The increasing shall continue until breakage which shall occur at minimum 80 % of the MBF of the suspension.

If terminations are tested in pairs, the distance between the inner faces of the socket bodies shall be at least 30 times the tension member diameter or thickness.

4.13.3.6 Charpy impact test

Charpy V-notch impact tests shall be carried out in accordance with ISO 148-1:2016 on materials of socket bodies and pins of all sizes.

Three samples shall be tested at a temperature of -20 °C.

For tests where the size of socket body is too small to provide a suitable test piece, tests may be carried out on sample material which shall be of the same specification and heat treatment.

For steel socket body and/or pin a minimum average Charpy impact value of 27 J, with no individual value less than 18 J shall be reached.

For spheroidal graphite cast iron and any other cast irons the socket body a minimum average Charpy impact value of 12 J, with no individual value less than 9 J shall be reached.

4.13.4 Minimum breaking force (MBF)

The MBF for elastomeric coated suspension means and for steel wire ropes not in accordance with ISO 4344:2022 shall be verified in accordance with ISO 3108:2017 with the following deviations:

a) the minimum free test length shall be 500 mm excluding any terminations for elastomeric coated suspension means;

b) the test may be terminated without breaking the suspension means when the MBF is achieved or exceeded;

c) the test may be discounted when the MBF has not been reached and if the suspension means fractures within a distance from the base of the grip or termination, that is smaller than 6 times the nominal diameter of the tension member of the elastomeric coated suspension means.

4.13.5 Fatigue lifetime testing

The maximum number of simple bends N_{SB} and reverse bends N_{RB} for suspension means shall be verified by means of bend-over-sheave fatigue testing.

Tests shall be performed with sheaves of the design specified in the instructions as per 4.13.9.

If different designs for traction sheaves and pulleys are applied the following characteristics shall be used to evaluate N_{SB} and N_{RB}:

— the smallest diameter;

— the hardest groove material;

— in case of semi-circular groove, the maximum undercut;

— in case of V-groove, the minimum angle of groove;

— the biggest fleet angle;

— maximum permitted twist [°/m] for belts.

From the bending fatigue test the number of simple bends, N_{SB} and the number of reverse bends, N_{RB} reaching the residual breaking force requirements of the standard calling for use of this document (e.g. ISO 8100-1:2026, Table 13) shall be derived.

For steel wire ropes < 6 mm, the tests shall prove that at a diameter reduction of 6 % related to the nominal diameter, the residual breaking force (RBF) is not less than 80 % of the MBF.

Bending fatigue test shall fulfil the following requirements:

— minimum bending length 30 times the tension member diameter or thickness and at least 100 mm;

— minimum wrapping angle of the suspension means over the test sheave 40°;

— minimum safety factor in accordance with the standard calling for use of this document (e.g. ISO 8100-1:2026, 4.5.2.2) that is considered in the application.

4.13.6 Friction factor

4.13.6.1 Calculation of friction factor

4.13.6.1.1 General

This calculation method is applicable for steel wire ropes with:

— steel/cast iron traction sheave;

— elastomeric coated traction sheave;

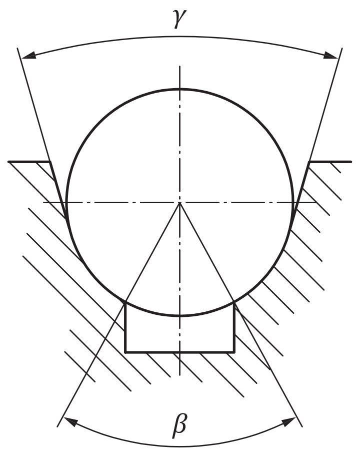
— non-metallic replaceable traction sheave groove liners.

To ensure traction in case of adhesion failure or coating damage on the elastomeric coated traction sheave and the non-metallic replaceable traction sheave groove liners, the friction factor evaluation for car loading and emergency stop shall be based on the same calculation methods assuming always a steel to steel/cast iron contact.

For steel wire ropes with elastomeric coated traction sheave and with non-metallic replaceable traction sheave groove liners, the friction factor calculation for stalled condition is not applicable and the friction factor shall be verified in accordance with 4.13.6.2.

4.13.6.1.2 Grooving considerations

4.13.6.1.2.1 Semi-circular and semi-circular undercut grooves (see Figure 9).



Key

β	undercut angle
γ	groove angle

Figure 9 — Semi-circular groove, undercut

Formula (24) shall be used:

$$f_{load} = f_{brake} = f_{stall} = \mu \cdot \frac{4\left(\cos\frac{\gamma}{2} - \sin\frac{\beta}{2}\right)}{\pi - \beta - \gamma - \sin\beta + \sin\gamma} \quad (24)$$

where

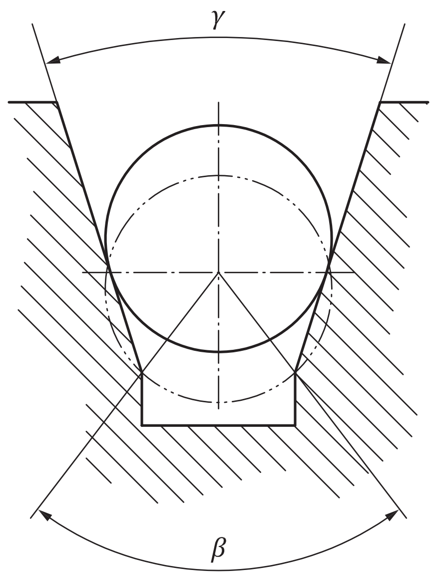
β	is the value of the undercut angle, in radian;
γ	is the value of the groove angle, in radian;
μ	is the friction coefficient;
f_{load}	is the friction factor for car loading condition;
f_{brake}	is the friction factor for emergency braking condition;
f_{stall}	is the friction factor for car/counterweight stalled condition.

The maximum value of the undercut angle, β, shall not exceed 105° (1,83 rad).

The value of the groove angle, γ, shall never be less than 25° (0,44 rad).

4.13.6.1.2.2 V-grooves (see Figure 10)

For metallic traction sheaves with non-hardened grooves and for elastomeric coated traction sheaves an undercut shall be provided to limit the traction loss due to wear.



Key

β	undercut angle
γ	groove angle

Figure 10 — V-groove

Formulae (25) to (27) shall apply:

— in the case of car loading and emergency braking:

— for non-hardened steel/cast iron and elastomeric coated traction sheave grooves:

$$f_{load} = f_{brake} = \mu \cdot \frac{4\left(1 - \sin\frac{\beta}{2}\right)}{\pi - \beta - \sin\beta} \quad (25)$$

— for hardened steel/cast iron grooves:

$$f_{load} = f_{brake} = \mu \cdot \frac{1}{\sin\frac{\gamma}{2}} \tag{26}$$

— in the case of car/counterweight stalled conditions (not applicable for elastomeric coated traction sheave grooves):

— for hardened and non-hardened steel/cast iron grooves

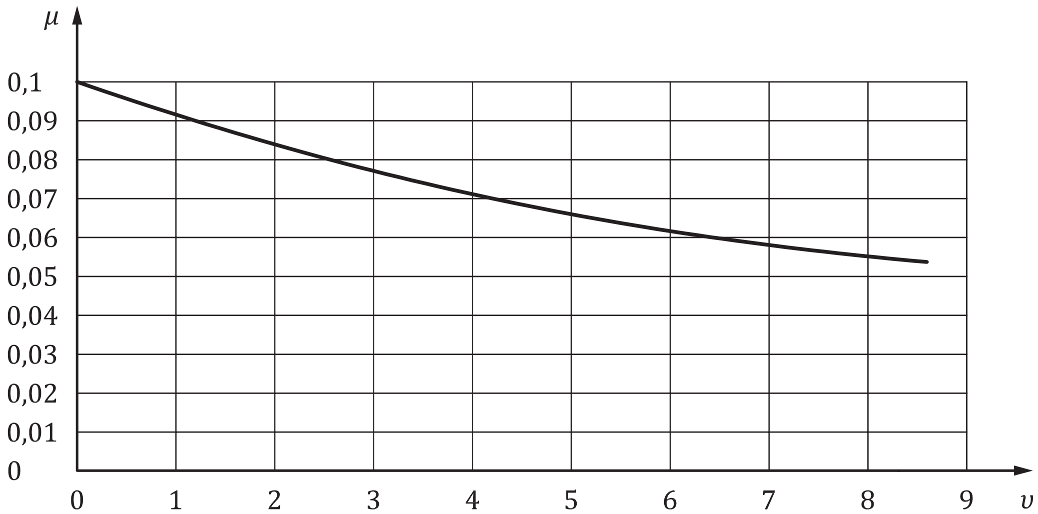
$$f_{stall} = \mu \cdot \frac{1}{\sin\frac{\gamma}{2}} \tag{27}$$

where

β	is the value of the undercut angle, in radian;
γ	is the value of the groove angle, in radian;
μ	is the friction coefficient;
f_{load}	is the friction factor for car loading condition;
f_{brake}	is the friction factor for emergency braking condition;
f_{stall}	is the friction factor for stalled condition.

The maximum value of the undercut angle, β, shall not exceed 105° (1,83 rad). Angle γ shall never be less than 35° (0,61 rad) for lifts.

4.13.6.1.3 Friction coefficient consideration (see Figure 11)



Key

μ	friction coefficient for steel/cast iron and elastomeric grooves
υ	rope speed at rated speed of the car in meters per second

Figure 11 — Minimum friction coefficient

The following values shall apply for steel/cast iron and elastomeric grooves:

— μ = 0,1 for loading conditions;

— μ = 0,2 for car/counterweight stalled conditions;

— Formula (28) for emergency braking conditions:

$$\mu = \frac{0,1}{1 + \frac{v}{10}} \qquad (28)$$

where

μ	is the friction coefficient;
v	is the rope speed at rated speed of the car, in metres per second.

4.13.6.2 Verification of friction factor

4.13.6.2.1 General

The friction factor shall be verified for the traction conditions loading, emergency braking and stalled under maximum and minimum T_1 / T_2 ratio and the maximum and minimum loads representing the full range of intended application.

The verification tests shall include an evaluation of:

— a single or multiple suspension means installed on a traction sheave design as applied in the lift;

— the minimum and maximum wrap angles as specified in the instructions as per 4.13.9;

— the lowest and highest suspension means load applicable;

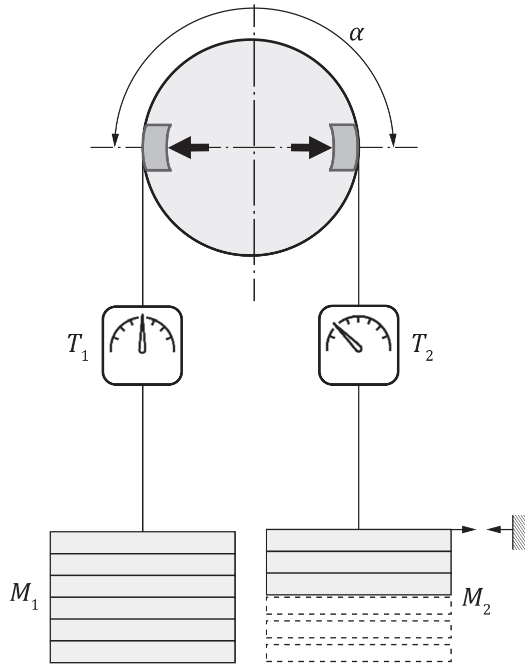
— the environmental limitations and forbidden contaminants as stated in the instructions as per 4.13.9;

— new suspension means and used samples having reached the discard limit.

Using the result of this verification tests, only the lowest friction factor shall be considered for the traction conditions loading and emergency braking and only the highest friction factor shall be considered for the traction condition stalled.

4.13.6.2.2 Friction factor verification for loading condition

The friction factor f_{load} for car loading condition (see 4.11.2.1) shall be verified in a test setup with relative speed v = 0 m/s between the suspension means and blocked traction sheave (see Figure 12).



Key

α	is the angle of wrap of the suspension means on the traction sheave
M_1, M_2	test load
T_1, T_2	are the forces measured on suspension means

Figure 12 — Static friction test setup

Before the test, T_1 and T_2 shall be selected to correspond the highest suspension means load, depending on the position of the car in the well, with 125 % of the rated load.

NOTE The test load is applied by weights or other means.

During the test T_2 shall be successively reduced until the suspension means slips. The highest T_1 / T_2 ratio measured without slippage shall be used for the calculation of f_{load} in accordance with Formula (29).

$$f_{load} = \frac{1}{\alpha} \cdot \ln\left(\frac{T_1}{T_2}\right) \tag{29}$$

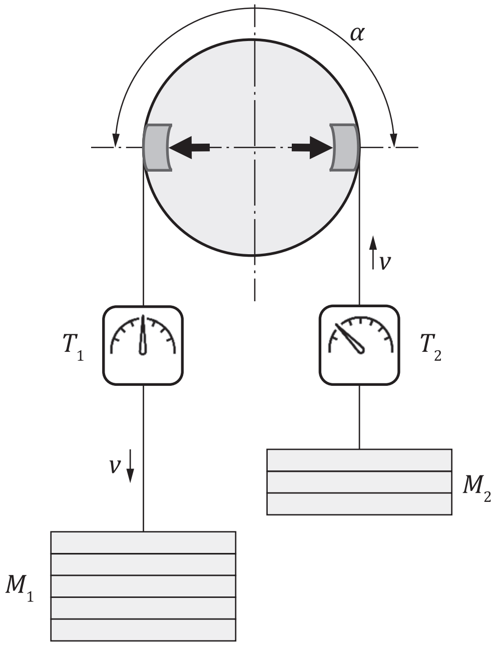
where

f_{load}	is the friction factor for car loading condition;
α	is the angle of wrap of the suspension means on the traction sheave in radian;
T_1, T_2	are the forces measured on suspension means.

4.13.6.2.3 Friction factor verification for emergency braking condition

The friction factor f_{brake} for emergency braking condition (see 4.11.2.2) shall be verified with the maximum suspension means speed occurring at rated car speed.

It shall be performed in a system test using a moving suspension means and braked traction sheave (see Figure 13).



Key

T_1, T_2	are the forces measured on suspension mean
α	is the angle of wrap of the suspension means on the traction sheave
v	is the suspension means speed at rated speed of the car, in metres per second
M_1, M_2	test load

Figure 13 — Dynamic friction test setup with moving suspension means

The following two emergency braking situations shall be verified.

a) For the verification of the emergency braking situation of the car moving downwards, M_1 shall be selected so that it corresponds the highest suspension means load, depending on the position of the car in the well, loaded with rated load. M_2 shall be selected to correspond the lowest suspension means load from the counterweight, depending on its position in the well.

b) For verification of the emergency braking situation of the empty car moving upward, M_2 shall be selected to correspond the lowest suspension means load, depending on the position of the empty car in the well. M_1 shall be selected to correspond the highest suspension means load from the counterweight, depending on its position in the well.

The test loads shall be accelerated to a speed that corresponds to the suspension means speed at rated speed of the car. After reaching this speed the traction sheave shall be stopped. During the test the retardation of the test loads shall not exceed that resulting from operation of the safety gear or stopping on the buffer. The averaged T_1 / T_2 ratio measured during the deceleration shall be used for the calculation of f_{brake} in accordance with Formula (30).

$$f_{brake} = \frac{1}{\alpha} \cdot \ln\left(\frac{T_1}{T_2}\right) \quad (30)$$

where

f_{brake}	is the friction factor for car emergency braking condition;
α	is the angle of wrap of the suspension means on the traction sheave in radian;
T_1, T_2	are the forces measured on suspension means.

4.13.6.2.4 Friction factor verification for stalled condition

The friction factor verification for car or counterweight stalled condition (see 4.11.2.3) shall be performed using a single moving suspension means and a driven traction sheave (see Figure 14).

For the initial test setup T_1 and T_2 shall be selected to correspond to the lowest suspension means load, depending on the position of the car in the well.

Two stalling situations shall be verified:

a) the suspension means speed at rated speed of the car; and

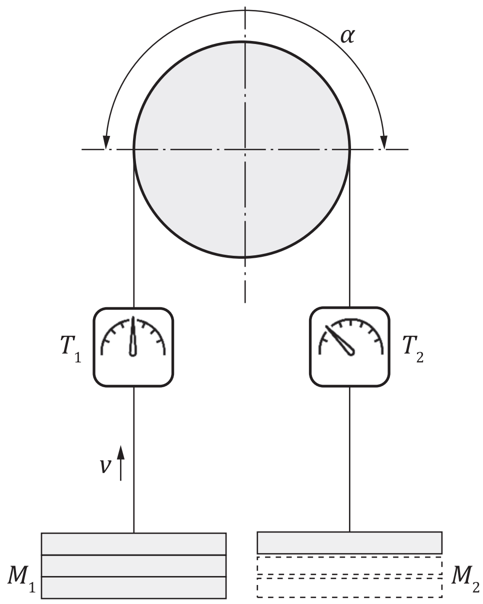
b) the suspension means speed at a car speed of 0,15 m/s [e.g. ISO 8100-1:2026, 4.12.1.5.2.1 g) 1)].

During the verification, the T_2 load shall be reduced until slip of the suspension means occurs on the traction sheave. At that situation, the measured T_1 / T_2 ratio shall be used for the calculation of f_{stall} in accordance with Formula (31). If the measured values differ for stalling situation a) and b) the highest T_1 / T_2 ratio shall be used for the calculation of f_{stall}.

$$f_{stall} = \frac{1}{\alpha} \cdot \ln\left(\frac{T_1}{T_2}\right) \quad (31)$$

where

f_{stall}	is the friction factor for stalled condition;
α	is the angle of wrap of the suspension means on the traction sheave in radian;
T_1, T_2	are the forces measured on suspension means.



Key

T_1, T_2	are the forces measured on suspension mean
α	is the angle of wrap of the suspension means on the traction sheave
v	is the suspension means speed at rated speed of the car
M_1, M_2	test load

Figure 14 — Stalled condition friction test setup

4.13.6.3 Elastomeric coated timing belts and sprockets

The strength of the teeth-sprocket contact shall be verified with a test setup consisting of the elastomeric coated timing belt and the corresponding sprocket. The test setup shall be loaded with:

— the maximum T_1 / T_2 or T_2 / T_1 to be expected for the conditions car loading, emergency stop and stalled; and

— the minimum wrapping angle applicable.

After the test the elastomeric coated timing belt and the sprocket shall not be damaged.

NOTE Termination test covers teeth physical strength requirement as required by the standard calling for this device (e.g. ISO 8100-1:2026, 4.5.2.3.3).

4.13.7 Additional mechanical tests for elastomeric coated suspension means

4.13.7.1 General

Each combination of suspension means and traction sheave design shall pass the tests for slip and emergency stop.

4.13.7.2 Slip test

One or more suspension means shall be loaded in tension over the intended traction sheave, to the maximum load to be qualified. The suspension means shall be secured such that it/they cannot move. The traction sheave shall be running at a speed corresponding to the maximum inspection speed of the lift to which the suspension means will be applied.

The test shall run for 4 minutes, no suspension means or traction sheave shall break.

4.13.7.3 Emergency-stop test

The suspension means shall be loaded in tension over the intended traction sheave to the maximum load to be qualified. The suspension means shall run at the maximum speed. The driving sheave shall perform an emergency stop.

The test shall be repeated for a total of 20 emergency stops, and the test arranged such, that suspension means stop and possible slippage occurs over the same portion of the suspension means in each test.

The test setup shall ensure, that the stop and possible the duration of the slip corresponds to that, attained in the intended application. The suspension means shall not experience damage such, that the suspension means require replacement due to the discard criteria provided.

4.13.8 Additional mechanical tests for CFRP elastomeric coated suspension means

4.13.8.1 Adhesion strength test

It shall be tested that the adhesive strength between the coating and a single tension member is not less than:

a) 5 N/mm in the length of the tested tension member, if the tension member section is circular and the diameter does not exceed 5 mm;

b) 10 N/mm in the length of the tested tension member, if the tension member section is circular and the diameter exceeds 5 mm;

c) 3 N/mm in the width of the tested tension member, if the tension member section is non-circular.

4.13.8.2 Heat radiation performance test

Additional to the test in 4.13.3 the combination of the elastomeric coated suspension means and its termination shall be tested at 120 °C, the combination shall be able to withstand a load equal to 1/12 the minimum breaking load of the suspension means and keep it for 2 hours without slipping out of the termination.

4.13.8.3 Climate conditions exposure simulation

Four groups of three samples shall be prepared in accordance with 4.13.8.2.

First, the samples shall be stored in a climate chamber at a temperature of 70 °C ± 2 K with a relative humidity not less than 90 %, for 168 hours.

Second, the samples shall be stored in a climate chamber at a temperature of -10 °C ± 2 K for 96 hours.

After this, the samples shall be stored 7 days at a temperature between 10 °C and 35 °C.

The first group of samples shall be tested in accordance with 4.13.4.

The second group of samples shall be tested in accordance with 4.13.5.

The third group of samples shall be tested in accordance with 4.13.6.

The fourth group of samples shall be tested in accordance with 4.13.8.1.

4.13.9 Instructions

In additional to the information for assembly, connection, adjustment and maintenance, the instructions of the suspension and compensation means verified in accordance with 4.13, shall contain information in accordance with Table 3, and:

— for elastomeric coated traction belts with CFRP tension members additional information shall be provided for the environmental conditions for use, installation, storage, and transport (temperature, humidity, pollution, UV, etc.);

— for elastomeric coated traction belts with CFRP tension members additional information shall be provided for the maximum lifetime.

Table 3 — Instructions information

	Steel wire ropes with steel/cast iron sheaves	**Steel wire ropes with elastomeric coated traction sheaves**	**Steel wire ropes with non-metallic replaceable traction sheave groove liners**	**Elastomeric coated traction belts**	**Elastomeric coated steel wire ropes**	**Elastomeric coated timing belts**
Identification of the product	X	X	X	X	X	X
Construction verified as per 4.13.1	Rope construction	Rope construction	-	Construction and number of the tension members	Construction of the tension members	Construction and number of the tension members
Technical specification of the traction sheave, sprocket or pulleys verified as per 4.13	X	X	X	X	X	X
Unit mass [kg/m]	X	X	-	X	X	X
Maximum permitted twist [°/m] verified as per 4.13	-	-	-	X	-	X
Maximum permitted fleet angle of the suspension means [°] verified as per 4.13	X	-	-	X	X	X
- not applicable						

Table 3 *(continued)*

	Steel wire ropes with steel/cast iron sheaves	Steel wire ropes with elastomeric coated traction sheaves	Steel wire ropes with non-metallic replaceable traction sheave groove liners	Elastomeric coated traction belts	Elastomeric coated steel wire ropes	Elastomeric coated timing belts
Nominal tensile grade [N/mm^2]	X	X	-	-	-	-
Nominal dimension of the suspension means [mm]	X	X	-	X	X	X
Minimum breaking force [kN] verified as per 4.13.4	X	X	-	X	X	X
Safety factor as verified per 4.13.5	X	X	-	X	X	X
Maximum number of simple bends (N_{SB}) and reverse bends (N_{RB}) as per 4.13.5	X	X	-	X	X	X
Friction factor f	f_{load} and f_{stall} as per 4.13.6.1 f_{brake} as per 4.13.6.1 or 4.13.6.2	f_{load} and f_{brake} as per 4.13.6.1 f_{stall} as per 4.13.6.2	f_{load} and f_{brake} as per 4.13.6.1 f_{stall} as per 4.13.6.2	f_{load}, f_{stall} and f_{brake} as per 4.13.6.2	f_{load}, f_{stall} and f_{brake} as per 4.13.6.2	-
Environmental limitations and forbidden contaminants see 4.13.6.2.1	X	X	X	X	X	X
Maximum speed of the suspension means [m/s] as verified in 4.13.7.3	-	-	-	X	X	-
Maximum speed of the suspension means at inspection operation as verified in 4.13.7.2 [m/s]	-	-	-	X	X	-
Maintenance and discard information as per 4.14	X	X	X	X	X	X
Information about the terminations verified in 4.13.3	-	-	-	X	X	X
- not applicable						

4.14 Discard criteria for suspension means and sheaves

4.14.1 General

Discard criteria shall be as specified in the standard calling for the use of this document (e.g. ISO 8100-1:2026, Table 13) and the following clauses.

4.14.2 Steel wire ropes

4.14.2.1 Steel wire ropes in combination with steel/cast iron traction sheaves

For steel wire ropes, the discard criteria in accordance with ISO 4344:2022, Annex G shall apply.

4.14.2.2 Coated traction sheave

For coated traction sheaves the following visual discard criteria shall be applied.

— coating discard limit as specified in the verification report as per 4.13.9, Table 3;

— wear or damages of coating exposing the traction sheave metallic part; and

— delamination of coating.

4.14.2.3 Steel wire ropes with non-metallic replaceable traction sheave groove liners

For steel wire ropes the discard criteria in accordance with ISO 4344:2022, Annex G shall apply, including additional discard criteria. Where rouge or red dust is present due to fretting corrosion the reduction in diameter shall be limited to 3 % and the number of visible broken wires listed within ISO 4344:2022, Table G.1 shall be reduced by 50 %, no valley breaks allowed.

4.14.3 Elastomeric coated suspension means

4.14.3.1 General

Beside the discard condition indicated by the discard monitoring means visual discard criteria shall be considered and defined based on the specific design needs of the suspension means.

The free length of the suspension means including the portion at the termination shall be visually inspected.

4.14.3.2 Elastomeric coated traction belts

The following visual discard criteria shall apply:

- worn coating, or cracks in the coating exposing the tension member;
- worn or damaged belt profile affecting guidance or traction capability;
- piercing of the coating by foreign objects;
- for steel wire tension members:
  - broken wires or cords protruding the elastomeric coating;
  - corrosion from the tension member protruding through the coating material;
- for carbon fibre reinforced polymer tension member (CFRP):
  - delamination of carbon fibre reinforced polymer (CFRP) affecting guidance capability;
  - deformation of the coating due to delamination of the CFRP.

4.14.3.3 Elastomeric coated steel wire ropes

The following visual discard criteria shall apply:

- broken wires or a single strand protruding the elastomeric coating;
- the coating is worn, damaged or has lost its bonding to the steel wire rope;
- corrosion coming from the tension member protruding through the coating material;
- steel wire rope with a kink or corkscrew.

4.14.3.4 Elastomeric coated timing belts

Following visual discard criteria shall apply:

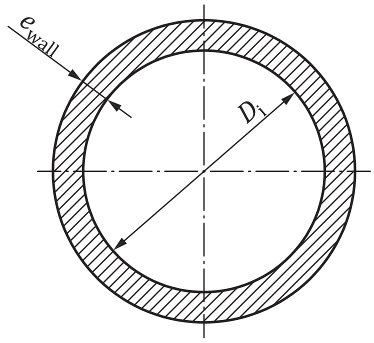
- requirements as per 4.14.3.2; and
- damaged or missing tooth.

4.15 Calculations of rams, cylinders, rigid pipes and fittings

4.15.1 Calculation against over pressure

4.15.1.1 Calculation of wall thickness of rams, cylinders, rigid pipes and fittings (see Figure 15)

Dimensions in millimetres



Key

e_{wall} wall thickness of the cylinder/ram/rigid pipe

D_i inside diameter of the cylinder/ram/rigid pipe

Figure 15 — Wall thickness calculation

Calculate wall thickness, e_{wall}, with Formula (38):

$$e_{wall} \geq \frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{p0,2}} \cdot \frac{D_i}{2} + e_o \tag{38}$$

where

D_i	is the inside diameter of the cylinder in millimetres;
e_o	1,0 mm for wall and base of cylinders and rigid pipes between the cylinder and the rupture valve, if any;
e_o	0,5 mm for rams and other rigid pipes;
p	is the full load pressure in megapascals;
$R_{p0,2}$	is the yield strength of the material in newtons per square millimetre;
2,3	is the factor for friction losses (1,15) and pressure peaks (2);
1,7	is the safety factor referred to the yield strength.

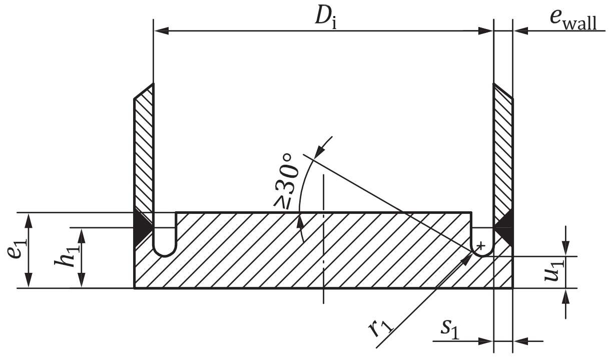
4.15.1.2 Calculation of the base thickness of cylinders

4.15.1.2.1 General

The bases of cylinders shall be designed in accordance with 4.15.1.2.2, 4.15.1.2.3 or 4.15.1.2.4.

4.15.1.2.2 Flat bases with relieving groove (see Figure 16)

Dimensions in millimetres



Key

e_1	thickness of the flat base
h_1	height outer base wall
D_i	inside diameter of the cylinder
e_{wall}	wall thickness of the cylinder
u_1	thickness of the base at the bottom of the relieving groove
r_1	radius of the relieving groove
s_1	thickness of the base wall

Figure 16 — Flat bases with relieving groove

Conditions for the stress relief of the welding seam, see Formulae (39) to (44):

$$r_1 \geq 0{,}2 \cdot e_1 \qquad (39)$$

$$\text{and } r_1 \geq 5 \text{ mm} \qquad (40)$$

$$u_1 \leq 1{,}5 \cdot s_1 \qquad (41)$$

$$h_1 \geq u_1 + r_1 \qquad (42)$$

$$e_1 \geq 0{,}4 \cdot D_i \sqrt{\frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{p0{,}2}}} + e_o \qquad (43)$$

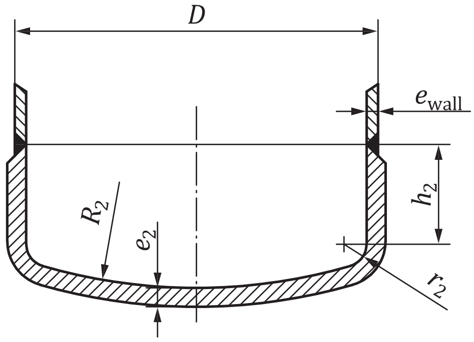
$$u_1 \geq 1,3 \cdot \left(\frac{D_i}{2} - r_1 \right) \cdot \frac{2,3 \cdot 1,7 \cdot p}{R_{p0,2}} + e_o \quad (44)$$

where

D_i	is the inside diameter of the cylinder in millimetres;
e_o	is 1,0 mm for wall and base of cylinders;
e_1	is the thickness of the flat base in millimetres;
h_1	is the height of the base wall in millimetres;
p	is the full load pressure in megapascals;
$R_{p0,2}$	is the yield strength of the material in newtons per square millimetres;
r_1	is the inside radius of the base in millimetres;
s_1	is the thickness of the base wall in millimetres;
u_1	is the thickness of the base at the bottom of the relieving groove in millimetres;
2,3	is the factor for friction losses (1,15) and pressure peaks (2);
1,7	is the safety factor referred to the yield strength.

4.15.1.2.3 Cambered based (see Figure 17)

Dimensions in millimetres



Key

D	outer diameter of the cylinder
e_2	thickness of the cambered base
e_{wall}	wall thickness of the cylinder
h_2	height of the base wall
r_2	inside radius of the base
R_2	radius of the camber

Figure 17 — Cambered based

Conditions, see Formulae (45) to (48):

$$h_2 \geq 3,0 \cdot e_2 \quad (45)$$

$$r_2 \geq 0,15 \cdot D \quad (46)$$

$$R_2 = 0,8 \cdot D \quad (47)$$

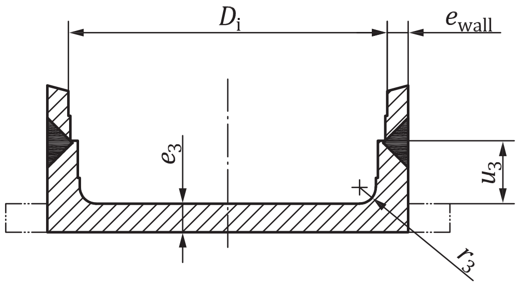
$$e_2 \geq \frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{p0,2}} \cdot \frac{D}{2} + e_o \qquad (48)$$

where

D	is the outer diameter of the cylinder in millimetres;
e_o	is 1,0 mm for wall and base of cylinders;
e_2	is the thickness of the cambered base in millimetres;
h_2	is the height of the base wall in millimetres;
p	is the full load pressure in megapascals;
r_2	is the inside radius of the base in millimetres;
R_2	is the inside radius of the cambered base in millimetres;
$R_{p0,2}$	is the yield strength of the material in newtons per square millimetre;
2,3	is the factor for friction losses (1,15) and pressure peaks (2);
1,7	is the safety factor referred to the yield strength.

4.15.1.2.4 Flat bases with welded flange (see Figure 18)

Dimensions in millimetres



Key

D_i	inside diameter of the cylinder
e_3	thickness of the flat base
e_{wall}	wall thickness of the cylinder
r_3	inside radius of the base
u_3	height base wall

Figure 18 — Flat bases with welded flange

Conditions, see Formulae (49) to (52):

$$u_3 \geq e_3 + r_3 \qquad (49)$$

$$r_3 \geq \frac{e_{wall}}{3} \qquad (50)$$

and $r_3 \geq 8\,\text{mm}$ (51)

$$e_3 \geq 0,4 \cdot D_i \sqrt{\frac{2,3 \cdot 1,7 \cdot p}{R_{p0,2}}} + e_o \qquad (52)$$

where

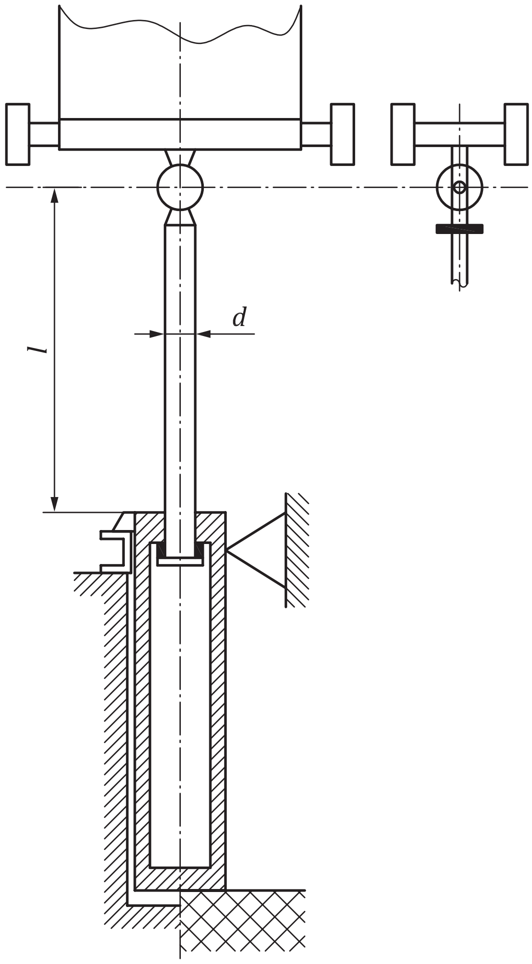
u_3	is the height base wall in mm;
e_3	is the thickness of the flat base in mm;
r_3	is the inside radius of the base in mm;
e_{wall}	is the wall thickness of the cylinder in mm;
D_i	is the inside diameter of the cylinder in mm;
p	is the full load pressure in megapascals;
$R_{p0,2}$	is the yield strength of the material in newtons per square millimetre;
e_o	is 1,0 mm for wall and base of cylinders;
2,3	is the factor for friction losses (1,15) and pressure peaks (2);
1,7	is the safety factor referred to the yield strength.

4.15.2 Calculations of the jacks against buckling

4.15.2.1 General

The buckling calculation shall be made on the part with least buckling resistance in accordance with Formulae (53) to (71) as applicable.

4.15.2.2 Single acting jacks (see Figure 19)



Key

d	diameter of ram
l	length of ram subject to buckling

Figure 19 — Single acting jacks

$$\lambda = \frac{l}{i} \tag{53}$$

For $\lambda \geq 100$:

$$F_s \leq \frac{\pi^2 \cdot E \cdot J}{2 \cdot l^2} \tag{54}$$

For $\lambda < 100$:

$$F_s \leq \frac{A}{2}\left[R_{p0,2} - \left(R_{p0,2} - 210\right) \cdot \left(\frac{\lambda}{100}\right)^2\right] \tag{55}$$

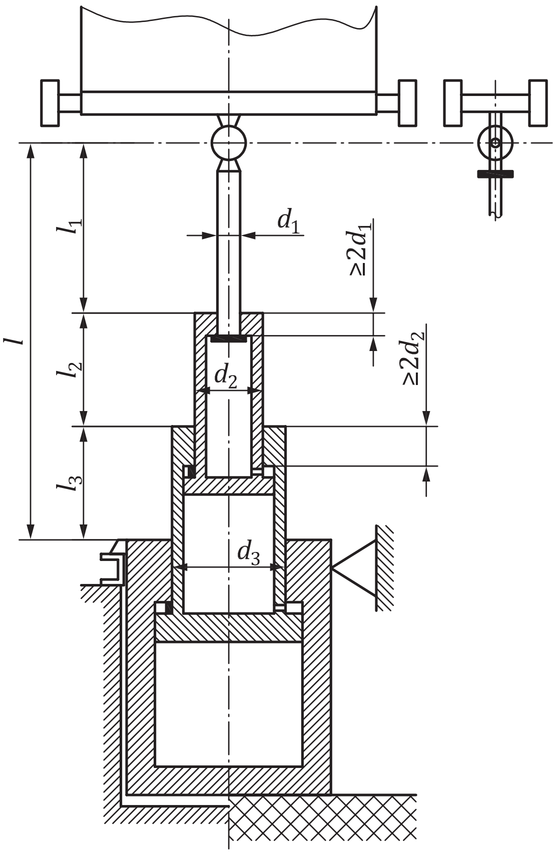
Valid for rams extending in upward direction:

$$F_s = k_p \cdot g_n \cdot \left[r \cdot (P + Q) + 0{,}64 \cdot P_r + P_{rh}\right] \tag{56}$$

where

A	is the cross-sectional area of the material of the ram in square millimetres;
r	is the reeving factor;
E	is the modulus of elasticity in newtons per square millimetre (for steel: $E = 2{,}1 \times 10^5$ N/mm^2);
F_s	is the actual buckling force applied in newtons;
g_n	is the standard acceleration of free fall in metres per square second;
i	is the radius of gyration of the ram in millimetres;
J	is the second moment of area of the ram in fourth power millimetres;
k_p	is the over pressure factor in accordance with ISO 8100-1:2026, 4.9.3.5.3.2;
l	is the length of the ram in millimetres;
P	is the sum of the mass of the empty car and the mass of the portion of the travelling cables suspended from the car in kilograms;
P_r	is the mass of the ram in kilograms;
P_{rh}	is the mass of the ram head equipment, if any, in kilograms;
Q	is the rated load in kilograms;
$R_{p0,2}$	is the yield strength of the material in newtons per square millimetre;
λ	is the coefficient of slenderness of the ram;
2	is the safety factor against buckling.

4.15.2.3 Telescopic jacks without external guidance, calculation of ram (see Figure 20)



Key

d_1, d_2, d_3	diameter of telescopic ram sections
l	length of unsupported section
l_1, l_2, l_3	length of telescopic ram sections subject to buckling

Figure 20 — Telescopic jacks without external guidance

$$l = l_1 + l_2 + l_3; \qquad l_1 = l_2 = l_3 \tag{57}$$

$$\nu = \sqrt{\frac{J_1}{J_2}}\,; \qquad J_3 \geq J_2 > J_1 \tag{58}$$

assumption for simplified calculation: $J_3 = J_2$

for 2 sections: for $0{,}22 < \nu \leq 0{,}65$:

$$\phi = 1{,}25 \cdot \nu - 0{,}2 \tag{59}$$

for 3 sections for $0{,}22 < \nu \leq 0{,}65$:

$$\phi = 1{,}5 \cdot \nu - 0{,}2 \tag{60}$$

for $0{,}65 < \nu \leq 1$:

$$\phi = 0{,}65 \cdot \nu + 0{,}35 \tag{61}$$

$$\lambda_e = \frac{l}{i_e} \tag{62}$$

$$i_e = \frac{d_m}{4}\sqrt{\phi \cdot \left[1 + \left(\frac{d_{mi}}{d_m}\right)^2\right]} \tag{63}$$

$$\lambda_n = \frac{l_n}{i_n} \tag{64}$$

For $\lambda_e \geq 100$:

$$F_s \leq \frac{\pi^2 \cdot E \cdot J_2}{2 \cdot l^2} \cdot \phi \tag{65}$$

For $\lambda_e < 100$:

$$F_s \leq \frac{A_n}{2} \cdot \left[R_{p0,2} - \left(R_{p0,2} - 210\right) \cdot \left(\frac{\lambda_n}{100}\right)^2\right] \tag{66}$$

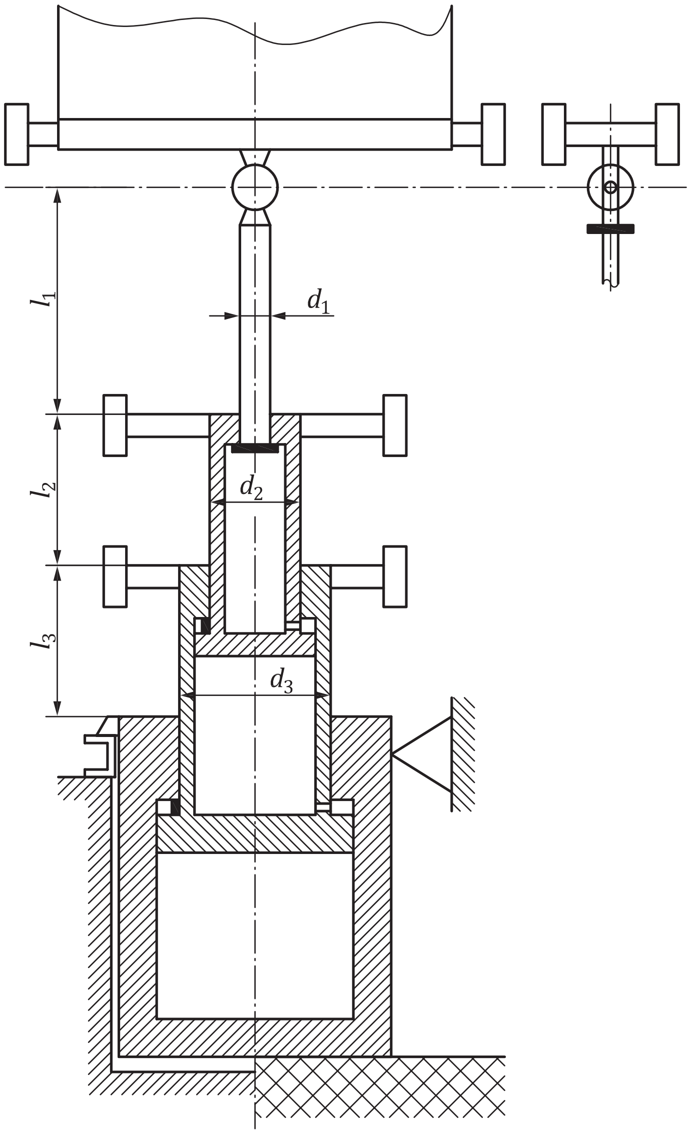
Valid for rams extending in upward direction:

$$F_s = k_p \cdot g_n \cdot \left[r \cdot (P + Q) + 0{,}64 \cdot P_r + P_{rh} + P_{rt}\right] \tag{67}$$

where

A_n	is the cross-sectional area of the material of the ram to be calculated in square millimetres (n = 1, 2, 3);
r	is the reeving factor;
d_m	is the outside diameter of the biggest ram of a telescopic jack in millimetres;
d_{mi}	is the inner diameter of the biggest ram of a telescopic jack in millimetres;
E	is the modulus of elasticity in newtons per square millimetre (for steel: E = 2,1 × 10^5 N/mm^2);
F_s	is the actual buckling force applied in newtons;
g_n	is the standard acceleration of free fall in metres per square second;
i_e	is the equivalent radius of gyration of a telescopic jack in millimetres;
i_n	is the radius of gyration of the ram to be calculated in millimetres (n = 1, 2, 3);
J_n	is the second moment of area of the ram to be calculated in fourth power millimetres (n = 1, 2, 3);
k_p	is the over pressure factor in accordance with ISO 8100-1:2026, 4.9.3.5.3.2;
l	is the total length of the rams subject to buckling in millimetres;
l_n	is the length of the ram to be calculated in millimetres (n = 1, 2, 3);
P	is the sum of the mass of the empty car and the mass of the portion of the travelling cables suspended from the car in kilograms;
P_r	is the mass of the ram to be calculated in kilograms;
P_{rh}	is the mass of the ram head equipment, if any, in kilograms;
P_{rt}	is the mass of the rams acting on the ram to be calculated in kilograms;
Q	is the rated load in kilograms;
$R_{p0,2}$	is the yield strength of the material in newtons per square millimetre;
λ_e	is the equivalent coefficient of slenderness of a telescopic jack;
λ_n	is the coefficient of slenderness of the ram to be calculated (n = 1, 2, 3);
v, ϕ	are the factors used to represent approximate values given by experimentally determined diagrams;
2	is the safety factor against buckling.

4.15.2.4 Telescopic jacks with external guidance (see Figure 21)



Key

d_1, d_2, d_3	diameter of telescopic ram sections
l_1, l_2, l_3	length of telescopic ram sections subject to buckling

Figure 21 — Telescopic jacks with external guidance

$$\lambda_n = \frac{l_n}{i_n} \quad (68)$$

For $\lambda_n \geq 100$:

$$F_s \leq \frac{\pi^2 \cdot E \cdot J_n}{2 \cdot {l_n}^2} \quad (69)$$

For $\lambda_n < 100$:

$$F_s \leq \frac{A_n}{2}\left[R_{p0,2} - \left(R_{p0,2} - 210\right) \cdot \left(\frac{\lambda_n}{100}\right)^2\right] \quad (70)$$

Valid for rams extending in upward direction:

$$F_s = k_p \cdot g_n \cdot \left[r \cdot (P + Q) + 0{,}64 \cdot P_r + P_{rh} + P_{rt}\right] \quad (71)$$

where

A_n	is the cross-sectional area of the material of the ram to be calculated in square millimetres (n = 1, 2, 3);
r	is the reeving factor;
E	is the modulus of elasticity in newtons per square millimetre (for steel: $E = 2{,}1 \times 10^5$ N/mm^2);
F_s	is the actual buckling force applied in newtons;
g_n	is the standard acceleration of free fall in metres per square second;
i_n	is the radius of gyration of the ram to be calculated in millimetres (n = 1, 2, 3);
J_n	is the second moment of area of the ram to be calculated in fourth power millimetres (n = 1, 2, 3);
k_p	is the over pressure factor in accordance with ISO 8100-1:2026, 4.9.3.5.3.2;
l_n	is the length of ram to be calculated in millimetres (n = 1, 2, 3);
P	is the sum of the mass of the empty car and the mass of the portion of the travelling cables suspended from the car in kilograms;
P_r	is the mass of the ram to be calculated in kilograms;
P_{rh}	is the mass of the ram head equipment, if any in kilograms;
P_{rt}	is the mass of the rams acting on the ram to be calculated in kilograms;
Q	is the rated load kilograms;
$R_{p0,2}$	is the yield strength of the material in newtons per square millimetre;
λ_n	is the coefficient of slenderness of the ram to be calculated (n = 1, 2, 3);
2	is the safety factor against buckling.

4.16 Pendulum shock tests

4.16.1 General

Pendulum shock tests shall be carried out in accordance with the following prescriptions.

NOTE Pendulum shock test can be specified for a “family” of doors based, for example, on type and minimum/maximum dimensions.

4.16.2 Test rig

4.16.2.1 Hard pendulum shock device

The hard pendulum shock device shall be a body in accordance with Figure 22. This body shall consist of:

— a shocking ring made of steel S 235 JR in accordance with EN 10025-2:2019; and

— a case made of steel E 295 in accordance with EN 10025-2:2019.

The overall mass of this body will be brought up to 10 kg ± 0,01 kg by filling with lead balls of a diameter of 3,5 mm ± 0,5 mm.

4.16.2.2 Soft pendulum shock device

The soft pendulum shock device shall be:

a) a shot bag in accordance with Figure 23 made of leather, which is filled with lead balls of a diameter of 3,5 mm ± 0,5 mm up to an overall mass of 45 kg ± 0,5 kg; or

b) a bag in accordance with ISO 29584:2015, 5.1.

4.16.2.3 Suspension of the pendulum shock device

The pendulum shock device shall be suspended by a wire rope with a diameter of 3,0 mm ± 0,5 mm in such a way that the horizontal distance between the outer edge of the free hanging shock device and the panel to be tested does not exceed 15 mm ± 10 mm.

The pendulum length (lower end of the hook to reference point of the shock device) shall be at least 1,5 m.

4.16.2.4 Pulling and triggering device

The suspended pendulum shock device shall be swung away from the panel by a pulling and triggering device and thus lifted to the specified falling height required in 4.16.3.2 and 4.16.3.3. The triggering device shall not give an additional impulse to the pendulum shock device in the moment of releasing.

The suspension wire rope shall be hooked to shock device without any torque to prevent spinning of device after triggering.

The suspension wire rope shall have no angle in swung position before triggering; consistent results shall be realized by a triangle hooking keeping the shocking device’s centre of gravity in line with the hoisting wire at triggering position.

4.16.2.5 Test samples

The test samples shall be complete and shall have the intended size and fixations as per the specific application. The test samples shall be fixed to the test frame in such a way that at the fixation points, no deformations under test conditions are possible (stiff fixation).

4.16.3 Tests

4.16.3.1 The tests shall be carried out at a temperature of 23 °C ± 5 °C. The panels shall be stored directly before the tests for at least 4 h at that temperature.

4.16.3.2 The hard pendulum shock test shall be carried out with the device as per 4.16.2.1 with a falling height specified in the standard calling for this test and a test arrangement in accordance with Figure 24.

4.16.3.3 The soft pendulum shock test shall be carried out with the device as per 4.16.2.2 with a falling height specified in the standard calling for this test and a test arrangement in accordance with Figure 24.

4.16.3.4 The pendulum shock device shall be brought to the specified falling height (e.g. ISO 8100-1:2026, 4.4.3.2.3 or ISO 8100-1:2026, 4.3.5.4) and released.

For side opening doors: if it is not possible to hit the specified striking point of the relevant part of the test sample (e.g. the panel width is smaller than 240 mm), the pendulum shock device shall hit 150 mm from the closing edge as specified in the standard calling for this device [e.g. ISO 8100-1:2026, Figure 18 h)].

4.16.3.5 Only one test for each striking point is required with each of the devices called for in 4.16.2.1 and 4.16.2.2.

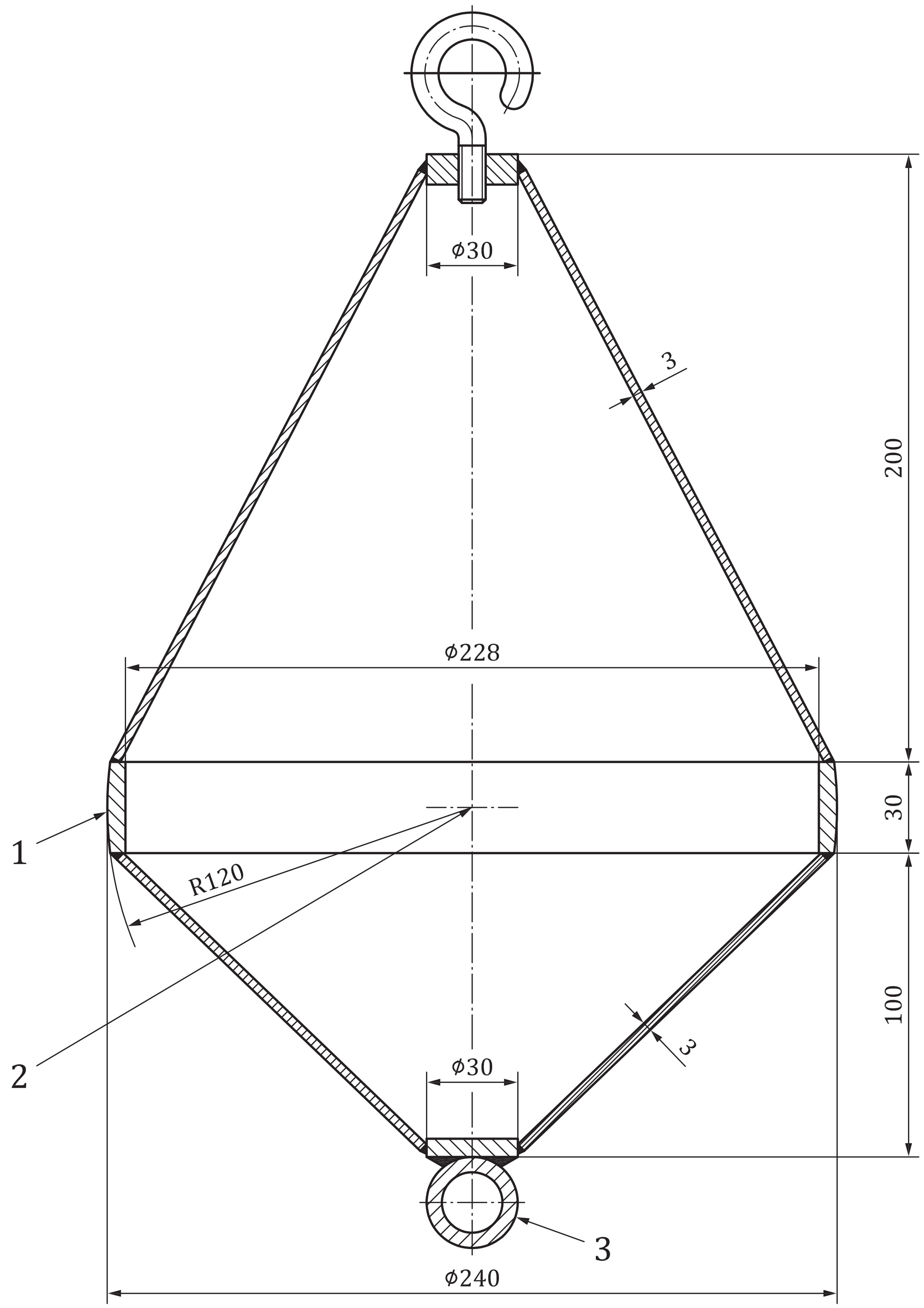
When both hard and soft pendulum shock tests shall be made, they shall be made on the same test sample and the hard pendulum test shall be performed first.

4.16.3.6 Landing doors shall be tested from the landing side. Car doors and car walls shall be tested from the car side.

4.16.4 Assessment of the test results

After the test, checks shall be carried out against the requirements specified in the standard calling for this test.

Dimensions in millimetres



Key

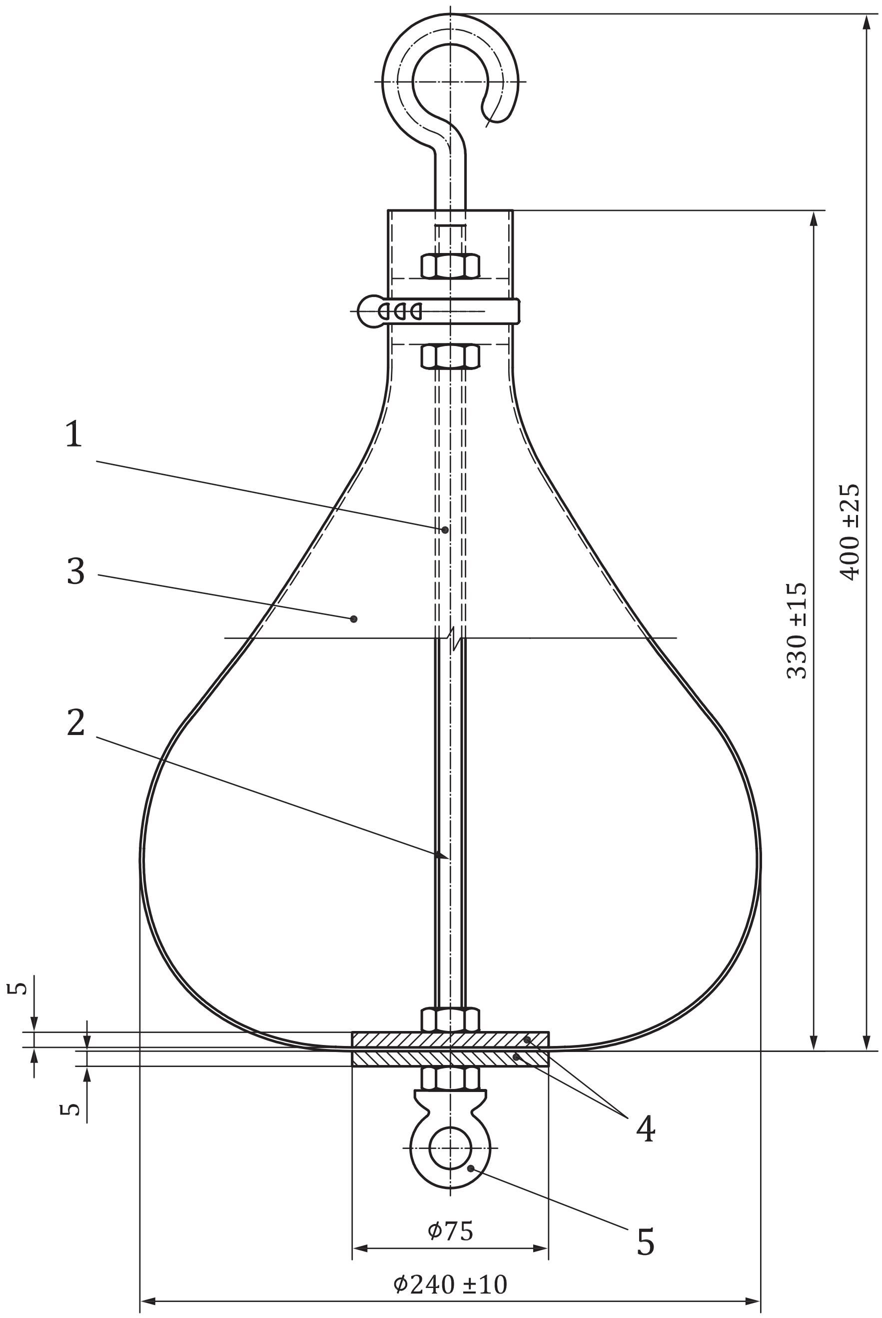
1 shocking ring

2 reference point for measuring the falling height

3 triggering device attachment

Figure 22 — Hard pendulum shock device

Dimensions in millimetres

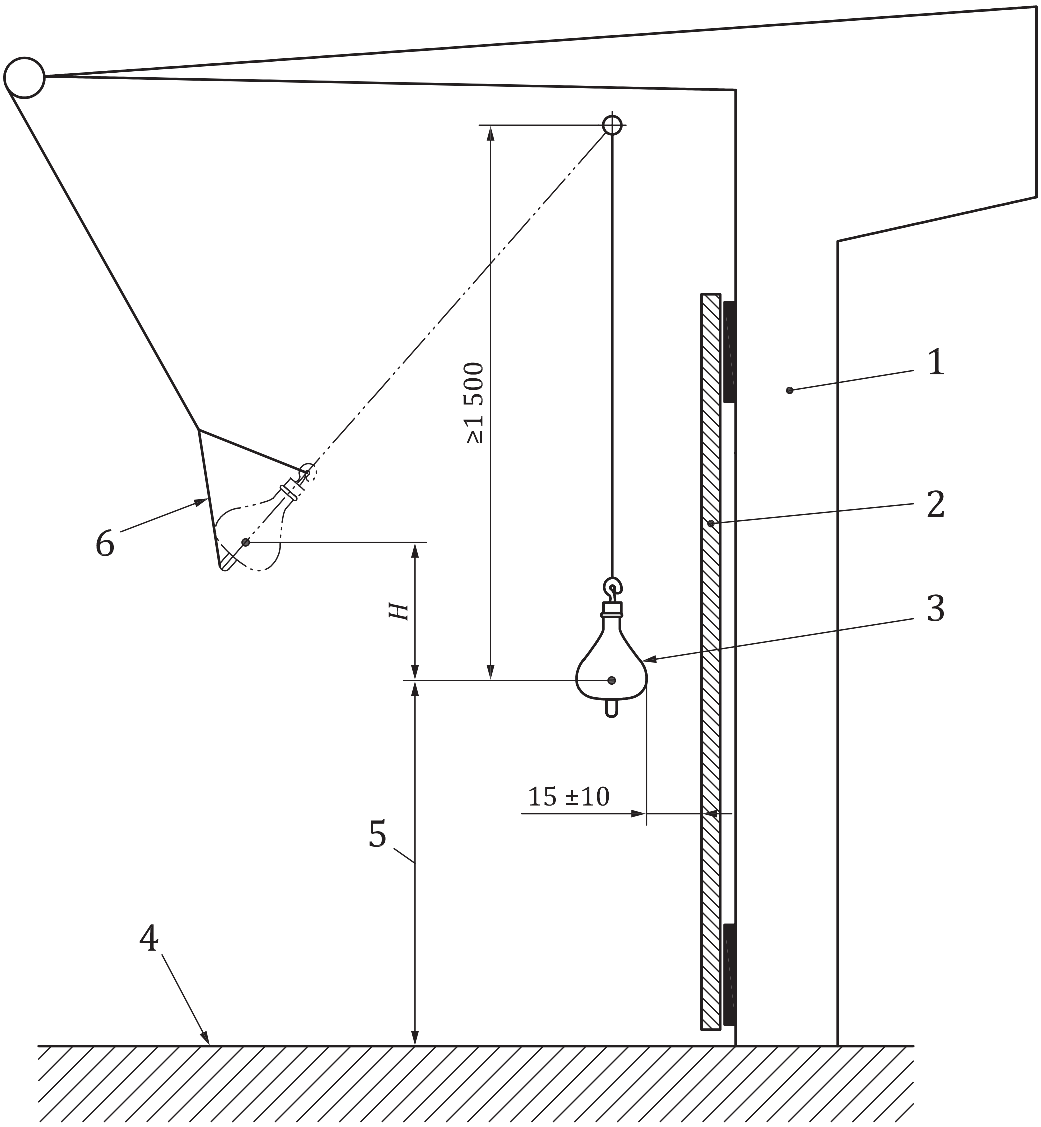


Key

1	screwed rod
2	reference point for measuring the falling height in the plane of the maximum diameter
3	leather bag
4	steel disk
5	triggering device attachment

Figure 23 — Soft pendulum shock device

Dimensions in millimetres



Key

1	frame
2	door or car wall-element to be tested
3	shock device
4	floor level with respect to the door or car wall-structure element to be tested
5	height of striking point: value for the height of striking points is given in relevant clauses
6	triangle hooking configuration as considered in 4.16.2.4
H	falling height

Figure 24 — Test rig falling height

4.17 Electrical and electronic components — Fault exclusion

Fault exclusion shall only be considered provided that components are applied within their worst-case limits of characteristics, value, temperature, humidity, voltage and vibrations.

When fault exclusion is applied, an over-dimensioning factor of at least 1,5 shall be used for relevant operating parameters at normal operating conditions.

Fault exclusions in accordance with Table 4 may be applied.

Table 4 is not a comprehensive list of possible fault exclusions as specified in the standard calling for use of this document (e.g. ISO 8100-1:2026, 4.11.1.1). Other fault exclusion methods may be used as an example solid insulation as per IEC 60664-1:2020. All fault exclusions shall be justified and documented.

The possible fault exclusions shall not be applied for protection against electric shock. The requirements for protection against electric shock remain valid in any case (e.g. double or reinforced insulation between PELV and other circuits).

Table 4 — Exclusions of faults

Component		Possible fault exclusion					Conditions	Remarks
		Open circuit	Short circuit	Change to higher value	Change to lower value	Change of function		
1	Passive components							
1.1	Resistor fixed	NO	(a)	NO	(a) (b) (c)		(a) can be excluded if: The resistor is of the film type or wire-wound single-layer type with protection to prevent unwinding of wire in the event of breakage, with axial wire connections, axial-mounted and varnished. OR Resistors in surface-mount technology must be of the thin film metal type in package types MELF, miniMELF or µMELF. (b) Random change of value $0{,}5R_N$ to R_N, where R_N is the nominal value of resistor cannot be excluded. (c) On the surface layer of PCB below the resistor, there shall be no PCB-track and no via.	
1.2	Resistor variable	NO	NO	NO	NO			
1.3	Resistor, non linear NTC, PTC, VDR, IDR	NO	NO	NO	NO			
1.4	Capacitor	NO	NO	NO	NO			
1.5	Inductive components — coil — choke	NO	(a)	(b)	(b)		(a) Short circuit can be excluded if coil is single-layered, enamelled or potted, with axial wire connections and axial-mounted. (b) random change of value between $0{,}5*L_N<L<1{,}2*L_N$ cannot be excluded	
2	Semiconductors							
2.1	Diode, LED	NO	NO			NO		Change of function refers to a change in reverse current value.
2.2	Zener Diode	NO	NO		NO	NO		Change to lower value refers to change in Zener voltage. Change of function refers to change in reverse current value.
2.3	Thyristor, Triac, GTO	NO	NO			NO		Change of function refers to self-triggering or latching of components.
2.4	Optocoupler, Digital isolator	NO	(a)			NO	(a) Short circuit across the isolation barrier can be excluded if:	see also ISO 13849-2 and IEC 61800-5-2.
In the table: The “NO” in the cell means: fault not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.								

Table 4 *(continued)*

<table>
<tr><th rowspan="2" colspan="2">Component</th><th colspan="5">Possible fault exclusion</th><th rowspan="2">Conditions</th><th rowspan="2">Remarks</th></tr>
<tr><th>Open circuit</th><th>Short circuit</th><th>Change to higher value</th><th>Change to lower value</th><th>Change of function</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>The signal isolation component is built in accordance with overvoltage category III as per IEC 60664-1:2020.
Measures are taken to ensure that an internal fault of the signal isolation component cannot result in excessive temperature of its insulating material.
<table>
<tr><td>Voltage phase-to-earth derived from rated system voltage up to and including V_{rms} and DC</td><td>Preferred series of impulse withstand voltages in volts for installation</td></tr>
<tr><td></td><td>Category III</td></tr>
<tr><td>50</td><td>800</td></tr>
<tr><td>100</td><td>1 500</td></tr>
<tr><td>150</td><td>2 500</td></tr>
<tr><td>300</td><td>4 000</td></tr>
<tr><td>600</td><td>6 000</td></tr>
<tr><td>1 000</td><td>8 000</td></tr>
</table></td><td></td></tr>
<tr><td>2.5</td><td>Hybrid circuit</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td></td><td></td></tr>
<tr><td>2.6</td><td>Integrated circuit</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td></td><td>Change in function to oscillation, “and” gates becoming “or” gates, etc.</td></tr>
<tr><td>3</td><td colspan="8">Miscellaneous</td></tr>
<tr><td>3.1</td><td>Connectors Terminals Plugs</td><td>NO</td><td>(a)</td><td></td><td></td><td></td><td>(a) The clearances and creepage distances are dimensioned at least as per IEC 60664-1:2020 with the conditions:
— overvoltage category III;
— the pollution degree is 3;
— the material group is III;
— inhomogeneous field.
The column “printed wiring material” of IEC 60664-1:2020, Table F.5 is not used. That means that the creepage distances are 4 mm and the clearances 3 mm up to 2000 m altitude for 250 V_{rms} For other voltages and higher altitude see IEC 60664-1:2020, Tables A.2, F.1, F.2 and F.5.
These are absolute minimum values which can be found on the connected unit, not pitch dimension or theoretical values.
If the protection of the connector is IP 54 or better, pollution degree 2 can be used.</td><td></td></tr>
<tr><td>3.2</td><td>Neon bulb</td><td>NO</td><td>NO</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.3</td><td>Transformer</td><td>NO</td><td>(a)</td><td>(a)</td><td>(a)</td><td></td><td>(a) Can be excluded on condition that transformer complies with IEC 61558-1:2017, 18, for double or reinforced insulation between windings and between windings and core.</td><td>Short-circuits include short-circuits of primary or secondary windings, or between primary and secondary coils.
Change in value refers to change of ratio by partial short-circuit in a winding</td></tr>
<tr><td colspan="9">In the table:
The “NO” in the cell means: fault not excluded, i.e. shall be considered;
The unmarked cell means: the identified fault type is not relevant.</td></tr>
</table>

Table 4 *(continued)*

Component	Possible fault exclusion					Conditions	Remarks
	Open circuit	**Short circuit**	**Change to higher value**	**Change to lower value**	**Change of function**		
3.4 Fuse	NO	(a)				(a) Can be excluded if the fuse is correctly rated, and constructed as per the applicable IEC standards.	Short circuit means short circuit of the blown fuse.
3.5 Relay	NO	(a) (b)				(a) Short-circuits between contacts, and between contacts and coil can be excluded if the relay fulfils the requirements laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.10.3.2.2). (b) Welding of contacts cannot be excluded. However, , the assumptions laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.10.3.1.2 and 4.10.3.1.3) apply.	
3.6 Printed circuit board (PCB)	NO	(a)				(a) The short circuit can be excluded provided: As base material, EP GC with low flammability as per IEC 60893-3-1:2012, Table 1 is used. The clearances and creepage distances are dimensioned at least as per IEC 60664–1:2020 with the conditions: — Overvoltage category III; — The pollution degree is 3; — The material group is III; — Inhomogeneous field. The column “printed wiring material” of IEC 60664-1:2020, Table F.5 is not used. That means that the creepage distances are 4 mm and the clearances 3 mm up to 2000 m altitude for 250 V_{rms}. For other voltages and higher altitude see IEC 60664-1:2020 Tables A.2, F.1, F.2 and F.5. Pollution degree 2 may be used for the printed side (surface) of the PCB when the protection of the PCB is IP54 or better, and where the printed side is coated with an ageing-resistant varnish. Pollution degree 2 may also be used for conductor paths when the protection of the PCB is IP54 or better, and where these conductor paths are coated with protective layer such as solder mask. Pollution degree 2 may also be used for the inner layers of multilayer PCB. For multi-layer boards short circuit between conductive parts of different layers can be excluded if insulation material between layers fulfil following conditions: — Insulation material with minimum thickness of 0,4 mm; or — At least 3 pre-preg or other thin sheet insulating materials.	NEMA FR4 equals EP GC 202 NEMA FR5 equals EP GC 204
In the table: The “NO” in the cell means: fault not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.							

Table 4 *(continued)*

Component		Possible fault exclusion					Conditions		Remarks
		Open circuit	Short circuit	Change to higher value	Change to lower value	Change of function			
3.7	Assembly of components on printed circuit board (PCB)	NO	(a)				(a)	Short circuit can be excluded under circumstances where the short circuit of the component itself can be excluded and the component is mounted in a way that the creepage distances and clearances are not reduced below the minimum required values as listed in 3.1 and 3.6 of this table, neither by the mounting technique nor by the PCB itself.	
In the table: The “NO” in the cell means: fault not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.									

4.18 Design rules for SIL-rated circuits

SIL-rated circuits shall be in accordance with the requirements in the standard calling for the use of this document (e.g. ISO 8100-1:2026, 4.11.2.4.1) and with one of the following:

a) the relevant requirements listed in Annex A, or

b) the relevant requirements of IEC 61508-1:2010, IEC 61508-2:2010 and IEC 61508-3:2010, with the following restrictions:

— IEC 61508-2:2010: in Table 2 and Table 3, safe failure fraction less than 60 % shall not be used;

— IEC 61508-3:2010, Annex G, G.2 Limited variability configuration: limited application configurability is only permitted to be used.

4.19 Verification of the tripping element

4.19.1 General provisions

The tripping element shall be verified as described in 4.19.2.

4.19.2 Check of the characteristics of the tripping element

4.19.2.1 Testing

4.19.2.1.1 Test method

Measurements shall be made of:

a) the delay time between the trigger signal and the full engagement of the tripping element;

b) the operation of the electric safety device checking that the tripping element is in the position ready to trip the safety gear;

c) the tripping force produced by the tripping element when triggered;

d) the travelled distance when the tripping element is relying on friction on the guide rails.

4.19.2.1.2 Test procedure

Twenty tests shall be made for the tripping element which directly generate a tripping force not relying on friction on the guide rails.

When the tripping element relies on friction on the guide rails to generate the tripping force:

— for every different guide rail condition, the following set of tests shall be made:

  — ten tests shall be made for the minimum values of the tripping speed of the tripping element;

  — ten tests shall be made for the maximum values of the tripping speed of the tripping element and the tripping element shall apply its tripping force throughout a distance which corresponds to the maximum travel distance of the safety gear to be tripped.

— five additional tests shall be made for the different environmental conditions as stated in the instructions as per 4.19.3.

4.19.2.1.3 Assessment of the test results

After the tests the following shall be verified.

a) The delay time during the tests shall be always below the value as specified in the instructions as per 4.19.3.

b) The electric safety device shall always be operated when the tripping element is not in the position ready to trip the safety gear.

c) The tripping force determined during the tests shall be at least the value as specified in the instructions as per 4.19.3.

4.19.3 Instructions

In addition to the information for assembly, connection, adjustment and maintenance, the instructions of the tripping element shall contain the following information:

a) the type and the tripping force of the of the tripping element;

b) the minimum and maximum tripping speed of the tripping element;

c) environmental conditions for use of the tripping element;

d) the delay time of the tripping element;

e) for friction based tripping elements only:

   1) the type of guide rail;

   2) the permissible thickness of the guide rail blade;

   3) the minimum width of the gripping areas;

   4) the surface condition of the guide rails (drawn, milled, ground);

   5) the state of lubrication of the guide rails. If they are lubricated, the category and specification of the lubricant.

Annex A
(normative)

SIL-rated circuits

A.1 Principles

As a consequence of the detection of a failure, the SIL-rated circuit (Src) shall initiate a safe state [see 4.6.1.2 i)].

For sub-systems with hardware fault tolerance of 0, credit shall only be taken for the diagnostics if:

— the sum of the diagnostic test interval and the time to perform the specified action to achieve or maintain a safe state is less than the maximum response time required for SIL-rated circuit; or;

— the ratio of the diagnostic test rate to the demand rate is at least 100.

For electromechanical components, where failures can't be detected without being operated the following shall apply:

— for SIL 3 electromechanical components shall be operated at least once a month;

— for SIL 2 and 1 electromechanical components shall be operated at least once a year.

Measures in Tables A.1, A.2 and A.3 shall be applied for all SIL

A.2 Techniques and measures for failure avoidance and detection

Table A.1 — Common measures to avoid and detect failures — Hardware design

Object	Measure	Description of measure	Informative reference IEC 61508-7:2010
Component selection	Over-dimensioning of hardware components	See 4.17 and other standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.11.2.3.2 and 4.11.2.4.2).	A.2.8
I/O units and interfaces incl. communication links	Safeguarding of the safe state	During start-up, power failure or reset the defined safe state of the safety function(s) shall be ensured.	----
Variable memory ranges in programmable electronic systems	Technology to be used	Only memories built up by solid state elements shall be used. No memories with electro-mechanical operated elements (e.g. hard disks) shall be used.	---
	Method of failure detection	Variable data memory shall be tested with the applicable test measure (see Table A.7) — during start-up; the transition into normal operation mode shall only be performed if the test has been performed successfully; — periodically at runtime.	A.5
	Safeguarding of safety related data on remote access	Direct remote access to variable memory ranges is only allowed by a safety related function which ensures safety integrity	--
Invariable memory ranges	Failure detection of invariable memory ranges	Program code memory as well as fixed data memory shall be tested with the applicable test measure (see Table A.6) — during start-up; the transition into normal operation mode shall only be performed if the test has been performed successfully; — periodically at runtime.	A.4.2
Invariable memory ranges (continued)	Protection against modification of program code	Program code shall be stored and sealed in a way that no undetected modification can be performed, either by the SIL-rated circuit itself or by an external device.	

Table A.2 — Common measures to avoid and detect failures — Software design

Object	Measure	Description of measure	Informative reference IEC 61508-7:2010
Structure	Program structure: — Modularisation	— A software function (or equivalently, subprogram) shall have a single well-defined task or function to fulfil. — Connections between software functions shall be limited and strictly defined. — Software functions shall communicate with other software functions via their interfaces only. — All software function interfaces shall be fully documented. — Any software function's interface shall contain only those parameters necessary for its function. — The software function's interface is limited to 8 input and 2 output parameters. — Each function is functionally isolated by its interfaces and local variables. — Global or common variables shall be well structured, access shall be controlled and their use shall be justified in each instance. — Each function shall have only one entry, one normal exit, and may have one separate failure exit.	B.3.4 C.2.9
	— Structured programming	— Only one statement per line of code — Function- and variable names shall have a meaningful name — Modules are decoupled by its interfaces and all interactions are explicit. — No unconditional jumps (goto) in higher level language — No complex calculations as the basis of branching and loop decisions — No assignments within conditions — Each case statement of a switch-case structure shall have a break and a default case; deviations shall be justified in each instance — Well documented source code. For further rules to be applied see Table A.17	C.2.7
Interrupts	Predictable behaviour of the software.	Application driven interrupts shall be limited to three interrupt sources. No use of nested interrupts except it has been demonstrated that all possible sequences of interrupts do not harm the safety function(s). Traps (e.g. division by zero, access violation, etc.) and hardware interrupts used for communication purposes (e.g. CAN, UART) are not considered as an application interrupt. For each interrupt source a defined behaviour shall be implemented.	C.2.6.5
Power down	Ensure consistency of safety related data on power off.	Saving of persistent data for safety related functions shall not be delayed until power down.	---
Memory management	Safeguarding against memory shortage and bottlenecks of resources during runtime.	— No dynamic allocation of memory resources. — All memory resources shall be allocated at start-up. — Stack(s) shall be monitored against overrun and underrun. — No recursive programming allowed.	C.2.6.3 C.5.4 C.2.6.7
Program	Suitable programming language.	Use of C with subset and coding standard, and use of static analysis tool(s) covering the following aspects: — Boundary check	C.2.6.2 C.4.1

Table A.2 *(continued)*

Object	Measure	Description of measure	Informative reference IEC 61508-7:2010
		— Control flow analysis (instruction coverage for architectures I + II, branch coverage for architecture III) Assembler shall be used only in a limited scope, e.g. startup, run-time critical code sections, run-time background tests.	C.4.5
	Safeguarding of response time.	— Cyclic behaviour, with guaranteed maximum cycle time or time-triggered architecture. — Iteration loops shorter than response time (for example by limiting number of loops or checking execution time).	C.3.11
	Safeguarding of unintended modification of variable data memory.	— Indexed access of arrays — Pointer access only if array boundary checks are performed. — No function calls via a pointer to a function, except assigned at startup and not being modified during runtime.	C.2.6.6
	Safeguarding against unexpected program faults.	Defined handling of exceptions (for example division by zero, overflow, variable range checking etc.) which forces the system into a defined safe state. Plausibility checks on data (for example input patterns, input ranges, and internal data).	C.2.5 C.3.1
Bus system and I/O handling	Static system architecture.	No change of logical architecture during runtime	

Table A.3 — Common measures for the design and implementation process

Measure	Description of measure	Informative reference IEC 61508-7:2010
Documentation of the functional, environmental and interface aspects of the application		B.1.1 B.1.2 A.14
Documentation of the requirements specification including the safety requirements		
— Structured specification	— Creation of (sub-)requirements — Description of the interfaces — Consistency checks	B.2.1
— Semiformal methods	Use of at least one of the measures as applicable — Logic/function block diagrams — Sequence diagrams — Finite state machines/state transition diagrams — Decision/truth tables as applicable in order to systematically partition and document the system.	B.2.3 C.2.1
Reviews of all specifications		B.2.6
Design documentation as required in 4.6.1	and additionally: — function description including system architecture and hardware/software interaction — software documentation including function and program flow description.	B.2.3 B.3.2 B.3.4 C.5.9

Key

PFD_{Src}: Probability of a dangerous failure on demand (Valid for a request of the safety function less than once a year)

PFH_{Src}: Probability of a dangerous failure per hour (Valid for a request of the safety function more than once a year)

Table A.3 *(continued)*

Measure	Description of measure	Informative reference IEC 61508-7:2010
Design review reports		B.3.7 B.3.8 C.5.16
Performing a safety analysis in the form of a failure mode effect and diagnostic analysis (FMEDA)	— Consideration of failures, internal (component failures) and external (via interfaces) — Application of the valid failure modes — Definition of the planned measures for failure detection and control (c.f. Table A.4 to A.13) — Assignment of component failure rates (λ_D)	B.6.6
Manufacturer's test specifications and test reports	— static code check, branch code coverage (C1), module testing, — hardware/software integration and fault insertion testing, — system testing in a real lift application — testing of relevant system configurations.	B.5.1 B.5.2 B.5.3 B.6.4 B.6.8 B.6.9 B.6.10 C.4.7 C.5.2 C.5.4 C.5.8
Manufacturer's test specifications and test reports about environmental testing incl. EMC.	See 4.6.3 and other standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.10.1.1.1).	B.6.1 B.6.2
Documentation about installation, configuration, operation, maintenance and testing incl. the limits for intended use.	This information has to be documented in a manual, provided together with the SIL-rated circuit [See standards calling for the use of this document (e.g. ISO 8100-1:2026, 6.2)]	B.4
Design modification.	Repeat and update all relevant measures based on an impact analysis describing the effects of the modification on the existing SIL-rated circuit.	C.5.23 C.5.25
Implementation of requirements tracking for the development life cycle phase of the SIL-rated circuit.		C.2.11
Implementation of a version control for hardware and software and allowed combinations.	The versions having been tested and being part of the SIL-rated circuit shall be identified.	C.5.24
Determination and calculation of the safety-related parameters (response time, PFH_{Src}, PFD_{Src}).	— For the response time of a safety function see other standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.11.2.1.6) — For details about PFH_{Src}, PFD_{Src} calculation, see Table A.16 — For the time interval to detect a failure by online diagnostics, see A.1	

Key

PFD_{Src}: Probability of a dangerous failure on demand (Valid for a request of the safety function less than once a year)

PFH_{Src}: Probability of a dangerous failure per hour (Valid for a request of the safety function more than once a year)

A.3 Techniques and measures for failure detection and control during operation

Table A.4 — Structure

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
The structure shall be such that random failures are detected.	1	One channel structure with self-test	Even though the structure consists of a single channel, a redundant shutdown path shall be provided to ensure a safe shutdown either by the processing unit itself or by the watchdog. The hardware is built using standard techniques which do not take any special safety requirements into account. See Table A.15, for designated architecture for SIL 1	Electric safety circuit: A.1.1
	2	One channel with self-test and external monitoring	At least two independent shut down paths are needed so that a shut-down can be caused either by the processing unit itself or by the monitoring unit. A one channel structure with self-test and monitoring consists of a separate hardware monitoring unit which, independent of the application, periodically receives test data from the system which might result from self-test procedures. Additional special hardware facilities support self-test functions for failure detection. For example, this could be a hardware unit which cyclically monitors the output for a certain bit pattern as per the watch-dog principle. See Table A.15, for designated architecture for SIL 2	A.3.3
	3	Two channels or more with comparison	Two-channel safety related design consists of two independent and feedback-free functional units. This allows the specified functions to be processed independently in each channel. For a two-channel SIL-rated circuit exclusively designed for the function of one safety device the design of the channels may be identical in terms of hardware and software. In the case of a two-channel SIL-rated circuit used for complex solutions (e.g. combinations of several safety functions) and where the processes or conditions are not definitely verifiable, diversity for hardware and software should be considered. The structure includes a function which compares internal signals (e.g. bus comparison) and/or output signals which are relevant to safety functions in order to aid failure detection. At least two independent shut down paths are needed so that a shut-down can be caused either by the channels themselves or by the comparator. The comparison itself also shall be subject to the failure recognition. See Table A.15, for designated architecture for SIL 3	A.2.5
A measure for a SIL 3 can be used also for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1. If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.				

Table A.5 — Processing units

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
Failures in processing units, which can lead to incorrect results, shall be detected.	1	Self-test by software	All the functions of the processing unit, which are used in the safety related application, shall be tested cyclically. These tests can be combined with the test of the sub-components, e.g. memories, I/O's etc. The failure detection is realised entirely by additional software functions which perform self-tests using at least two complementary data patterns (for example 55hex and AAhex).	A.3.1
	2	Software self-test supported by hardware for one-channel structure	Additional special hardware facilities support self-test functions to detect failure. For example, this could be a hardware unit which cyclically monitors the output of a certain bit pattern as per the watch-dog principle.	A.3.3
		Self-test by software	The failure detection is realised entirely by additional software functions which perform self-tests using a data pattern (for example walking-bit pattern) which tests the physical storage (data and address registers) and the instruction decoder.	A.3.2
	3	Reciprocal comparison by software for two-channel structure	Two processing units exchange data (input state(s), output state(s), program sequence information, diagnostic test results) reciprocally. A comparison of the data is carried out using software in each unit.	A.3.5

A measure for a SIL 3 can be used also for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1.

If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.

Table A.6 — Invariable memory ranges

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
Incorrect information modification shall be detected.	1 2	Block safety with CRC	This procedure calculates a 32-bit signature using a cyclic redundancy check (CRC-32) algorithm. It is the "signature" of the memory block and is stored non-volatile during production. The signature is re-computed in later tests and compared with the one already stored.	A.4.4 (32-bit)
		Word saving with multi-bit redundancy	Every word of memory is extended by several redundant bits to produce a modified Hamming code with a Hamming distance of at least 4. Every time a word is read, checking of the redundant bits can determine whether or not a corruption has taken place.	A.4.1
	3	Block safety procedure with block replication	The memory is split up into two memory ranges. The second memory range contains the inverted information of the first memory range. The first memory range is periodically compared with the second one.	A.4.5
		Block safety with CRC	This procedure calculates a 32-bit signature using a cyclic redundancy check (CRC-32) algorithm. It is the "signature" of the memory block and is stored non-volatile during production. The signature is re-computed in later tests and compared with the one already stored.	A.4.4 (32-bit)

A measure for a SIL 3 can be used also for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1.

If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.

Table A.7 — Variable memory ranges

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
Global failures during addressing, writing, storing and reading shall be detected.	1 2	Word-saving with multi-bit redundancy	Every word of memory is extended by several redundant bits to produce a modified Hamming code with a Hamming distance of at least 4. Every time a word is read, checking of the redundant bits can determine whether or not a corruption has taken place	A.5.6
		Check via test pattern against static or dynamic faults	The memory range to be tested is initialised by a uniform byte stream. The first byte is then inverted and the remaining memory area is inspected to ensure that the remaining byte stream is correct. After this, the first byte is re-inverted to return it to its original value, and the whole procedure is repeated for the next byte. A second run of the "wandering byte model" is carried out with an inverse byte stream pre-assignment.	A.5.2
	3	Inspection checks	In the RAM test "galpat", the memory is first initialized uniformly (i.e. all zeros or all ones). The first bit of the memory to be tested is then inverted and all the remaining bits of the memory are inspected to ensure that their contents are correct. After every read access to one of the remaining bytes, the inverted bit is also checked. This procedure is repeated for each bit in the memory. A second run is carried out with the opposite initialisation. The "transparent galpat" test is a variation of the above procedure: Instead of initialising all bits of the memory, the existing memory content is left unchanged and CRC signatures are used for failure detection. The first bit of the memory is selected, and the CRC signature S1 of all remaining bytes of the memory is calculated. The bit to be tested is then inverted and the CRC signature S2 of all the remaining bytes is recalculated. (After every read access to one of the remaining bytes, the byte with the inverted bit is also checked.) CRC signature S2 is compared with CRC signature S1. The bit under test is re-inverted to re-establish the original contents, and the CRC signature S3 of all the remaining bytes is re-calculated and compared with CRC signature S1. All other bits of the memory are tested in the same manner. In order not to impact response time negatively, this test can be executed in slices. If time consumption is too long for an acceptable start-up period, the RAM test method March C- transparent symmetric test as an alternative method at start-up is acceptable. In this case and where the cycle time for a full execution of the “transparent galpat” is longer than the expected operation time (operation in shifts) the galpat test needs to be resumed at power-up from that point where it has been stopped at power-down.	A.5.3
		Block safety procedure with block replication	The memory is split up into two memory ranges. The second memory range contains the inverted information of the first memory range. The first memory range is periodically compared with the second one.	A.5.7
Detection of Soft Errors	2 3	Block safety procedure with block replication	The memory is split up into two memory ranges. The second memory range contains the inverted information of the first memory range. Whenever a content of the first memory range is used, the integrity of that content is checked by comparison with the inverted content of the second memory range.	A.5.7
		Block safety with CRC	This procedure calculates a signature using a cyclic redundancy check (CRC) algorithm of the memory block to be protected, whenever the content is modified. It is the "signature" of the memory block and is stored separately. Whenever a content of the protected memory block is used, its integrity is checked be re-computing the signature and comparing it with the one already stored.	A.4.4
	3	Cross comparison between two channels	Safety-relevant data is exchanged between the two channels and compared.	
A measure for a SIL 3 can be used for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1. If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives. For block safety with CRC a CRC-16 may be applied up to a max. memory block size of 1 024 Bytes, otherwise a CRC-32 shall be applied.				

Table A.8 — I/O Units and Interfaces

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
Static failures and cross talk on I/O lines as well as random and systematic failures in the data flow shall be detected.	1 2 3	Test pattern	By applying a test pattern – superimposed to the I/O-signal – the quasi-static I/O is being made dynamic in order to allow failure detection (e.g. stuck.at). For a single digital I/O-signal simple pulses are sufficient. For more than one digital I/O-signal the pulses shall be separated in time in order to be able to detect cross-talk. For analogue I/O-signals the test patterns (test values) shall cover the whole analogue range in adequate steps with respect to the required accuracy.	A.6.1
		Multi-channel parallel input	Use of two or more redundant inputs in order to detect random failures based on comparison (voting) of the input signal levels and/or their temporal behaviour. This measure is only effective if the input signals change during the diagnostic test interval and signal separation against short circuit between the parallel inputs is ensured.	A.6.5
		Multi-channel parallel output	Use of two or more redundant outputs in order to detect random failures based on comparison (voting) of the output signal levels and/or their temporal behaviour. This measure is only effective if the output signals change during the diagnostic test interval and signal separation against short circuit between the parallel outputs is ensured.	A.6.3
		Monitored output	Use of an independent input signal derived from the output signal in order to detect random failures based on comparison of the input signal level and the expected output signal level and/or their temporal behaviour. This measure is only effective if the output signal changes during the diagnostic test interval and signal separation against short circuit between the output and input signal is ensured.	A.6.4
A measure for a SIL 3 can be used for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1. If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.				

Table A.9 — On-board safety related data communication links of SIL-rated circuits

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
Detect failures caused by a defect in the information transfer in 1:n on-board / back-plane communication links	1	One-bit hardware redundancy	Parallel or serial byte oriented (8-bit) communication using a parity bit for failure detection	A.7.1
	2	Multi-bit hardware redundancy	Parallel or serial (multi-)byte (n x 8-bit) oriented communication using more than one bit for failure detection providing a Hamming Distance at least 4.	A.7.2
	3	Transmission redundancy	Serial (multi-)byte (n x 8-bit) oriented communication. Each transmission consists of two transmission cycles. In the first transmission cycle the information is transmitted non-inverted while in the second transmission cycle the same information is transmitted bit-inverted.	A.7.5
		Information redundancy	Serial (multi-)byte (n x 8-bit) oriented communication The transmission uses a cyclic redundancy check (CRC) algorithm for failure detection.	A.7.6
A measure for a SIL 3 can be used for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1. If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.				

Table A.10 — Clock

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
Failures in clock generation for processing units like frequency modification or break down shall be detected.	1	Watchdog with separate time base without time-window	Timing elements with a separate time base (for example watch-dog timer) externally to the unit being monitored. The timing elements are periodically triggered to monitor the unit's behaviour and the plausibility of the program sequence. It is important that the triggering points are correctly placed in the program. The timing elements are not triggered at a fixed period, but a maximum time-out interval is specified.	A.9.1
	2	Watchdog with separate time base and time-window	Timing elements with a separate time base (for example watch-dog timer) externally to the unit being monitored. The timing elements are periodically triggered to monitor the unit's behaviour and the plausibility of the program sequence. It is important that the triggering points are correctly placed in the program. A lower and upper time-out limit is given.	A.9.2
	3	Combination of temporal and logical monitoring of program sequences	This facility, monitoring the program sequence, is retriggered only if the sequence of the program sections is executed within the response time. See also Table A.5, measure 'Reciprocal comparison by software for two-channel structure'.	A.9.4
A measure for a SIL 3 can be used also for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1. If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.				

Table A.11 — Program sequence

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
Wrong program sequence and inappropriate execution time of the safety related functions shall be detected.	1 2 3	Combination of timing and logical monitoring of program sequence	Use of an independent temporal facility (for example a watch-dog timer with separate time base) which is monitoring the program execution. This facility shall be re-triggered only if all functions required performing the safety function(s) and all diagnostic functions are executed correctly with respect to sequence by at least one checkpoint per function. The temporal facility shall not be triggered by an interrupt procedure except in combination with other program sequence conditions.	A.9.4
A measure for a SIL 3 can be used also for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1. If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.				

Table A.12 — Power supply

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61508-7:2010
A voltage outside the specified operating voltage range shall be detected	1 2 3	Voltage control (secondary) with safety shut-off	To monitor the secondary voltages and initiate a safe condition if the voltage is not in its specified range.	A.8.2
A measure for a SIL 3 can be used also for SIL 2 and SIL 1; a measure for a SIL 2 can be used also for SIL 1, however the target DC_{Src} shall be applied. If more than one measure is indicated for a specific architecture, the measures are equivalent alternatives.				

Table A.13 — Interboard safety related data communication links of SIL-rated circuits

Requirement	SIL	Measure	Description of measure	Informative reference IEC 61784-3:2021+AMD1:2025
Structure	1 2 3		Any communication shall be based on a point-to-point request-response or time-stamped principle. The components shall have a direct interconnection	
Failure detection of failures caused by a defect in the information transfer between the SIL-rated components				
— Corruption	1 2 3	Data integrity assurance	The transmitted message, consisting of the safety related information, the sequence number resp. time-stamp and the connection authentication information (if applicable) shall be protected using a cyclic redundancy check (CRC) algorithm for failure detection.	5.3.2 + 5.4.7
— Unintended repetition	1 2 3	Sequence number	A sequence number with length of at least 16 bit is integrated into each message being transmitted. The sequence number is incremented in a pre-determined way for every message and checked by the receiver against continuity. After the full range of the sequence number is reached, the sequence number re-starts.	5.3.3 + 5.4.2
— Incorrect sequence	1 2 3	Sequence number		5.3.4 + 5.4.2
— Loss	1 2 3	Sequence number		5.3.5 + 5.4.2
— Insertion	1 2 3	Sequence number		5.3.7 + 5.4.2
— Unacceptable delay	1 2 3	Time expectation	Time-stamped principle: The receiver checks that at least one communication cycle is performed successfully and the received time-stamp does not exceed a predetermined expectation with a deviation which shall be smaller than the response time in case of failure, so that in case of a violation, the SIL-rated component transitions into safe state within the response time in case of failure.	5.3.6 + 5.4.3
	1 2 3		Request-response principle: The transmitter checks that at least one successful request-response communication cycle is performed successfully and does not exceed a predetermined time interval which shall be smaller than the response time in case of failure, so that in case of a violation, the SIL-rated component transitions into safe state within the response time in case of failure.	5.3.6 + 5.4.4
— Masquerade	1 2 3	Different data protection	If the communication link is also used for non-safety related (NSR) communication, the safety related (SR) message shall have a different length than the NSR message. If the NSR communication is using a CRC, the CRC of the SR communication shall use a different CRC. CRC of the SR shall be different than the CRC of the communication link. Example Ethernet communication link SR shall not use same CRC as used for Ethernet link.	5.3.8 + 5.4.9
— Addressing	1 2 3	Connection authentication	Messages may have a unique source and/or destination identifier that describes the logical address of the safety related participant.	5.3.9 + 5.4.5
Black channel	1 2 3	$\lambda_{Srcl} \leq 1 * 10^{-7}\ h^{-1}$ $\lambda_{Srcl} \leq 1 * 10^{-8}\ h^{-1}$ $\lambda_{Srcl} \leq 1 * 10^{-9}\ h^{-1}$	Residual error rate λ_{Srcl} of any logical connection of each safety function. In case of dual channel communication (physical or time redundant) the logical connection's residual error rates λ_{Srcl} of the associated safety function can be multiplied.	5.8

Key

PFD_{Src}: Probability of a dangerous failure on demand (Valid for a request of the safety function less than once a year) of the SIL-rated circuit

PFH_{Src}: Probability of a dangerous failure per hour (Valid for a request of the safety function more than once a year) of the SIL-rated circuit

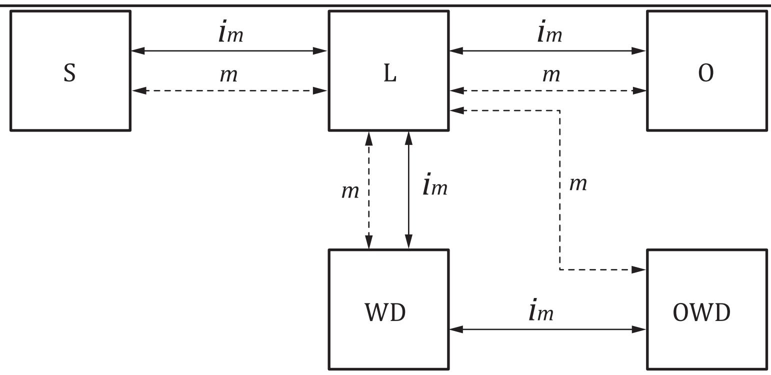
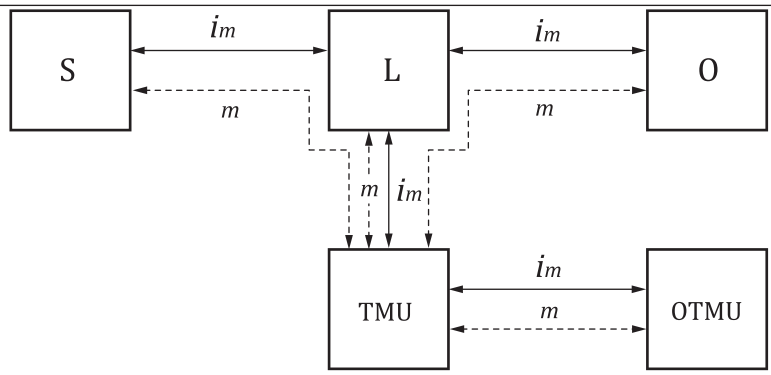
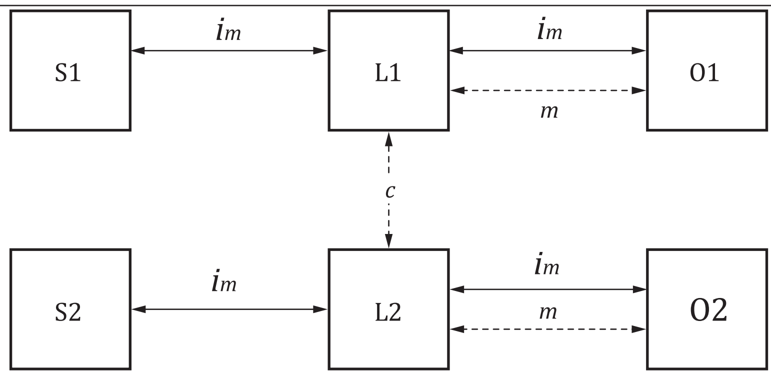
A.4 Functional safety management

Table A.14 — Functional safety management measures

Measure	Description of measures	Informative reference IEC 61508-1:2010
Quality measurement measures		
— Project description	— Name(s) of the product(s) — Objective of the project — What does/do the product(s) intend to achieve	7.2, 7.3
— Project organization	— Description of roles, responsibilities and functions involved in the project for internal and external organizations — Project related organizational chart of internal and external organizations involved in the project	6.2.1
— Roles	— List of all persons involved in the project with their roles	6.2.1, 6.2.3
— Competencies	— Documented evidence about competence of the assigned persons performing the assigned task(s) and about the use of tools based on training(s) and experience.	6.2.13, 6.2.14, 6.2.15
— Responsibilities	— Assignment of responsibilities regarding creation and verification of work products	6.2.1, 6.2.3
— Communication	— Documentation how and by which means the members of the project and how the involved organizations of the project communicate with each other regularly	6.2.2, 6.2.4
— Information exchange and access	— How is ensured that all members of the project have access to the actual (same) database	6.2.2, 6.2.4
Modifications	— The development activities shall be tailored with respect to the planned modifications, based on an impact analysis	6.2.8
Configuration Management	— All parts (HW and SW) building the product shall be clearly determinable; in case of configurable systems, compatibility between system components shall be identified.	6.2.10
Suppliers	— Suppliers shall have a proper quality management system (e.g. ISO 9001).	6.2.17
Lifecycle	— Relevant life cycle phase with respect to the verification of an SIL-rated circuit is the development phase of the SIL-rated circuit. — Nevertheless the product/user documentation shall cover the risks of subsequent phases such as production, installation, operation, maintenance and decommissioning.	6.2.18
Functional Safety Assessment	— Assessment of the functional safety is performed by an independent body.	8
Verification	— Planning and execution of verification activities independent from the creator.	7.18
Tools	— Listing of all tools and its versions generating any output which goes directly into the product or which are being used to test or verify the design or executable code of the product. For these tools unless certified for this purpose: — a bug list shall be available, — evidence of increased confidence from use shall exist, — the version of a tool shall not be changed unless justified.	IEC 61508-7:2010 B.3.5 C.4.4

A.5 Designated architectures and calculation formulas

Table A.15 — Designated architectures

Requirement	SIL	Architecture
Failure detection and control methods as required by Tables A.5 to A.12 shall be applied in accordance with the selected architecture.	1	
	2	
	3	

Key

S, S1, S2: Input device, e.g. sensor

L, L1, L2: Logic

O, O1, O2: Output device, e.g. relay (safety function)

im: Interconnecting means

m: Monitoring

c: Cross monitoring

WD: Watchdog

OWD: Output of WD (shut-down only, not safety function)

TMU: Test and monitoring unit

OTMU: Output of TMU (shut-down only, not safety function)

NOTE The architecture for SIL 3 can be used also for SIL 2 and SIL 1; the architecture for SIL 2 can also be used also for SIL 1.

Table A.16 — Calculation of safety-related parameters

Requirement	SIL	Formula
Sufficiently low probability of a dangerous failure on demand (PFD_{Src}) and probability of a dangerous failure per hour (PFH_{Src})	1	$PFD_{Src_{SLO}} = 0{,}25 \lambda_D T_1 \frac{1}{2}$ $PFH_{Src_{SLO}} = 0{,}5 \lambda_D$
	2	$PFD_{Src_{SLO}} = 0{,}1 \lambda_D T_1$ $PFH_{Src_{SLO}} = 0{,}2 \lambda_D$
	3	Sensor subsystem: $PFD_{Src_S} = 0{,}0027 (\lambda_D T_1)^2 + 0{,}005 \lambda_D T_1$ $PFH_{Src_S} = 0{,}081 \lambda_D{}^2 T_1 + 0{,}01 \lambda_D$ Logic subsystem: $PFD_{Src_{LO}} = 0{,}003 (\lambda_D T_1)^2 + 0{,}0025 \lambda_D T_1$ $PFH_{Src_{LO}} = 0{,}0903 \lambda_D{}^2 T_1 + 0{,}005 \lambda_D$ Sum: $PFD_{Src_{SLO}} = PFD_{Src_S} + PFD_{Src_{LO}}$ $PFH_{Src_{SLO}} = PFH_{Src_S} + PFH_{Src_{LO}}$

Key

PFD: Probability of a dangerous failure on demand (Valid for a request of the safety function less than once a year)

PFH: Probability of a dangerous failure per hour (Valid for a request of the safety function more than once a year)

Src_SLO: SIL-rated circuit's sensor or logic+output

Src_S: SIL-rated circuit's sensor

Src_LO: SIL-rated circuit's logic+output

T1: Proof test interval; for the value see other standards calling for the use of this document (e.g. ISO 8100-1:2026, 4.11.2.4.3)

The formulae for SIL 1 and SIL 2 are applicable for the SIL-rated circuit's sensor part as well as for the SIL-rated circuit's logic part including its output elements.

For SIL 3, individual formulas are to be applied to the SIL-rated circuit's sensor part (Src_S), and the SIL-rated circuit's logic part (Src_L) including its output elements.

The formulae for SIL 3 assume an architecture consisting of two identical channels.

For the component failure rates, the manufacturer's failure rates shall be used. If not available IEC 61709:2017 shall be used.

For SIL 1 and SIL 2, λ_D is derived – dependent on the formula being applied, by adding all component's λ_D identified by the FMEDA (see Table A.3) either of the sensor plus the logic (Src_SL) or, on the one hand for the sensor (Src_S) and on the other hand for the logic (Src_LO).

For SIL 3, λ_D is derived – dependent on the formula being applied, by adding the individual λ_D of all components identified by the FMEDA (see Table A.3) in the considered part of the Src (Src_SLO , Src_S, Src_LO).

For SIL 2 and SIL 3, a dangerous soft-error failure rate λD_Soft of 500 FIT/Mbit shall be included to the total component's failure rate λD for any safety related variable information storage (e.g. memory, CPU timer and I/O registers, etc.).

NOTE WD / OWD / TMU / OTMU have not been included in the calculation of PFH/PFD, but all other measures apply.

A.6 Practices and rules of structured programming

Table A.17 — List of practices and rules of structured programming

Measure	Obligation	Description of measure	Informative reference IPA/SEC ESCR 3.0
Reliability 1: Initialize areas and use them by taking their sizes into consideration.			
Use areas after initializing them.	M	Automatic variables shall be initialized at the time of declaration, or the initial values shall be assigned just before using them.	R1.1.1
		const variables shall be initialized at the time of declaration.	R1.1.2
Describe initializations without excess or deficiency	M	Arrays with specified number of elements shall be initialized with values that match the number of the elements.	R1.2.1
		Initialization of enumeration type (enum type) members shall be by either: not specifying any constants; specifying all the constants; or specifying only the first member.	R1.2.2
Pay attention to the range of the area pointed by a pointer.	HR	(1) Integer addition to or subtraction from (including ++ and --) pointers shall not be made; Array format with [ ] shall be used for references and assignments to the allocated area. (2) Integer addition to or subtraction from (including ++ and --) pointers shall be made only when the pointer points to the array and the result must be pointing within the range of the array.	R1.3.1
	M	Subtraction between pointers shall only be applied to pointers that address elements of the same array.	R1.3.2
	M	Comparison between pointers shall be used only when the two pointers are both pointing at either the elements in the same array or the members of the same structure.	R1.3.3
	M	The restrict type qualifier shall not be used.	R1.3.4
Reliability 2: Use data by taking their ranges, sizes and internal representations into consideration.			
Make comparisons that do not depend on internal representations.	M	Floating-point expressions shall not be used to perform equality or inequality comparisons.	R2.1.1
	M	Floating-point variable shall not be used as a loop counter.	R2.1.2
	HR	memcmp shall not be used to compare structures and unions.	R2.1.3
When values such as logical values are defined as a range, do not make a judgment by finding whether or not a value is equivalent to any particular value (representative value) within this range.	HR	Comparison with a value defined as true shall not be made in expressions that examine true or false.	R2.2.1
Use the same data type to perform operations or comparisons.	M	Unsigned integer constant expressions shall be described within the range that can be represented with the result type.	R2.3.1
	M	When using conditional operator (?: operator), the logical expression shall be enclosed in parentheses ( ) and both return values shall be the same type.	R2.3.2
	M	Loop counters and variables used for comparison of loop iteration conditions shall be the same type.	R2.3.3
Describe code by taking operation precision into consideration.	HR	When the type of an operation and the type of the destination to which the operation result is assigned (assignment destination) are different, the operation shall be performed after casting them to the type of expected operation precision.	R2.4.1
	HR	When performing arithmetic operations or comparisons of expressions mixed with signed and unsigned, an explicit cast to the expected type shall be performed.	R2.4.2
Obligation: M: The technique or measure is required (mandatory); HR: The technique or measure is highly recommended. If this technique or measure is not used then the rationale behind not using it shall be detailed; Rules which can be selected from several alternatives are indicated in column 'Description of measure' with brackets, e.g.(1), (2) Specific rules that need to be defined for each project or rules that need to be prescribed in a document are enclosed by 《 》			

Table A.17 *(continued)*

Measure	Obligation	Description of measure	Informative reference IPA/SEC ESCR 3.0
Do not use operations that have the risk of information loss.	M	When performing assignments (=operation, actual arguments passing of function calls, function return) or operations to data types that may cause information loss, they shall be first confirmed that there are no problems, and a cast shall be described to explicitly state that they are problem-free.	R2.5.1
	M	Unary operator ‘-’ shall not be used in unsigned expressions.	R2.5.2
	M	When ones’ complement (~) or left shift (<<) is applied to unsigned char or unsigned short type data, an explicit cast to the type of the operation result shall be performed.	R2.5.3
	HR	The right-hand side of a shift operator shall be zero or more, and less than the bit width of the left-hand side.	R2.5.4
Use types that can represent the target data.	M	(1) The types used for bit fields shall only be signed int or unsigned int. If a bit field of 1-bit width is required, unsigned int type shall be used, and not the signed int type. (2) The types used for bit fields shall be signed int, unsigned int or _Bool. If a bit field of 1 bit width is required, unsigned int type or _Bool type shall be used. (3) The types used for bit fields shall be signed int, unsigned int, _Bool, or those allowed by the compiler that are either enum or the type that specifies signed or unsigned. If a bit field of 1-bit width is required, the type that specifies unsigned or _Bool type shall be used.	R2.6.1
	M	Data used as bit sequences shall be defined with unsigned type, and not with the signed type.	R2.6.2
Pay attention to pointer types.	M	(1) Pointer type shall not be converted to other pointer type or integer type, and vice versa, with the exception of mutual conversion between “pointer to data” type and “pointer to void*” type. (2) Pointer type shall not be converted to other pointer type or integer type with less data width than that of the pointer type, with the exception of mutual conversion between “pointer to data” type and “pointer to void*” type. (3) Pointer type shall not be converted to other pointer type or integer type with less data width than that of the pointer type, with the exception of mutual conversion between “pointer to data” type and “pointer to other data” type, and between “pointer to data” type and “pointer to void*” type.	R2.7.1
	M	A cast shall not be performed that removes any const or volatile qualification from the type addressed by a pointer.	R2.7.2
	M	Comparison to check whether a pointer is negative or not shall not be performed.	R2.7.3
Write in a way that will enable the compiler to check that there are no conflicting declarations, usages and definitions.	M	Functions with no parameters shall be declared with a void type parameter.	R2.8.1
	M	(1) Functions shall not be defined with a variable number of arguments (2) When using functions with a variable number of arguments,《they shall be used after documenting the intended behaviors based on the compiler used.》	R2.8.2
	M	One prototype declaration shall be made at one place from where it can be referenced by both the function calls and function definition.	R2.8.3
Reliability 3: Write in a way that ensures intended behavior.			
Write in a way that is conscious of area size.	HR	(1) In an extern declaration of an array, the number of elements shall always be specified. (2) In an extern declaration of an array, the number of elements shall always be specified, except for extern declarations of arrays that correspond to the array definition that includes initialization and has omitted the number of elements.	R3.1.1
	M	Iteration conditions for a loop to sequentially access array elements shall include the decision to whether the access is within the range of the array or not.	R3.1.2
	M	The size of the array initialized with a designated initializer shall be clearly indicated.	R3.1.3
	M	Variable length array type shall not be used.	R3.1.4
	M	(1) sizeof operator shall not be applied to pointer-type variable. (2) sizeof operator shall not be applied to array-type argument.	R3.1.5

Obligation:

M: The technique or measure is required (mandatory);

HR: The technique or measure is highly recommended. If this technique or measure is not used then the rationale behind not using it shall be detailed;

Rules which can be selected from several alternatives are indicated in column ‘Description of measure’ with brackets, e.g.(1), (2)

Specific rules that need to be defined for each project or rules that need to be prescribed in a document are enclosed by《 》

Table A.17 *(continued)*

Measure	Obligation	Description of measure	Informative reference IPA/SEC ESCR 3.0
Prevent operations that may cause runtime error from falling into error cases.	M	Operations shall be performed after confirming that the right-hand side expression of division or remainder operation is not 0.	R3.2.1
	M	Destination pointed by a pointer shall be referenced to after checking that the pointer is not the null pointer.	R3.2.2
Check the interface restrictions when a function is called.	M	If a function returns error information, then that error information shall be tested.	R3.3.1
	M	The function shall check if there are constraints on parameters before starting to process.	R3.3.2
Do not perform recursive calls.	M	Functions shall not call themselves, either directly or indirectly.	R3.4.1
Pay attention to branch conditions and describe how to handle cases that do not follow the predefined conditions when they occur.	M	《The else clause shall be written at the end of an if-else if statement. If it is known that the else condition does not normally occur, the description of the else clause shall be either one of the following: (i) An exception handling process shall be written in the else clause. (ii) A comment specified by the project shall be written in the else clause.》	R3.5.1
	M	《The default clause shall be written at the end of a switch statement. If it is known that the default condition does not normally occur, the description of the default clause shall be either one of the followings. 《(i) An exception handling process shall be written in the default clause. (ii) A comment specifi d by the project shall be written in the default clause.》	R3.5.2
	HR	Equality operators (==) or inequality operators (!=) shall not be used for comparisons of loop counters. (<=, >=, <, or > shall be used.)	R3.5.3
Pay attention to the order of evaluation.	M	Variables whose values are changed in an expression shall not be referred to or modified in the same expression.	R3.6.1
	M	Function calls with side effects and volatile variables shall not be described more than once in a sequence of actual arguments or binary operation expressions.	R3.6.2
	HR	sizeof operator shall not be used in expressions that have side effect.	R3.6.3
Be careful with how to access the shared data in programs that use threads or signals.	M	For concurrent processing, volatile shall not be used as synchronization primitive.	R.3.11.1
	M	The bit fields that may be allocated in the same memory space shall not be accessed by multiple threads or shall be exclusively controlled properly.	R.3.11.2
Maintainability.1: Keep in mind that others will read the program			
Do not leave unused descriptions.	HR	Unused functions, variables, parameters, typedefs, tags, labels or macros shall not be declared (defined).	M1.1.1
	HR	Sections of code should not be “commented out”.	M1.1.2
Do not write confusingly.	HR	(1) Only one variable shall be declared in one declaration statement (avoid multiple declarations.) (2) Automatic variables of the same type used for the similar purposes may be declared in one declaration statement, but variables with initialization and variables without initialization shall not be mixed.	M1.2.1
	M	Suffixes shall be added to constant descriptions that can use them to indicate appropriate types. Only an uppercase letter “L” shall be used for a suffix indicating a long type integer constant.	M1.2.2
Do not write in an unconventional style.	HR	Expressions evaluating to true or false shall not be described in switch (expression).	M1.3.1
	M	The case labels and default label in a switch statement shall be described only in the compound statement (excluding nested compound statements) within the body of the switch statement.	M1.3.2
	M	The types shall be explicitly described for definitions and declarations of functions and variables.	M1.3.3

Obligation:

M: The technique or measure is required (mandatory);

HR: The technique or measure is highly recommended. If this technique or measure is not used then the rationale behind not using it shall be detailed;

Rules which can be selected from several alternatives are indicated in column ‘Description of measure’ with brackets, e.g.(1), (2)

Specific rules that need to be defined for each project or rules that need to be prescribed in a document are enclosed by 《 》

Table A.17 *(continued)*

Measure	Obli-gation	Description of measure	Informative reference IPA/SEC ESCR 3.0
Write in a style that clearly specifies the operator precedence.	M	Expressions described at the right hand and left hand of && and || operations shall be either simple variables or expressions enclosed with ( ). However, if only && operations or only || operations are successively combined, it is not necessary to enclose each && and || expression with ( ).	M1.4.1
	M	《Usage of parentheses to explicitly indicate operator precedence shall be defined.》	M1.4.2
Explicitly describe the operations that are likely to cause misunderstanding when they are omitted.	M	A function identifier (function name) shall only be used with either a preceding "&", or with a parenthesized parameter list, which may be empty.	M1.5.1
Use one area for one purpose.	M	Variables shall be prepared for each purpose.	M1.6.1
	HR	(1) Unions shall not be used. (2) If unions are used, the same members that are assigned values shall be referenced.	M1.6.2
Do not reuse names.	HR	The rules below shall be followed for name uniqueness. 1. An identifier declared in an inner scope shall not hide an identifier declared in an outer scope. 2. A typedef name shall be a unique identifier. 3. A tag name shall be a unique identifier. 4. Identifiers that define objects or functions with external linkage shall be unique. 5. Identifiers that define objects or functions with internal linkage should be unique. 6. No identifier in one name space should have the same spelling as an identifier in another name space, with the exception of structure member and union member names.	M1.7.1
	M	Names for functions, variables and macros in the standard library shall not be redefined or reused. In addition, those macro names shall not be undefined.	M1.7.2
	M	Names (variables) that start with an underscore shall not be defined.	M1.7.3
Do not use language specifications that are likely to cause misunderstanding.	HR	The right-hand operand of a logical && or || operator shall not contain side effects.	M1.8.1
	HR	C macros shall only expand to a braced initializer, a constant, a parenthesised expression, a type qualifier, a storage class specifier, or a do-while-zero construct.	M1.8.2
	M	#line shall not be used, unless it is automatically generated by a tool.	M1.8.3
	M	Sequences of three or more characters starting with ?? and alternative tokens shall not be used.	M1.8.4
	M	A sequence starting with zero (0) that is two or more digits long shall not be used as a constant.	M1.8.5
When writing in an unconventional style, explicitly state its intention.	HR	If statements that do nothing need to be intentionally described, comments or empty macros shall be used to make them noticeable.	M1.9.1
	HR	《The unified style of writing infinite loops shall be defined.》	M1.9.2
Do not embed magic numbers.	HR	A meaningful constant shall be used after defining it as a macro.	M1.10.1
Explicitly state the area attributes	M	Read-only areas shall be declared as const type.	M1.11.1
	M	Areas that may be updated by other execution units shall be declared as volatile.	M1.11.2
Correctly describe the statements even if they are not compiled.	HR	Correct code shall be described even if it is going to be deleted by the preprocessor.	M1.12.1
Maintainability 2: Write in a style that can prevent modification errors			
Clarify the grouping of structured data and blocks.	M	If arrays and structures are initialized with values other than 0, their structural form shall be indicated by using braces '{ }'. Data shall be described without any omission, except when all values are 0.	M2.1.1
	HR	The body of if, else if, else, while, do, for, and switch statements shall be enclosed into blocks.	M2.1.2

Obligation:

M: The technique or measure is required (mandatory);

HR: The technique or measure is highly recommended. If this technique or measure is not used then the rationale behind not using it shall be detailed;

Rules which can be selected from several alternatives are indicated in column 'Description of measure' with brackets, e.g.(1), (2)

Specific rules that need to be defined for each project or rules that need to be prescribed in a document are enclosed by 《 》

Table A.17 *(continued)*

Measure	Obligation	Description of measure	Informative reference IPA/SEC ESCR 3.0
Localize access ranges and related data.	M	Variables used only in one function shall be declared within the function.	M2.2.1
	M	Variables accessed by several functions defined in the same file shall be declared with static in the file scope..	M2.2.2
	M	Functions that are called only by functions defined in the same file shall be static.	M2.2.3
	HR	enum shall be used rather than #define when defining related constants.	M2.2.4
Maintainability 3: Write programs simply.			
Do structured programming.	HR	For any iteration statement, there shall be at most one break statement used for loop termination.	M3.1.1
	HR	(1)The goto statement shall not be used. (2) When using a goto statement, the destination to jump to shall be the label declared after the goto statement that is in the same block or within the block enclosing the goto statement.	M3.1.2
	M	(1) Each case clause and default clause in a switch statement shall always end with a break statement. (2) If the case clause or default clause in a switch statement is not going to be ended with a break statement, 《a project-specific comment shall be defined》 and that comment shall instead be inserted.	M3.1.4
	M	(1) A function shall end with one return statement. (2) A return statement to return in the middle of processing shall be written only in case of recovery from abnormality.	M3.1.5
One statement should have one side effect.	HR	(1) Comma expressions shall not be used. (2) Comma expressions shall not be used, other than in expressions for initializing or updating in for statements.	M3.2.1
	M	Multiple assignments shall not be written in one statement, except when the same value is assigned to multiple variables.	M3.2.2
Separately describe expressions with different purposes.	M	The three expressions of a for statement shall be concerned only with loop control.	M3.3.1
	M	Numeric variables being used within a for loop for iteration counting shall not be modified in the body of the loop.	M3.3.2
	M	(1) Assignment operators shall not be used in expressions to examine true or false. (2) Assignment operators shall not be used in expressions to examine true or false, except for conven- tionally used notations.	M3.3.3
Do not use complicated pointer operations.	M	Three or more pointer indirections shall not be used.	M3.4.1
Maintainability 4: Write in a unified style.			
Unify the coding styles.	HR	《Conventions regarding the style of using, such as, the braces'{ }', indentation and space shall be defined.》	M4.1.1
Unify the style of writing comments.	HR	《Convention regarding the style of writing file header comments, function header comments, end of line comments, block comments and copyright shall be defined. 》	M4.2.1
Unify the naming conventions.	HR	《Convention for naming external variables and internal variables shall be defined.》	M4.3.1
	HR	《Convention for naming files shall be defined.》	M4.3.2
Unify the contents to be described in a file and the order of describing them.	HR	《The descriptive contents of header files (declarations, definitions, etc) and the order they are described in shall be defined.》	M4.4.1

Obligation:

M: The technique or measure is required (mandatory);

HR: The technique or measure is highly recommended. If this technique or measure is not used then the rationale behind not using it shall be detailed;

Rules which can be selected from several alternatives are indicated in column 'Description of measure' with brackets, e.g.(1), (2)

Specific rules that need to be defined for each project or rules that need to be prescribed in a document are enclosed by 《 》

Table A.17 *(continued)*

Measure	Obligation	Description of measure	Informative reference IPA/SEC ESCR 3.0
Unify the contents to be described in a file and the order of describing them.	HR	《The descriptive contents of source files (declarations, definitions, etc) and the order they are described in shall be defined.》	M4.4.2
	HR	To use or define external variables or functions (except for functions used only in the file), the header file de- scribing their declarations shall be included.	M4.4.3
	HR	External variables shall not be defined in multiple locations.	M4.4.4
	HR	Variable definitions or function definitions shall not be described in a header file.	M4.4.5
	M	Header files shall be descriptively capable of handling redundant inclusions.《The descriptive method to achieve this capability shall be defined.》	M4.4.6
Unify the style of writing declarations.	HR	(1) In a function prototype declaration, all the parameters shall not be named (types only.) (2) In a function prototype declaration, all the parameters shall be named. In addition, the types of the parameters, their names and the type of the return value shall be literally the same as those of the function definition.	M4.5.1
	HR	Structure tags and variables shall be declared separately.	M4.5.2
Unify the style of writing null pointers.	M	NULL shall be used for the null pointer. NULL shall not be used for anything other than the null pointer.	M4.6.1
Unify the style of writing preprocessor directives.	M	The body and parameters of a macro that includes operators shall be enclosed with parentheses ( ).	M4.7.1
	HR	#else, #elif or #endif that correspond to #ifdef, #ifndef or #if shall be described in the same file, and《their correspondence relationship shall be clearly stated with a comment defined in the project》.	M4.7.2
	HR	defined(macro_name) or defined macro_name shall be used to check whether the macro name has already been defined by #if or #elif.	M4.7.3
	M	Macros shall not be #define'd or #undef'd within a block.	M4.7.5
	HR	#undef shall not be used.	M4.7.6
	HR	Controlling expression of #if or #elif preprocessing directive shall be evaluated as 0 or 1.	M4.7.7
Maintainability 5: Write in a style that makes testing easy.			
Write in a style that makes it easy to investigate the causes of problems when they occur.	HR	《The rules for writing the code for setting debug options and for recording logs in release modules shall be defined.》	M5.1.1
	HR	(1) The # and ## preprocessor operators should not be used. (2) A macro parameter immediately following a # operator shall not immediately be followed by a ## operator.	M5.1.2
	HR	Function shall be used rather than using function-like macro.	M5.1.3
Be careful when using dy- namic memory allocations.	M	Dynamic memory shall not be used.	M5.2.1
Portability 1: Write in a style that is not dependent on the compiler.			
Do not use functionalities that are advanced features or implementation-defined.	HR	(1) Functionalities not specified in the language standard shall not be used. (2) If functionalities not specified in the language standard are used,《the func- tionalities used and their usage shall be documented.》	P1.1.1
	M	《All usage of implementation-defined behavior shall be documented. 》	P1.1.2
	M	To use a program written in another language, 《its interface shall be documented and its usage shall be defined.》	P1.1.3
Use only the characters and escape sequences defined in the language standard.	M	To use characters other than those defined in the language standard for writing a program, the compiler specifications shall be confirmed, and《their usage shall be defined.》	P1.2.1
	HR	Only escape sequences defined in the language standard shall be used.	P1.2.2
Obligation: M: The technique or measure is required (mandatory); HR: The technique or measure is highly recommended. If this technique or measure is not used then the rationale behind not using it shall be detailed; Rules which can be selected from several alternatives are indicated in column 'Description of measure' with brackets, e.g.(1), (2) Specific rules that need to be defined for each project or rules that need to be prescribed in a document are enclosed by《 》			

Table A.17 *(continued)*

Measure	Obli-gation	Description of measure	Informative reference IPA/SEC ESCR 3.0
Confirm and document data type representations, behavioral specifications of advanced functionalities and implementation-dependent parts.	M	Simple char type (that does not specify the signedness) shall be used only for storing character values. If a process that depends on signedness (implementation-defined) is required, unsigned char or signed char that specifies its signedness shall be used. Note: use <stdint.h> header and types	P1.3.1
	HR	The members of an enumeration type (enum) shall be defined with values that can be represented as int type.	P1.3.2
	HR	(1) Bit fields shall not be used. (2) bit fields shall not be used for data whose bit positions are meaningful. (3)《If it is being relied upon, the implementation-defined behavior and packing of bit fields shall be documented.》	P1.3.3
For source file inclusion, confirm the implementation-dependent parts and write in a style that is not implementation-dependent.	M	The #include directive shall be followed by either a <file- name> or “filename” sequence.	P1.4.1
	HR	《 The usage of <> format and “” format for #include file specification shall be defined.》	P1.4.2
	M	Characters ‘, \, “, /*, // and: shall not be used for file specification in #include.	P1.4.3
Write in a style that does not depend on the environment used for compiling.	M	The absolute path shall not be written for #include file specification.	P1.5.1
	HR	sizeof shall be used to determine the size of a type or variable.	P1.5.2
Portability 2: Localize the code that has a problem with portability.			
Localize the code that has a problem with portability.	HR	When assembly language programs are called from C language,《how to localize such parts shall be defined》,such as, by expressing them as functions or inline functions of C language that contain only inline assembly language code or describing them using macros.	P2.1.1
	HR	(1) The basic types (char, int, long, long long, float, double and long double) shall not be used. Instead, the types defined by typedef shall be used.《The types defined by typedef that are used in the project shall be defined.》 (2) When using any of the basic types (char, int, long, long long, float, double and long double) in a form that is dependent on its size, the type defined by typedef for each of these basic types shall be used. 《The types defined by typedef that are used in the project shall be defined.》	P2.1.3

Obligation:

M: The technique or measure is required (mandatory);

HR: The technique or measure is highly recommended. If this technique or measure is not used then the rationale behind not using it shall be detailed;

Rules which can be selected from several alternatives are indicated in column ‘Description of measure’ with brackets, e.g.(1), (2)

Specific rules that need to be defined for each project or rules that need to be prescribed in a document are enclosed by《 》

Annex B
(informative)

Example for calculation of guide rails

B.1 General

B.1.1 The following example is used to explain the calculation of T-Section guide rails with an analytical structural calculation method, based on a lift with guide rails which extend to the pit floor and a single acting safety gear. This example does not include the calculation of other operational scenarios (e.g. buffer impact, bouncing scenarios, etc.).

B.1.2 The following symbols for the dimensions in the lift are used with a Cartesian coordinates system for all possible geometrical cases (see Figures B.1 to B.4):

C	is the car centre;
D_x	is the car dimension in X-direction, car depth;
D_y	is the car dimension in Y-direction, car width;
h	is the distance between car guide shoes;
l	is the distance between brackets;
P	are the masses of the empty car and components supported by the car, i.e. part of travelling cable, compensating ropes/chains (if any), etc. in kilograms;
Q	is the rated load in kilograms;
S	is the car suspension;
x_C, y_C	is the position of the car centre (C) in relation to the guide rail cross coordinates;
x_i, y_i	is the position of the car door, i = 1, 2, 3 or 4;
x_p, y_p	is the position of the car mass (P) in relation to the guide rail cross coordinates;
x_Q, y_Q	is the position of the rated load (Q) in relation to the guide rail cross coordinates
x_S, y_S	is the position of the suspension (S) in relation to the guide rail cross coordinates;
1, 2, 3, 4	is the centre of the car door 1, 2, 3 or 4;
——→	is the direction of loading.

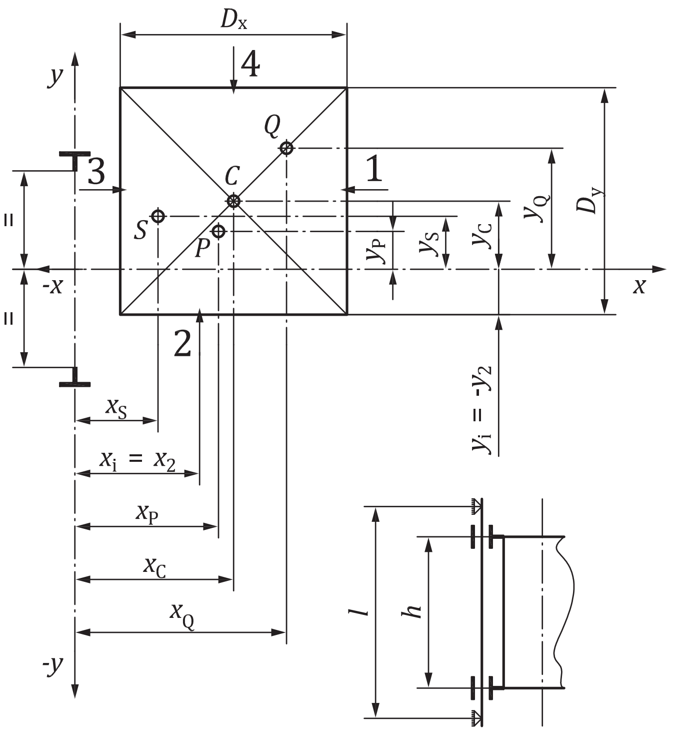


Figure B.1 — Load distribution in lift car — General case

B.1.3 The following symbols are used in Formulae (B.1) to (B.45), see B.2:

A	is the cross-sectional area of a guide rail in square millimetres;
c	is the width of the connecting part of the foot to the blade in millimetres;
δ_{perm}	is the maximum permissible deflection in millimetres;
δ_x	is the deflection in the X-axis in millimetres;
δ_y	is the deflection in the Y-axis in millimetres;
$\delta_{str\text{-}x}$	is the deflection of the fixings (brackets, separation beams) in the X-axis in millimetres;
$\delta_{str\text{-}y}$	is the deflection of the fixings (brackets, separation beams) in the Y-axis in millimetres;
E	is the modulus of elasticity in newtons per square millimetre;
F_{aux}	is the force in a guide rail due to auxiliary equipment and bouncing scenarios in newtons;
F_p	is the push through forces of all brackets at one guide rail line in newtons;
F_S	is the vertical force acting on the car sill due to loading and unloading, in newtons;
F_v	is the vertical force on a guide rail of the car, counterweight or balancing weight in newtons;
F_x	is the supporting force in the X-axis in newtons;
F_y	is the supporting force in the Y-axis in newtons;
g_n	is the standard acceleration of free fall in metres per square second;
I_x	is the second moment of area related to the X-axis in fourth power millimetres;

I_y is the second moment of area related to the Y-axis in fourth power millimetres;

k_1 is the impact factor for the type of safety gear used;

k_2 is the impact factor for the running condition;

M_g is the mass of one line of guide rails in kilograms;

M_m is the bending moment in newtons millimetres;

M_x is the bending moment related to the X-axis, in newtons millimetres;

M_y is the bending moment related to the Y-axis, in newtons millimetres;

n is the number of guide rails;

σ is the combined stress in newtons per square millimetre;

σ_k is the buckling stress in newtons per square millimetre;

σ_m is the bending stress in newtons per square millimetre;

σ_F is the local flange bending stress in newtons per square millimetre;

σ_{perm} is the permissible stress in newtons per square millimetre;

σ_x is the bending stress related to the X-axis in newtons per square millimetre;

σ_y is the bending stress related to the Y-axis in newtons per square millimetre;

W_x is the modulus of cross sectional area related to the X-axis in cubic millimetres;

W_y is the modulus of cross sectional area related to the Y-axis in cubic millimetres;

ω is the omega value.

B.2 General configuration for lifts with safety gear

B.2.1 Safety gear operation

B.2.1.1 Bending stress

a) Bending stress relative to the Y-axis of the guide rail due to guiding force as per 4.10.2.2:

$$F_x = \frac{k_1 \cdot g_n \cdot \left(Q \cdot x_Q + P \cdot x_P\right)}{n \cdot h} \quad \text{(B.1)}$$

$$M_y = \frac{3 \cdot F_x \cdot l}{16} \quad \text{(B.2)}$$

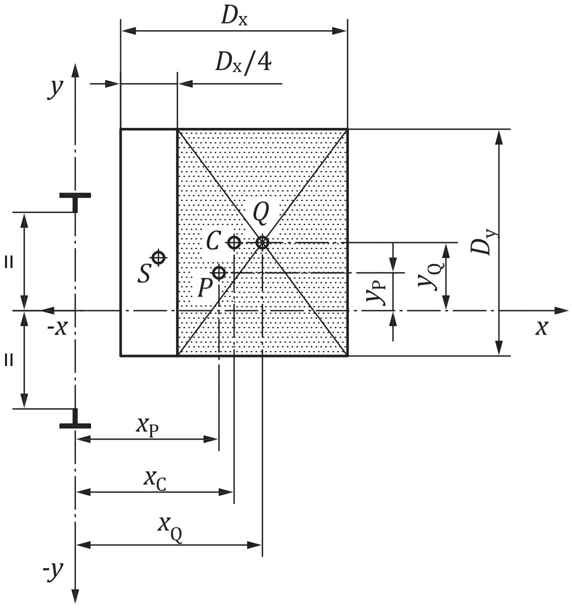
$$\sigma_y = \frac{M_y}{W_y} \quad \text{(B.3)}$$

b) Bending stress relative to the X-axis of the guide rail due to guiding force as per 4.10.2.2:

$$F_y = \frac{k_1 \cdot g_n \cdot \left(Q \cdot y_Q + P \cdot y_P\right)}{\frac{n}{2} \cdot h} \quad \text{(B.4)}$$

$$M_x = \frac{3 \cdot F_y \cdot l}{16} \quad (B.5)$$

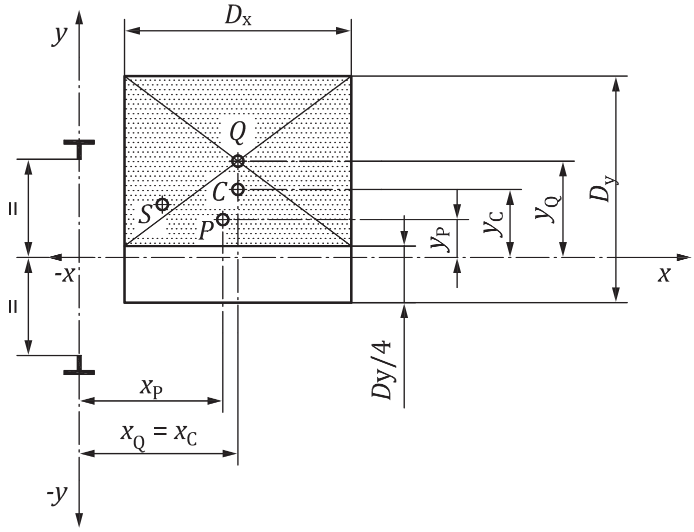
$$\sigma_x = \frac{M_x}{W_x} \quad (B.6)$$



NOTE 1 $x_Q = x_C + D_x/8$.

NOTE 2 $y_Q = y_C$.

Figure B.2 — Safety gear operation — Load distribution in lift car — Case 1 relative to X-axis



NOTE 1 $x_Q = x_C$.

NOTE 2 $y_Q = y_C + D_y/8$.

Figure B.3 — Safety gear operation — Load distribution in lift car — Case 2 relative to Y-axis

B.2.1.2 Buckling

Buckling is determined as per 4.10.3.

$$F_{\text{v}} = \frac{k_1 \cdot g_{\text{n}} \cdot (P+Q)}{n} + M_{\text{g}} \cdot g_{\text{n}} + F_{\text{p}} \tag{B.7}$$

$$\sigma_{\text{k}} = \frac{(F_{\text{v}} + F_{\text{aux}}) \cdot \omega}{A} \tag{B.8}$$

B.2.1.3 Combined stress

The combined stress is calculated as per 4.10.4. Formulae (B.9) to (B.11) apply to both load distribution cases 1 and 2, see B.2.1.1. If $\sigma_{perm} < \sigma$, 4.10.2.3 applies.

Combined bending

$$\sigma = \sigma_{\text{m}} = \sigma_{\text{x}} + \sigma_{\text{y}} \leq \sigma_{\text{perm}} \tag{B.9}$$

Combined bending and compression

$$\sigma = \sigma_{\text{m}} + \frac{F_{\text{v}} + F_{\text{aux}}}{A} \leq \sigma_{\text{perm}} \tag{B.10}$$

Combined bending and buckling

$$\sigma = \sigma_{\text{k}} + 0{,}9 \cdot \sigma_{\text{m}} \leq \sigma_{\text{perm}} \tag{B.11}$$

B.2.1.4 Flange bending

Flange bending is calculated as per 4.10.5. Formulae (B.12) to (B.13) apply to both load distribution cases 1 and 2, see B.2.1.1.

$$\sigma_{\text{F}} = \frac{1{,}85 \cdot F_{\text{x}}}{c^2} \leq \sigma_{\text{perm}}\text{, or} \tag{B.12}$$

$$\sigma_{\text{F}} = \frac{6 \cdot F_{\text{x}} \cdot (h_1 - b - f)}{c^2 \cdot [l + 2 \cdot (h_1 - f)]} \leq \sigma_{\text{perm}} \tag{B.13}$$

B.2.1.5 Deflections

Deflections are calculated as per 4.10.6. Formulae (B.14) to (B.15) apply to both load distribution cases 1 and 2, see B.2.1.1.

$$\delta_{\text{x}} = 0{,}7 \frac{F_{\text{x}} \cdot l^3}{48 \cdot E \cdot I_{\text{y}}} + \delta_{\text{str-x}} \leq \delta_{\text{perm}} \tag{B.14}$$

$$\delta_{\text{y}} = 0{,}7 \frac{F_{\text{y}} \cdot l^3}{48 \cdot E \cdot I_{\text{x}}} + \delta_{\text{str-y}} \leq \delta_{\text{perm}} \tag{B.15}$$

B.2.2 Running

B.2.2.1 Bending stress

a) Bending stress relative to the Y-axis of the guide rail due to guiding force as per 4.10.2.2:

$$F_x = \frac{k_2 \cdot g_n \cdot \left[Q \cdot \left(x_Q - x_S\right) + P \cdot \left(x_P - x_S\right)\right]}{n \cdot h} \quad \text{(B.16)}$$

$$M_y = \frac{3 \cdot F_x \cdot l}{16} \quad \text{(B.17)}$$

$$\sigma_y = \frac{M_y}{W_y} \quad \text{(B.18)}$$

b) Bending stress relative to the X-axis of the guide rail due to guiding force as per 4.10.2.2:

$$F_y = \frac{k_2 \cdot g_n \cdot \left[Q \cdot \left(y_Q - y_S\right) + P \cdot \left(y_P - y_S\right)\right]}{\frac{n}{2} \cdot h} \quad \text{(B.19)}$$

$$M_x = \frac{3 \cdot F_y \cdot l}{16} \quad \text{(B.20)}$$

$$\sigma_x = \frac{M_x}{W_x} \quad \text{(B.21)}$$

Load distribution:

Case 1 relative to the X-axis (see Figure B.2).

Case 2 relative to the Y-axis (see Figure B.3).

B.2.2.2 Buckling

Buckling is determined as per 4.10.3

$$F_v = M_g \cdot g_n + F_p \quad \text{(B.22)}$$

$$\sigma_k = \frac{\left(F_v + F_{aux}\right) \cdot \omega}{A} \quad \text{(B.23)}$$

B.2.2.3 Combined stress

Combined stress is calculated as per 4.10.4. Formulae (B.24) to (B.26) apply to both load distribution cases 1 and 2, see B.2.2.1. If $\sigma_{perm} < \sigma$, 4.10.2.3 applies.

Combined bending

$$\sigma_m = \sigma_x + \sigma_y \le \sigma_{perm} \quad \text{(B.24)}$$

Combined bending and compression

$$\sigma = \sigma_m + \frac{F_v + F_{aux}}{A} \le \sigma_{perm} \quad \text{(B.25)}$$

Combined bending and buckling

$$\sigma = \sigma_k + 0{,}9 \cdot \sigma_m \le \sigma_{perm} \quad \text{(B.26)}$$

B.2.2.4 Flange bending

Flange bending is calculated as per 4.10.5. These formulae apply to both load distribution cases 1 and 2, see B.2.1.1.

$$\sigma_F = \frac{1{,}85 \cdot F_x}{c^2} \quad \leq \sigma_{perm} \text{, or} \tag{B.27}$$

$$\sigma_F = \frac{6 \cdot F_x \cdot (h_1 - b - f)}{c^2 \cdot [l + 2 \cdot (h_1 - f)]} \quad \leq \sigma_{perm} \tag{B.28}$$

B.2.2.5 Deflections

Deflections are calculated as per 4.10.6. These formulae apply to both load distribution cases 1 and 2, see B.2.1.1.

$$\delta_x = 0{,}7 \frac{F_x \cdot l^3}{48 \cdot E \cdot I_y} + \delta_{str-x} \leq \delta_{perm} \tag{B.29}$$

$$\delta_y = 0{,}7 \frac{F_y \cdot l^3}{48 \cdot E \cdot I_x} + \delta_{str-y} \leq \delta_{perm} \tag{B.30}$$

B.2.3 Loading and unloading

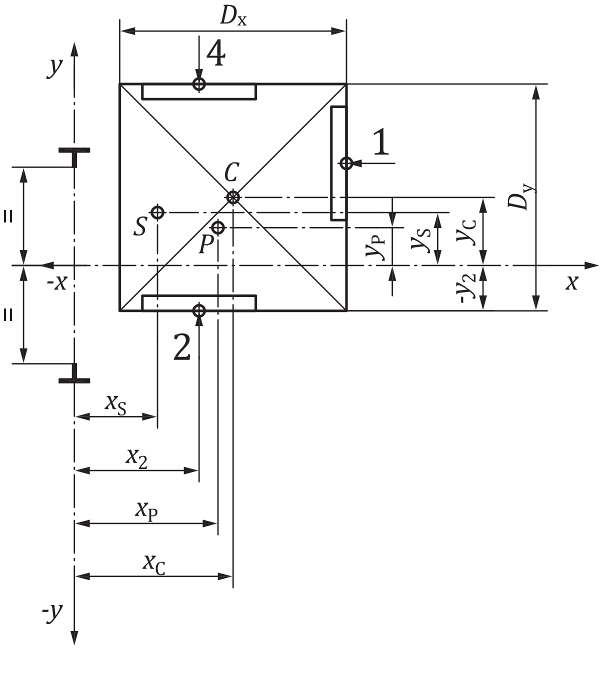


Figure B.4 — Load distribution

B.2.3.1 Bending stress

a) Bending stress relative to the Y-axis of the guide rail due to guiding force as per 4.10.2.2:

$$F_x = \frac{g_n \cdot P \cdot (x_P - x_S) + F_S \cdot (x_i - x_S)}{n \cdot h} \tag{B.31}$$

$$M_y = \frac{3 \cdot F_x \cdot l}{16} \tag{B.32}$$

$$\sigma_y = \frac{M_y}{W_y} \tag{B.33}$$

b) Bending stress relative to the X-axis of the guide rail due to guiding force as per 4.10.2.2:

$$F_y = \frac{g_n \cdot P \cdot (y_P - y_S) + F_S \cdot (y_i - y_S)}{\frac{n}{2} \cdot h} \tag{B.34}$$

$$M_x = \frac{3 \cdot F_y \cdot l}{16} \tag{B.35}$$

$$\sigma_x = \frac{M_x}{W_x} \tag{B.36}$$

B.2.3.2 Buckling

Buckling is determined as per 4.10.3

$$F_v = M_g \cdot g_n + F_p \tag{B.37}$$

$$\sigma_k = \frac{(F_v + F_{aux}) \cdot \omega}{A} \tag{B.38}$$

B.2.3.3 Combined stress

Combined stress is calculated as per 4.10.4. If $\sigma_{perm} < \sigma$, 4.10.2.3 applies.

Combined bending

$$\sigma = \sigma_m = \sigma_x + \sigma_y \le \sigma_{perm} \tag{B.39}$$

Combined bending and compression

$$\sigma = \sigma_m + \frac{F_v + F_{aux}}{A} \le \sigma_{perm} \tag{B.40}$$

Combined bending and buckling

$$\sigma = \sigma_k + 0{,}9 \cdot \sigma_m \le \sigma_{perm} \tag{B.41}$$

B.2.3.4 Flange bending

Flange bending is calculated as per 4.10.5

$$\sigma_F = \frac{1{,}85 \cdot F_x}{c^2} \le \sigma_{perm}\text{, or} \tag{B.42}$$

$$\sigma_F = \frac{6 \cdot F_x \cdot (h_1 - b - f)}{c^2 \cdot [l + 2 \cdot (h_1 - f)]} \le \sigma_{perm} \tag{B.43}$$

B.2.3.5 Deflections

Deflections are calculated as per 4.10.6

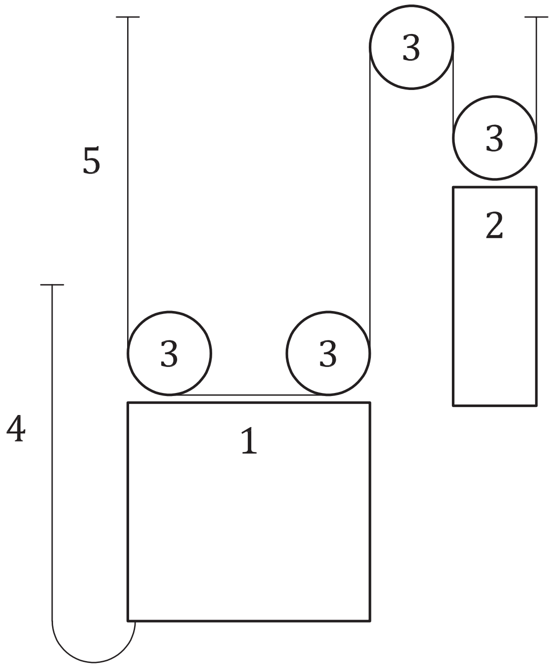
$$\delta_{\mathrm{x}} = 0,7 \frac{F_{\mathrm{x}} \cdot l^3}{48 \cdot E \cdot I_{\mathrm{y}}} + \delta_{\mathrm{str}-x} \leq \delta_{\mathrm{perm}} \quad \text{(B.44)}$$

$$\delta_{\mathrm{y}} = 0,7 \frac{F_{\mathrm{y}} \cdot l^3}{48 \cdot E \cdot I_{\mathrm{x}}} + \delta_{\mathrm{str}-y} \leq \delta_{\mathrm{perm}} \quad \text{(B.45)}$$

Annex C
(informative)

Calculation of traction — Example

For the example as per Figure C.1, Formulae (C.1) to (C.8) apply.



Key

1	car
2	counterweight
3	pulley
4	travelling cable
5	suspension means

Figure C.1 — Example 2:1, no compensation means

Car loading condition

Car loaded with 125 % rated load at lowest landing, no friction considered.

$$T_1 = \frac{(P + 1{,}25 \cdot Q)}{2} \cdot g_n + M_{SRcar} \cdot g_n \tag{C.1}$$

$$T_2 = \frac{M_{cwt}}{2} \cdot g_n \tag{C.2}$$

Emergency braking condition

Minimum friction due to pulleys and guiding force assumed

a) Car loaded with rated load at lowest landing

$$T_1 = \frac{(P+Q)}{2} \cdot (g_n + a) + M_{SRcar}(g_n + 2 \cdot a) + \left[\frac{m_{Pcar\_1} \cdot \left(\frac{v_{P\_1}}{v} \right)^2 \cdot a}{r} \right] + \left[\frac{m_{Pcar\_2} \cdot \left(\frac{v_{P\_2}}{v} \right)^2 \cdot a}{r} \right] - \frac{FR_{car}}{2} \quad \text{(C.3)}$$

$$T_2 = \frac{M_{cwt}}{2} \cdot (g_n - a) - \left[\frac{m_{Pcwt\_1} \cdot \left(\frac{v_{P\_1}}{v} \right)^2 \cdot a}{r} \right] + \frac{FR_{cwt}}{2} \quad \text{(C.4)}$$

b) Empty car at highest landing

$$T_1 = \frac{M_{cwt}}{2} \cdot (g_n + a) + M_{SRcwt}(g_n + 2 \cdot a) + \left[\frac{m_{Pcwt\_1} \cdot \left(\frac{v_{P\_1}}{v} \right)^2 \cdot a}{r} \right] - \frac{FR_{ctw}}{2} \quad \text{(C.5)}$$

$$T_2 = \frac{(P+M_{Trav})}{2} \cdot (g_n - a) - \left[\frac{m_{Pcar\_1} \cdot \left(\frac{v_{P\_1}}{v} \right)^2 \cdot a}{r} \right] - \left[\frac{m_{Pcar\_2} \cdot \left(\frac{v_{P\_2}}{v} \right)^2 \cdot a}{r} \right] + \frac{FR_{car}}{2} \quad \text{(C.6)}$$

Counterweight stalled condition

Empty car at highest position, no friction considered.

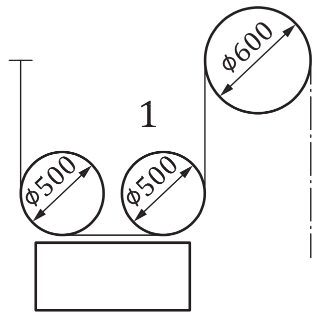
$$T_1 = \frac{(P+M_{Trav})}{2} \cdot g_n \quad \text{(C.7)}$$

$$T_2 = M_{SRcwt} \cdot g_n \quad \text{(C.8)}$$

Annex D
(informative)

Equivalent number of pulleys, N_{equiv} — Examples

NOTE For suspension means other than steel wire ropes in steel/cast iron traction sheaves, these examples are not applicable.



Key

1 car side

Figure D.1 — 2 to 1 roping — V grooves

γ		= 40°
$N_{equiv(t)}$		= 10 (as per Table 2)
K_p	$= (600 / 500)^4$	= 2,07
$N_{equiv(p)}$	$= 2{,}07 \times (2 + 0)$	= 4,14
N_{equiv}	= 10 + 4,14	= 14,14

NOTE No reversed bend because of moving pulley.

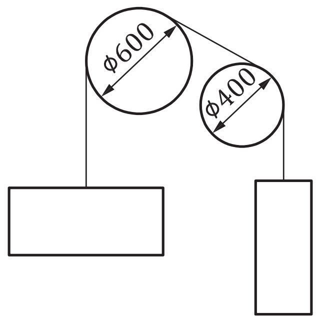


Figure D.2 — 1 to 1 roping — Undercut U grooves

β	= 90°	
$N_{equiv(t)}$	= 5 (as per Table 2)	
K_p	= $(600 / 400)^4$	= 5,06
$N_{equiv(p)}$	= 5,06×(1 + 0)	= 5,06
N_{equiv}	= 5 + 5,06	= 10,06

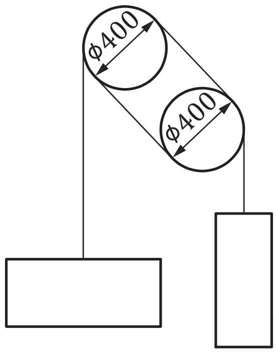


Figure D.3 — 1 to 1 roping (double wrap) — U grooves

$N_{equiv(t)}$	= 1 + 1	=2
K_p		= 1
$N_{equiv(p)}$	= 1×(1 + 1)	= 2
N_{equiv}	= 2 + 2	= 4

NOTE The rope passes traction sheave and secondary sheave 2 times.

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