
**Lifts for the transport of persons and
goods —**

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

Elévateurs pour le transport de personnes et d'objets —

*Partie 2: Règles de conception, calculs, examens et essais des
composants pour élévateurs*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 178, *Lifts, escalators, passenger conveyors*.

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.

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

Introduction

The content of this document was already published in EN 81-50:2014. This document contains only editorial changes and update of references.

The object of this document is to define safety rules related to lifts with a view to safeguarding persons and objects against the risk of accidents associated with the use, maintenance and emergency operations of lifts.

Reference is made to the respective introductions of the standards (e.g. ISO 8100-1:2019) calling for the use of this document with regard to persons and objects to be safeguarded, assumptions, principles, etc.

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Lifts for the transport of persons and goods —

Part 2:

Design rules, calculations, examinations and tests of lift components

1 Scope

This document specifies the design rules, calculations, examinations and tests of lift components which are referred to by other standards used for the design of passenger lifts, goods passenger lifts, goods only lifts, and other similar types of lifting appliances.

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 4344, *Steel wire ropes for lifts — Minimum requirements*

ISO 8100-1:2019, *Safety rules for the construction and installation of lifts — Lifts for the transport of persons and goods — Passenger and goods passenger lifts*

ISO/TS 8100-3, *Requirements from Other Standards (ASME A17.1/CSA B44 and JIS A 4307-1/ JIS A 4307-2) not included in ISO 8100-1 or ISO 8100-2*

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

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

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests*

IEC 60947-4-1, *Low-voltage switchgear and control gear — Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters*

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

EN 10025 (all parts), *Hot rolled products of non-alloy structural steels — Technical delivery conditions*

EN 12385-5, *Steel wire ropes — Safety — Part 5: Stranded ropes for lifts*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

— IEC Electropedia: available at <http://www.electropedia.org/>

3.1 approved body

organization or manufacturer, operating an approved full quality assurance system to undertake testing of *safety components* (3.2)

3.2 safety component

component provided to fulfil a safety function when in use

3.3 type examination certificate

document issued by an *approved body* (3.1) carrying out a type-examination in which it certifies that the product example under consideration complies with the provisions applicable to it

4 List of significant hazards

This clause contains all the significant hazards, hazardous situations and events, as far as they are dealt with in this document, identified by risk assessment as significant for this type of machinery, and they require action to eliminate or reduce the risk (see [Table 1](#)).

Table 1 — List of significant hazards

No.	Hazards as listed in ISO 12100:2010, Annex B	Relevant clauses
1	Mechanical hazards due to:	
	Acceleration, deceleration (kinetic energy)	5.3 ; 5.4 ; 5.5 ; 5.7 ; 5.8 ; 5.9
	Approach of a moving element to a fixed part	5.2
	Elastic elements	5.10 ; 5.11 ; 5.12 ; 5.13
	Falling objects	5.3 ; 5.4 ; 5.5 ; 5.9
	Gravity (stored energy)	5.3 ; 5.4 ; 5.5 ; 5.9
	Height from the ground	5.3 ; 5.4 ; 5.5 ; 5.9
	High pressure	5.13
	Moving elements	5.2 ; 5.3 ; 5.4 ; 5.5 ; 5.6 ; 5.7 ; 5.8 ; 5.9 ; 5.10 ; 5.11 ; 5.12 ; 5.13 ; 5.14 ; 5.15 ; 5.16
	Rotating elements	5.4 ; 5.11 ; 5.12
	Stability	5.10 ; 5.11 ; 5.12 ; 5.13 ; 5.14
Strength	5.10 ; 5.11 ; 5.12 ; 5.13 ; 5.14	
2	Electrical hazards	
	Arc	5.2 ; 5.4 ; 5.6 ; 5.7 ; 5.8 ; 5.15 ; 5.16
	Electrostatic phenomena	5.2 ; 5.4 ; 5.6 ; 5.7 ; 5.8 ; 5.15 ; 5.16
	Live parts	5.2 ; 5.4 ; 5.6 ; 5.7 ; 5.8 ; 5.15 ; 5.16
	Not enough distance to live parts under high voltage	5.2 ; 5.4 ; 5.6 ; 5.7 ; 5.8 ; 5.15 ; 5.16
	Overload	5.2 ; 5.4 ; 5.6 ; 5.7 ; 5.8 ; 5.15 ; 5.16
	Parts which have become live under faulty conditions	5.2 ; 5.4 ; 5.6 ; 5.7 ; 5.8 ; 5.15 ; 5.16
	Short-circuit	5.2 ; 5.4 ; 5.6 ; 5.7 ; 5.8 ; 5.15 ; 5.16

Table 1 (continued)

No.	Hazards as listed in ISO 12100:2010, Annex B	Relevant clauses
6	Hazards generated by radiation	
	Low frequency electromagnetic radiation	5.6 ; 5.15 ; 5.16
	Radio frequency electromagnetic radiation	5.6 ; 5.15 ; 5.16
9	Hazards associated with the environment in which the machine is used	5.2 ; 5.3 ; 5.4 ; 5.5 ; 5.6 ; 5.7 ; 5.8 ; 5.9 ; 5.10 ; 5.11 ; 5.12 ; 5.13 ; 5.14 ; 5.15 ; 5.16

5 Design rules, calculations, examinations and tests

5.1 General provisions for type examinations of safety components

5.1.1 Object and extent of the tests

The safety component/device is submitted to a test procedure to verify that insofar as construction and operation are concerned, it conforms to the requirements imposed by this document. It shall be checked, in particular, that the mechanical, electrical and electronic components of the device are properly rated and that, in the course of time, the device does not lose its effectiveness, particularly through wear or aging. If the safety component is needed to satisfy particular requirements (waterproof, dust proof or explosion proof construction), supplementary examinations and/or tests under appropriate criteria shall be made.

5.1.2 General provisions

5.1.2.1 For the purposes of this document, it is assumed that the laboratory undertakes both the testing and the certification as an approved body. An approved body may be that of a manufacturer operating an approved full quality assurance system. In certain cases, the test laboratory and the body approved for the issue of type examination certificates may be separate. In these cases, the administrative procedures can differ from those described in this document.

5.1.2.2 The application for type examination shall be made by the manufacturer of the component, or their authorized representative, and shall be addressed to an approved test laboratory.

5.1.2.3 The dispatch of samples for examination shall be made by agreement between the laboratory and the applicant.

5.1.2.4 The applicant may attend the tests.

5.1.2.5 If the laboratory entrusted with the complete examination of one of the components requiring the supply of a type examination certificate has no appropriate means available for certain tests or examinations, it may, under its responsibility, have these made by other laboratories with the agreement of the applicant.

5.1.2.6 Unless specified otherwise, 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) recording equipment shall be capable of detecting signals, which vary in time of 0,01 s;
- f) $\pm 2,5$ % for flow rate;
- g) ± 1 % for pressure, P , below 200 kPa;
- h) ± 5 % for pressure, P , above 200 kPa.

5.2 Type examination of landing and car door locking devices

5.2.1 General provisions

5.2.1.1 Field of application

These procedures are applicable to locking devices for landing and car doors. It is understood that each component taking part in the locking of doors and in the checking of the locking forms part of the locking device.

5.2.1.2 Documents to be submitted

5.2.1.2.1 Schematic arrangement drawing with description of operation

This drawing shall clearly show all the details relating to the operation and the safety of the locking device, including:

- a) the operation of the device in normal service, showing the effective engagement of the locking elements and the point at which the electrical safety device operates;
- b) the operation of the device for mechanical checking of the locking position if this device exists;
- c) the control and operation of the emergency unlocking device;
- d) the type (A.C. and/or D.C.), rated voltage and rated current.

5.2.1.2.2 Assembly drawing with key

This drawing shall show all parts important to the operation of the locking device, in particular those required to conform to the requirements of this document. A key shall indicate the list of the principal parts, the type of materials used, and the characteristics of the fixing elements.

5.2.1.3 Test samples

One door-locking device shall be submitted to the laboratory.

If the test is carried out on a prototype, it shall be repeated later on a production model.

If the test of the locking device is only possible when the device is mounted in the corresponding door, the device shall be mounted on a complete door in working order. However, the door dimensions may be reduced by comparison with a production model, on the condition that it does not falsify the test results.

5.2.2 Examination and tests

5.2.2.1 Examination of operation

This examination aims to verify that:

- the mechanical and electrical components of the locking device are operating correctly with respect to safety, and in conformity with:
 - the requirements of this document;
 - the standard calling for this locking device; and
- the device is in conformity with the particulars provided in the application.

In particular, it shall be verified that:

- a) there is at least 7 mm engagement of the locking elements before the electric safety device operates;
- b) it is not possible to operate the lift from positions normally accessible to persons with a door open or unlocked, after one single action not forming part of the normal operation.

5.2.2.2 Mechanical tests

5.2.2.2.1 General

These tests have the purpose of verifying the strength of the mechanical locking components and the electrical components.

The sample of the locking device in its normal operating position is controlled by the devices normally used to operate it.

The sample shall be lubricated in accordance with the requirements of the manufacturer of the locking device.

When there are several possible means of control and positions of operation, the endurance test shall be made in the arrangement which is regarded as the most unfavourable from the point of view of the forces on the components.

The number of complete cycles of operation and the travel of the locking components shall be registered by mechanical or electrical counters.

5.2.2.2.2 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.

The driving of the device shall be smooth, without shocks, and at a rate of 60 (± 10 %) cycles per minute.

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

If the locking device is provided with a mechanical checking device for the locking pin or the position of the locking element, this device shall be submitted to an endurance test of 100 000 (± 1 %) cycles.

The driving of the device shall be smooth, without shocks, and at a rate of 60 (± 10 %) cycles per minute.

5.2.2.2.3 Static test

For locking devices intended for hinged doors, a test shall be made consisting of the application over a total period of 300 s of a static force, increasing progressively to a value of 3 000 N.

This force shall be applied in the opening direction of the door and in a position corresponding as far as possible to that which can be applied when a user attempts to open the door. The force applied shall be 1 000 N in the case of a locking device intended for sliding doors.

5.2.2.2.4 Dynamic test

The locking device, in the locked position, shall be submitted to a shock test in the opening direction of the door.

The shock shall correspond to the impact of a rigid mass of 4 kg falling in free fall from a height of 0,50 m.

5.2.2.3 Criteria for the mechanical tests

After the endurance test (5.2.2.2.2), the static test (5.2.2.2.3) and the dynamic test (5.2.2.2.4), there shall not be any wear, deformation or breakage, which could adversely affect safety.

5.2.2.4 Electrical test

5.2.2.4.1 Endurance test of contacts

This test is included in the endurance test laid down in 5.2.2.2.2.

5.2.2.4.2 Test of ability to break circuit

5.2.2.4.2.1 General

This test shall be carried out after the endurance test. It shall check that the ability to break a live circuit is sufficient. This test shall be made in accordance with the procedure in IEC 60947-4-1 and IEC 60947-5-1. The values of current and rated voltage serving as a basis for the tests shall be those indicated by the manufacturer of the device.

If nothing is specified, the rated values shall be as follows:

- a) alternating current: 230 V, 2 A;
- b) direct current: 200 V, 2 A.

Unless indicated otherwise, the capacity to break circuit shall be examined for both A.C. and D.C. conditions.

The tests shall be carried out with the locking device in the working position. If several positions are possible, the test shall be made in the most unfavourable position.

The sample tested shall be provided with covers and electric wiring as used in normal service.

5.2.2.4.2.2 A.C. locking devices shall open and close an electric circuit under a voltage equal to 110 % of the rated voltage 50 times, at normal speed and at intervals of 5 s to 10 s. The contact shall remain closed for at least 0,5 s.

The circuit shall comprise a choke and a resistance in series. Its power factor shall be $0,7 \pm 0,05$ and the test current shall be 11 times the rated current indicated by the manufacturer of the device.

5.2.2.4.2.3 D.C. locking devices shall open and close an electric circuit under a voltage equal to 110 % of the rated voltage 20 times, at normal speed and at intervals of 5 s to 10 s. The contact shall remain closed for at least 0,5 s.

The circuit shall comprise a choke and a resistance 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 rated current indicated by the manufacturer of the device.

5.2.2.4.2.4 The tests are considered satisfactory if no tracking or arcing is produced and if no deterioration occurs which can adversely affect safety.

5.2.2.4.3 Test for resistance to leakage currents

This test shall be made in accordance with the procedure in IEC 60112. The electrodes shall be connected to a source providing an A.C. voltage which is sinusoidal at 175 V, 50 Hz.

5.2.2.4.4 Examination 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 8100-1:2019, 5.11.2.2.4).

5.2.2.4.5 Examination of the requirements appropriate to safety contacts and their accessibility

This examination shall be made taking account of the mounting position and the layout of the locking device, as appropriate.

5.2.3 Test particular to certain types of locking devices

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

According to the requirements laid down in the standards calling for the use of this document, the devices providing direct mechanical linkage between panels (e.g. ISO 8100-1:2019, 5.3.14.1) or indirect mechanical linkage (e.g. ISO 8100-1:2019, 5.3.14.2) are considered forming part of the locking device.

These devices shall be submitted to the tests mentioned in [5.2.2](#). The number of cycles per minute in such endurance tests shall be suited to the dimensions of the construction.

5.2.3.2 Flap type locking device for hinged door

If this device is provided with an electric safety device required to check the possible deformation of the flap, and if, after the static test envisaged in [5.2.2.2.3](#), there are any doubts on the strength of the device, the load shall be increased progressively until the safety device begins to open. No component of the locking device or of the door shall be damaged or permanently deformed by the load applied.

If, after the static test, the dimensions and construction leave no doubt as to its strength, it is not necessary to proceed to the endurance test on the flap.

5.2.4 Type examination certificate

The certificate shall indicate the following:

- a) information according to [Annex A](#);
- b) type and application of locking device;
- c) type (A.C. and/or D.C.) and values of the rated voltage and rated current;
- d) in the case of flap type door locking devices: the necessary force to actuate the electric safety device for checking the elastic deformation of the flap.

5.3 Type examination of safety gear

5.3.1 General provisions

The applicant shall state the range of use provided, i.e.:

- minimum and maximum masses;
- maximum rated speed and maximum tripping speed.

Detailed information shall be provided on the materials used, the type of guide rails and their surface condition (drawn, milled, ground).

The following documents shall be attached to the application:

- a) detailed and assembly drawings showing the construction, operation, materials used, dimensions and tolerances of the construction components;
- b) in the case of progressive safety gear, also a load diagram relating to elastic parts.

5.3.2 Instantaneous safety gear

5.3.2.1 Test samples

Two gripping assemblies with wedges or clamps and two lengths of guide rail shall be submitted to the laboratory.

The arrangement and the fixing details for the samples shall be determined by the laboratory 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.

5.3.2.2 Test

5.3.2.2.1 Method of test

The test shall be made using a press or similar device, which moves without abrupt speed change. 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.

5.3.2.2.2 Test procedure

The guide rail shall be moved through the safety gear.

Reference marks shall be traced onto the blocks in order to be able to measure their deformation.

The distance travelled shall be recorded as a function of the force.

After the test:

- a) the hardness of the block and the gripping element shall be compared with the original values quoted by the applicant. Other analyses may be carried out in special cases;
- b) if there is no fracture, deformations and other changes shall be examined (for example, cracks, deformations or wear of the gripping elements, appearance of the rubbed surfaces);

- c) if necessary, photographs shall be taken of the block, the gripping elements and the guide rail for evidence of deformations or fractures.

5.3.2.2.3 Documents

5.3.2.2.3.1 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 other shall show the deformation of the block. It shall be done in such a way that it can be related to the first chart.

5.3.2.2.3.2 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.

5.3.2.3 Determination of the permissible mass

5.3.2.3.1 Energy absorbed by the safety gear

A distance of free fall, calculated with reference to the maximum tripping speed of the overspeed governor fixed in the requirements laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2019, 5.6.2.2.1.2), shall be adopted.

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

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

where

g_n is the standard acceleration of free fall in metres per square second;

v_1 is the tripping speed of overspeed governor 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 [\(3\)](#):

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

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

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, compensating ropes/chains (if any), etc., in kilograms;
- Q is the rated load, in kilograms;
- $(P + Q)_1$ is the permissible mass, in kilograms.

5.3.2.3.2 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 [5.3.2.2.3.2 a\)](#);

2 is taken as the dividing safety coefficient.

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

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

where

K_1 is calculated by the integration of the area defined in [5.3.2.2.3.2 b\) 1\)](#);

2 is taken as the dividing safety coefficient.

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

where

K_2 is calculated by the integration of the area defined in [5.3.2.2.3.2 b\) 2\)](#);

3,5 is taken as the dividing safety coefficient.

5.3.3 Progressive safety gear

5.3.3.1 Statement and test sample

The applicant shall state for what mass in kilograms, and tripping speed in metres per second, of the overspeed governor the test will be carried out. If the safety gear needs to be certified for various

masses, the applicant shall specify them and indicate, in addition, whether the adjustment is by stages or continuous.

The applicant should choose the suspended mass in kilograms by dividing the anticipated braking force in newtons by 16, to aim at an average retardation of $0,6 g_n$.

A complete safety gear assembly, as agreed with the laboratory, together with the number of brake shoes necessary for all the tests, shall be placed at the disposal of the laboratory. The number of sets of brake shoes necessary for all the tests shall be attached. For the type of guide rail used, the length specified by the laboratory shall also be supplied.

5.3.3.2 Test

5.3.3.2.1 Method of test

5.3.3.2.1.1 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.

5.3.3.2.1.2 The following shall be determined:

- a) the average braking force;
- b) the greatest instantaneous braking force;
- c) the smallest instantaneous braking force.

5.3.3.2.2 Test procedure

5.3.3.2.2.1 Safety gear certified for a single mass

The laboratory shall carry out four tests with the mass $(P + Q)_1$. Between each test, the friction parts shall be allowed to return to their normal temperature.

During the tests, several identical sets of friction parts may be used.

However, one set of parts 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 overspeed governor for which the safety gear can be used.

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

For example, a rope may be used, the slack of which should be carefully calculated, fixed to a sleeve which can slide with friction over a fixed smooth rope. The friction effort should be the same as the effort applied to the operating rope by the governor attached to this safety gear.

5.3.3.2.2.2 Safety gear certified for different masses

Adjustment in stages or continuous adjustment.

Two series of tests shall be carried out for the maximum, and the minimum values applied for.

The applicant shall supply a formula, or a chart, showing the variation of the braking force as a function of a given parameter.

The laboratory shall verify by suitable means (in the absence of anything better, by a third series of tests for intermediary points) the validity of the supplied formula.

5.3.3.2.3 Determination of the braking force of the safety gear

5.3.3.2.3.1 Safety gear certified 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 $\pm 25\%$ 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.

It is accepted that, on an installation, an inadvertent operation of the safety gear would have every chance of occurring at an unused section of guide rail.

It is necessary to consider that if, by chance, this were not the case, the braking force would have a lower value until an unused portion of guide rail surface was reached. Hence, greater sliding than normal.

This is a further reason for not permitting any adjustment causing too small a retardation at the beginning.

5.3.3.2.3.2 Safety gear certified 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 [5.3.3.2.3.1](#) for the maximum and minimum values applied for.

5.3.3.2.4 Checking after the tests

After the tests, it shall be checked that:

- a) the hardness of the block and the gripping elements are compared with the original values submitted by the applicant;
- b) the deformations and modifications (for example, cracks, deformations or wear of the gripping elements, appearance of the rubbing surfaces) are checked;
- c) if necessary, the safety gear assembly, the gripping elements and the guide rails are photographed in order to reveal deformations or fractures.

5.3.3.3 Calculation of the permissible mass

5.3.3.3.1 Safety gear certified for a single mass

The permissible mass shall be calculated using [Formula \(7\)](#):

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

where

- F_B is the braking force in newtons, determined in accordance with [5.3.3.2.3](#);
- P is the masses of the empty car and components supported by the car, i.e. part of the travelling cable, compensating ropes/chains (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 $1 g_n$.

5.3.3.3.2 Safety gear certified for different masses

5.3.3.3.2.1 Adjustment in stages

The permissible mass shall be calculated for each adjustment as laid down in [5.3.3.3.1](#).

5.3.3.3.2.2 Continuous adjustment

The permissible mass shall be calculated as laid down in [5.3.3.3.1](#) for the maximum and minimum values applied for, and in accordance with the formula supplied for the intermediate adjustments.

5.3.3.4 Possible modification to the adjustments

If, during the tests, the values found differ by more than 20 % from those expected by the applicant, other tests may be made with their agreement, after modification of the adjustments, if necessary.

5.3.4 Comments

a) Applicable mass

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 [5.3.3.3](#) by $\pm 7,5$ %. It is accepted, in these conditions, that the requirements laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2019, 5.6.2.1) are met on the installation, notwithstanding the usual tolerances on the thickness of the guide rails, the surface conditions, etc.

- b) To evaluate the validity of welded parts, reference shall be made to standards on this subject.
- c) A check shall be made that the possible travel of the gripping elements is sufficient under the most unfavourable conditions (accumulation of manufacturing tolerances).
- d) The friction parts shall be suitably retained so that it can be certain that they will be in place at the moment of operation.

- e) In the case of a progressive type safety gear, it shall be checked that the travel of the components forming the spring is sufficient.

5.3.5 Type examination certificate

The certificate shall indicate the following:

- a) the information according to [Annex A](#);
- b) the type and application of safety gear;
- c) the limits of the permissible masses [see [5.3.4 a\)](#)];
- d) the tripping speed of the overspeed governor;
- e) the type of guide rail;
- f) the permissible thickness of the guide rail blade;
- g) the minimum width of the gripping areas;

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.

5.4 Type examination of overspeed governors

5.4.1 General provisions

The applicant shall indicate the following to the laboratory:

- a) the type (or the types) of safety gear which will be operated by the governor;
- b) the maximum and minimum rated speeds of lifts for which the governor may be used;
- c) the anticipated value of the tensile force produced in the rope by the overspeed governor when tripped.

Detailed and assembly drawings showing the construction, operation, materials used, dimensions and tolerances of the construction components shall be attached to the application.

5.4.2 Check on the characteristics of the overspeed governor

5.4.2.1 Test samples

The following shall be submitted to the laboratory:

- a) one overspeed governor;
- b) one rope of the type used for the overspeed governor, and the normal condition in which it should be installed. The length to be supplied is fixed by the laboratory;
- c) a tensioning pulley assembly of the type used for the overspeed governor.

5.4.2.2 Test

5.4.2.2.1 Method of test

The following shall be checked:

- a) the speed of tripping is within the range stated by the applicant;
- b) the operation of the electric safety device called for in the standards calling for the use of this document [e.g. ISO 8100-1:2019, 5.6.2.2.1.6 a)] causing the machine to stop, if this device is mounted on the overspeed governor;
- c) the operation of the electric safety device called for in the standards calling for the use of this document e.g. ISO 8100-1:2019, 5.6.2.2.1.6 b)] preventing all movement of the lift when the overspeed governor is tripped;
- d) the tensile force produced in the rope by the overspeed governor when tripped.

5.4.2.2.2 Test procedure

At least twenty tests shall be made in the speed range for tripping, corresponding to the range of rated speeds of the lift, indicated in [5.4.1 b\)](#).

The majority of tests should be made at the extreme values of the range.

The acceleration to reach the tripping speed of the overspeed governor should be as low as possible, in order to eliminate the effects of inertia.

In addition, a minimum of two tests shall be made with an acceleration between $0,9 g_n$ and $1 g_n$ in order to simulate a free fall situation and prove no deterioration of the governor has been caused.

5.4.2.2.3 Interpretation of the test results

In the course of twenty tests, the tripping speeds shall lie within the limits laid down for overspeed governors in the standards calling for the use of this document.

NOTE If the limits laid down are exceeded, an adjustment can be made by the manufacturer of the component and 20 new tests carried out.

In the course of the twenty tests, the operation of the devices for which the test is required in [5.4.2.2.1 b\)](#) and [c\)](#) shall occur within the limits laid down in the standards calling for the use of this document [e.g. ISO 8100-1:2019, 5.6.2.2.1.6 a) and 5.6.2.2.1.6 b)].

The tensile force in the rope produced by the overspeed governor when tripped shall be at least 300 N or any higher value specified by the applicant.

Unless otherwise requested by the manufacturer of the device and specified in the test report, the arc of engagement should be 180° .

In the case of a device which operates by gripping the rope, it should be checked that there is no permanent deformation of the rope.

5.4.3 Type examination certificate

The certificate shall indicate the following:

- a) the information according to [Annex A](#);
- b) the type and application of overspeed governor;
- c) the maximum and minimum rated speeds of the lift for which the overspeed governor may be used;

- d) the diameter of the rope to be used and its construction;
- e) in the case of an overspeed governor with traction pulley, the minimum tensioning force;
- f) the tensile force in the rope which can be produced by the overspeed governor when tripped.

5.5 Type examination of buffers

5.5.1 General provisions

The applicant shall state the range of use provided, i.e. maximum impact speed, minimum and maximum masses. The following shall be attached to the application:

- a) detailed and assembly drawings showing the construction, operation, materials used, dimensions and tolerances of the construction components. In the case of hydraulic buffers, the graduation (openings for the passage of the liquid), in particular, shall be shown as a function of the stroke of the buffer;
- b) specifications for the liquid used;
- c) information regarding environmental conditions for use (temperature, humidity, pollution, etc.) and of life cycle (aging, rejection criteria).

5.5.2 Samples to be submitted

The following shall be submitted to the laboratory:

- a) one buffer;
- b) in the case of hydraulic buffers, the necessary liquid sent separately.

5.5.3 Test

5.5.3.1 Energy dissipation buffers

5.5.3.1.1 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 at least from the moment of impact of the weights. The acceleration and the retardation shall be determined as a function of time throughout the movement of the weights.

5.5.3.1.2 Equipment to be used

5.5.3.1.2.1 Weights falling in free fall

The weights shall correspond, with the tolerances of [5.1.2.6](#), to the maximum and minimum masses. They shall be guided vertically with the minimum friction possible.

5.5.3.1.2.2 Recording equipment

The recording equipment shall be able to detect signals with the tolerances of [5.1.2.6](#). The measuring chain, including the recording device for the recording of measured values as a function of time, shall be designed with a system frequency of at least 1 000 Hz.

5.5.3.1.2.3 Measurement of speed

The speed shall be recorded at least from the moment of impact of the weights on the buffer or throughout the travel of the weights, with the tolerances of [5.1.2.6](#).

5.5.3.1.2.4 Measurement of the retardation

If there is a device for measuring retardation (see [5.5.3.1.1](#)), it shall be placed as close as possible to the axis of the buffer, and shall be capable of measurement with the tolerances of [5.1.2.6](#).

5.5.3.1.2.5 Measurement of time

Time pulses of duration of 0,01 s shall be recorded and measured with the tolerances of [5.1.2.6](#).

5.5.3.1.3 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 [5.1.2.6](#).

5.5.3.1.4 Mounting of the buffer

The buffer shall be placed and fixed in the same manner as in normal service.

5.5.3.1.5 Filling of the buffer

The buffer shall be filled up to the mark indicated, following the instructions of the component manufacturer.

5.5.3.1.6 Checks**5.5.3.1.6.1 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 stipulated in the application.

The retardation shall conform to the requirements of the standard calling for this device (e.g. ISO 8100-1:2019, 5.8.2.2.3).

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/s².

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.

5.5.3.1.6.2 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.

5.5.3.1.6.3 Checking of the liquid losses

The level of liquid shall be checked after having made the two retardation tests required in [5.5.3.1.6.1](#). After an interval of 30 min, the level of liquid shall again be sufficient to ensure normal operation of the buffer.

5.5.3.1.6.4 Checking of the condition of the buffer after tests

After the two retardation tests required in [5.5.3.1.6.1](#), no part of the buffer shall show any permanent deformation, or be damaged, so that its condition shall guarantee normal operation.

5.5.3.1.7 Procedure in the case of tests failing the requirements

When the test results are not satisfactory with the minimum and maximum masses appearing in the application, the laboratory may, in agreement with the applicant, establish the acceptable limits.

5.5.3.2 Energy accumulation buffers with non-linear characteristics

5.5.3.2.1 Test procedure

The buffer shall be tested with the aid of masses 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 masses shall correspond to the maximum and minimum masses called for. They shall be guided vertically with a minimum of friction possible, so that at least $0,9 g_n$ is reached at the moment of impact.

5.5.3.2.2 Equipment to be used

The equipment shall correspond to [5.5.3.1.2](#).

5.5.3.2.3 Ambient temperature

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

5.5.3.2.4 Mounting of the buffer

The buffer shall be placed and fixed in the same manner as in normal service.

5.5.3.2.5 Number of tests

Three tests shall be made with the maximum mass and 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 the applicant, equal to 50 % of the real height of the buffer, shall not vary by more than 5 %. In the tests with minimum mass, this shall be observed in analogy.

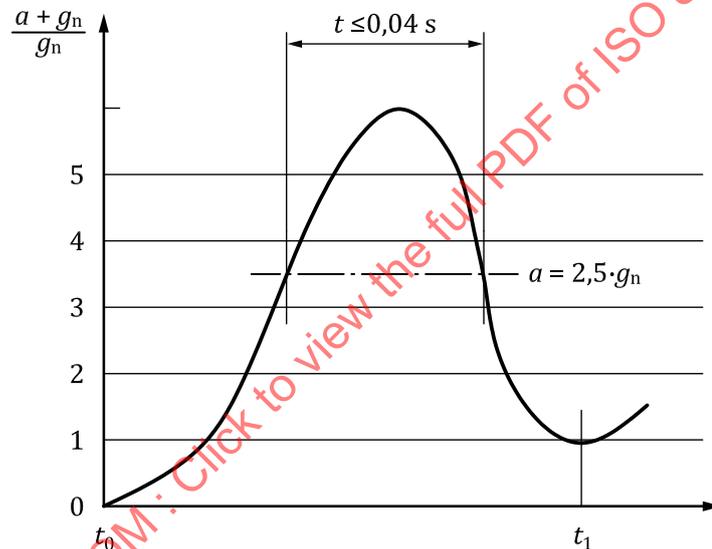
Within 30 min before the test, the buffer shall be once loaded, either statically or dynamically, in order to prevent further settlement and deviations during the test.

5.5.3.2.6 Checks

5.5.3.2.6.1 Checking of retardation

The retardation “a” (e.g. ISO 8100-1:2019, 5.8.2.1.2.1), shall conform to the following requirements:

- 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.
- Peaks 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 8100-1:2019, 5.8.2.1.2.1 b)]
- The maximum peak retardation shall not exceed the maximum as required in the standard calling for this device [e.g. ISO 8100-1, 5.8.2.1.2.1 e)].
- The return speed shall not exceed the maximum as required in the standard calling for this device.



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

5.5.3.2.6.2 Checking of the condition of the buffer after tests

After the tests with the maximum mass, no parts of the buffer shall show any permanent deformation or be damaged, so that its condition shall guarantee normal operation.

5.5.3.2.7 Procedure in the case of tests failing the requirements

When the test results are not satisfactory with the minimum and maximum masses appearing in the application, the laboratory may, in agreement with the applicant, establish the acceptable limits.

5.5.4 Type examination certificate

The certificate shall indicate the following:

- a) the information according to [Annex A](#);
- b) the type and application of buffer;
- c) the dimensions of the buffer;
- d) the maximum impact speed;
- e) the maximum mass;
- f) the minimum mass;
- g) the kind of fixation;
- h) the specification of the liquid in the case of hydraulic buffers;
- i) the environmental conditions for use according to instructions of the manufacturer (temperature, humidity, pollution, etc.).

5.6 Type examination of safety circuits containing electronic components and/or programmable electronic systems (PESSRAL)

5.6.1 General provisions

5.6.1.1 General

For safety circuits containing electronic components, laboratory tests are necessary because practical checks on site, by inspectors, are impossible.

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

5.6.1.2 Safety circuits containing electronic components

The applicant shall indicate to the laboratory:

- a) identification on the 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 board;
- h) method of failure analysis employed and documented results.

5.6.1.3 Safety circuits based on programmable electronic systems

In addition to [5.6.1.2](#), the following documentation shall be provided:

- a) documents and descriptions relating to the measures listed in [Annex B](#);

- 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.

5.6.2 Test samples

The following shall be submitted to the laboratory:

- a) one printed circuit board;
- b) one bare printed circuit board (without components).

5.6.3 Tests

5.6.3.1 Mechanical tests

5.6.3.1.1 General

During the tests, the tested object (printed circuit) shall be kept under operation. During and after the tests, no unsafe operation and condition shall appear within the safety circuit.

5.6.3.1.2 Vibration

Transmitter elements of safety circuits shall withstand the requirements of:

- a) IEC 60068-2-6:2007, Table C.2: 20 sweep cycles in each axis, at amplitude 0,35 mm, and in the frequency range 10 Hz–55 Hz; and
- b) IEC 60068-2-27:2008, Table 1: the combination of:
 - peak acceleration 294 m/s² or 30 g_n ;
 - corresponding duration of pulse 11 ms; and
 - corresponding velocity change 2,1 m/s half sine.

NOTE Where shock absorbers for transmitter elements are fitted, they are considered as part of the transmitter elements.

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

5.6.3.1.3 Bumping (IEC 60068-2-27)

5.6.3.1.3.1 General

Bumping tests shall simulate the cases when printed circuits fall, introducing the risk of rupture of components and unsafe situations.

Tests are divided into partial shockings and continuous shockings.

The tests object shall satisfy the following minimum requirements:

5.6.3.1.3.2 Partial shocking

- a) Shocking shapes: half-sinus;
- b) Amplitude of acceleration: 15 g ;

- c) Duration of shock: 11 ms.

5.6.3.1.3.3 Continuous shocking

- a) Amplitude of acceleration: 10 *g*;
- b) Duration of shock: 16 ms;
- c) 1) Number of shocks: 1 000 ± 10;
2) Shock frequency: 2/s.

5.6.3.2 Temperature tests (IEC 60068-2-14)

Operating ambient limits: 0 °C, +65 °C (the ambient temperature is of the safety device).

Test conditions:

- the printed circuit board shall be in operational position;
- the printed circuit board shall be supplied with rated operational voltage;
- the safety device shall operate during, and after the test. If the printed circuits board includes components other than safety circuits, they also shall operate during the test (their failure is not considered);
- tests shall be carried out for minimum and maximum temperature (0 °C, +65 °C). Tests shall last a minimum of four hours;
- if the printed circuit board is designed to operate within wider temperature limits, it shall be tested for these values.

5.6.3.3 Failure analysis of electric safety circuits

The failure analysis document as required by the relevant standard calling for the use of this document shall be validated. (e.g. ISO 8100-1:2019, 5.11.2.3).

5.6.3.4 Functional and safety test of PESSRAL

In addition to the verification of the measures defined in [Tables B.1](#) to [B.6](#), 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 all measures of [Tables B.1](#) and [B.2](#) and the measures chosen, for example, from [Table B.7](#) by using fault insertion testing (based on IEC 61508-2 and IEC 61508-7).

5.6.4 Type examination certificate

The certificate shall indicate:

- a) the information according to [Annex A](#);
- b) the type and application of the circuitry;
- c) the design for pollution degree according to IEC 60664-1;
- d) the operating voltages;
- e) the distances between the safety circuits and the rest of the control circuits on the board.

NOTE Other tests like humidity test, climatic shock test, etc., are not subject for tests because of the normal environmental situation where lifts are operating.

5.7 Type examination of ascending car overspeed protection means

5.7.1 General provisions

5.7.1.1 This specification applies to:

- ascending car overspeed protection means which are not using overspeed governors, or
- programmable electronic systems which are subject to verifications according to 5.4 and 5.6.

Test results of safety gears which have been verified according to 5.3 may be taken into account for verification of permissible application range.

5.7.1.2 The applicant shall state the range of use provided:

- a) minimum and maximum masses, or torque;
- b) minimum (if applicable) and maximum rated speed;
- c) use in installations with compensation means.

5.7.1.3 The following documents shall be attached to the applications:

- a) detailed and assembly drawings showing the construction, operation, materials used, dimensions and tolerances of the construction components;
- b) if necessary, also a load diagram relating to elastic parts;
- c) 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.).

5.7.2 Statement and test sample

5.7.2.1 The applicant shall state for what mass (in kilograms) and tripping speed (in meters per second) the test will be carried out. If the device needs to be certified for various masses, the applicant shall specify them and indicate, in addition, whether the adjustment is by stages or continuous.

5.7.2.2 As defined between the applicant and the laboratory, either:

- a complete assembly consisting of both elements, braking device and speed monitoring device; or
- only that device which was not subject to verifications according to 5.3, 5.4 and 5.6;

shall be provided by the applicant.

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 supplied with the dimensions agreed with the laboratory.

5.7.3 Test

5.7.3.1 Test method

The test method shall be defined between the applicant and the test laboratory, depending on the device and its function to achieve a realistic function of the system. Measurements shall be made of:

- a) the acceleration and speed;

- b) the braking distance;
- c) the retardation.

Measurements shall be recorded as a function of the time.

5.7.3.2 Test procedure

5.7.3.2.1 General

At least twenty tests shall be made with the speed monitoring element in the speed range for tripping, corresponding to the range of rated speeds of the lift indicated in [5.7.1.2](#).

The acceleration of the mass to reach the tripping speed should be as low as possible, in order to eliminate the effects of inertia.

5.7.3.2.2 Device certified for a single mass

The laboratory shall carry out four tests with the system mass representing an empty car.

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

During the tests, several identical sets of friction parts may be used.

However, one set of parts 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 test shall be made at the maximum tripping speed for which the device may be used.

5.7.3.2.3 Device certified for different masses

Adjustment in stages or continuous adjustment.

A series of tests shall be carried out for the maximum value applied, and a series for the minimum value. The applicant shall supply a formula, or a chart, showing the variation of the braking force as a function of a given parameter.

The laboratory shall verify by suitable means (in the absence of anything better, by a third series of tests for intermediary points) the validity of the supplied formula.

5.7.3.2.4 Overspeed monitoring device

5.7.3.2.4.1 Test procedure

At least twenty tests shall be made in the speed range for tripping without applying the braking device.

The majority of tests shall be made at the extreme values of the range.

5.7.3.2.4.2 Interpretation of the test results

In the course of twenty tests, the tripping speeds shall lie within the limits called for in the standards calling for the use of this document (e.g. ISO 8100-1:2019, 5.6.6.1).

5.7.3.3 Checking after the tests

After the test:

- a) the hardness of the gripping element shall be compared with the original values quoted by the applicant;
- b) if there is no fracture, deformations and other changes shall be examined (for example, cracks, deformations or wear of the gripping elements, appearance of the rubbing surfaces);
- c) if necessary, photographs shall be taken of the gripping elements and the parts on which the device acts for evidence of deformations or fractures;
- d) it shall be checked that the retardation with the minimum mass has not exceeded $1g_n$.

5.7.4 Possible modification to the adjustments

If, during the tests, the values found differ by more than 20 % from those expected by the applicant, other tests may be made with his agreement, after modification of the adjustments if necessary.

5.7.5 Test report

In order to achieve reproducibility, the type examination shall be recorded in all details, such as:

- the method of test defined between applicant and laboratory;
- the description of the testing arrangement;
- the location of the device to be tested in the testing arrangement;
- the number of tests carried out;
- the record of measured values;
- the report of observations during the test;
- the evaluation of the test results to show compliance with the requirements.

5.7.6 Type examination certificate

The certificate shall indicate:

- a) the information according to [Annex A](#);
- b) the type and application of overspeed protection means;
- c) the limits of the permissible masses;
- d) the tripping speed range of the overspeed monitoring device;
- e) the type of parts on which the braking elements act.

5.8 Type examination of unintended car movement protection means

5.8.1 General provisions

The unintended car movement protection means shall be type tested as a complete system. Alternatively, the subsystems for detection, activation and stopping may be submitted to an individual type examination. The type examination of subsystems shall define interface conditions and the relevant parameters of each subsystem if integrated in a complete system.

The applicant shall state the key parameters for use of the system or subsystem that form part of the type examination:

- minimum and maximum masses;
- minimum and maximum force or torque or fluid pressure, if applicable;
- individual response times of detector, control circuit and stopping element(s);
- highest speed anticipated before deceleration occurs (see Note 1);
- distance from the floor at which the detector device will be installed;
- test speed(s) (see Note 2);
- limits of temperature and humidity of the design and any other relevant information agreed between the applicant and test laboratory.

NOTE 1 As an example and indication, for traction lifts, where the natural acceleration is $1,5 \text{ m/s}^2$ and without any torque contribution from the motor, the maximum speed attainable would be in the magnitude of 2 m/s . This is based on the speed attained at start of deceleration e.g. being the result of a “natural” acceleration of $1,5 \text{ m/s}^2$ 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.

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 $2,5 \text{ m/s}^2$.

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

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 8100-1:2019, 5.6.7.5).

The following documents shall be attached to the application:

- a) Detailed and assembly drawings showing the construction, operation, dimensions and tolerances of the components;
- b) If necessary, also a load diagram relating to elastic parts;
- c) 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.).

5.8.2 Statement and test sample

5.8.2.1 The applicant shall state for what duty the means is intended.

5.8.2.2 Test samples shall be supplied as agreed between the applicant and the laboratory consisting of, as appropriate, a 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 supplied with the dimensions specified by the laboratory.

5.8.3 Test

5.8.3.1 Test method

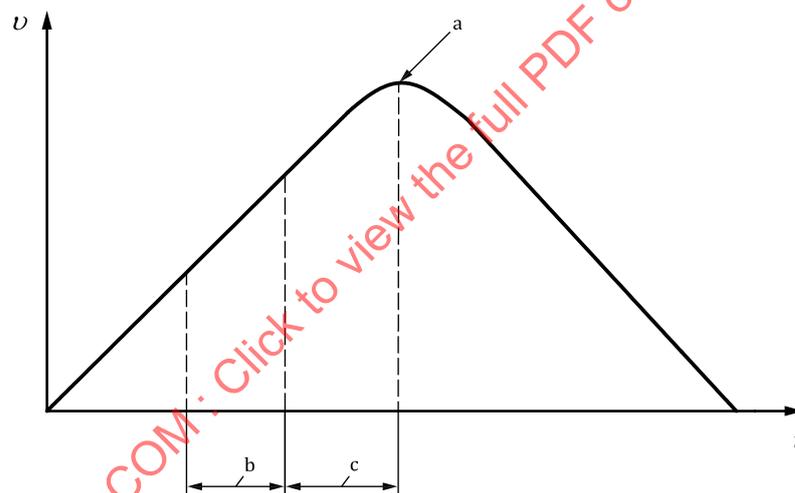
The test method shall be defined between the applicant and the test laboratory, depending on the device and its function, to achieve a realistic operation of the system.

Measurements shall be made of:

- the stopping distance;
- the average 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

- v speed in meters 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

5.8.3.2 Test procedure

5.8.3.2.1 General

Twenty tests shall be made on the stopping element with:

- no result outside the specification;
- each result within $\pm 20\%$ of the average value.

Average value shall be stated on the certificate.

5.8.3.2.2 Device certified for a single mass or torque or fluid pressure

The laboratory shall carry out:

- 10 tests with the system mass or torque or fluid pressure representing an empty car in the upward direction; and
- 10 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 their normal temperature.

During the tests, several identical sets of friction parts may be used. However, one set of parts shall be capable of 5 tests minimum.

5.8.3.2.3 Device certified for different masses or torques or fluid pressures

A series of tests shall be carried out for the maximum value applied for and a series for the minimum value.

The applicant shall supply a formula or a chart, showing the calculated variation of the braking force or torque or fluid pressure as a function of a given adjustment. The results is expressed in distance travelled.

The laboratory shall verify the validity of the formula or chart.

5.8.3.2.4 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.

5.8.3.2.5 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.

5.8.3.3 Checks after the test

After the test:

- a) the mechanical characteristics of the stopping element(s) shall be compared with the original values quoted by the applicant. Other analyses may be carried out in special cases;
- b) it shall be checked that there are no fractures, deformations or any other changes (e.g. cracks, deformations or wear of the gripping elements, appearance of the rubbing surfaces);
- c) if necessary, photographs shall be taken of the gripping elements and the parts on which the device acts for evidence of deformations or fractures.

5.8.4 Possible modification to the adjustments

If, during the tests, the values found differ by more than 20 % from those expected by the applicant, another series of tests may be made with his agreement, after modification of the adjustments, if necessary.

5.8.5 Test report

In order to achieve reproducibility, the type examination shall be recorded in all details, such as:

- the method of test defined between applicant and laboratory;
- the description of the testing arrangement;
- the location of the device to be used when installed in the testing arrangement;
- the number of tests carried out;
- the record of all measured values;
- the report of observations during the test;
- the evaluation of the test results to show compliance with the requirements.

5.8.6 Type examination certificate

The certificate shall indicate:

- a) the information according to [Annex A](#);
- b) the type and application of the unintended car movement protection system/subsystem;
- c) the limits of the key parameters (as agreed between the laboratory and the manufacturer);
- d) the test speed with relevant parameters for final inspection use;
- e) the type of parts on which the stopping elements act;
- f) the combination of “detecting” device and “stopping” element of the means in the case of complete systems;
- g) the interface conditions in case of subsystems.

5.9 Type examination of rupture valve/one-way restrictor

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

5.9.1 General provisions

5.9.1.1 General

The applicant shall state:

- a) the range of:
 - 1) flow;
 - 2) pressure;
 - 3) viscosity;
 - 4) ambient temperature; and
 - b) the method of mounting;
- of the rupture valve to be type examined.

Details and assembly drawings showing the construction, operation, adjustment, materials, dimensions and tolerances of the rupture valve and the construction components shall be attached to the application.

5.9.1.2 Samples to be submitted

The following shall be submitted to the laboratory:

- a) one rupture valve;
- b) a list of liquids which may be used together with the rupture valve, or a sufficient amount of special liquid to be used;
- c) if necessary, adaptation means to the test facilities of the laboratory.

5.9.1.3 Test

5.9.1.3.1 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 before¹⁾ and behind the rupture valve can be recorded;
- d) means to change the ambient temperature of the rupture valve and the viscosity of the hydraulic liquid 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.

5.9.1.3.2 Measuring instruments

The measuring instruments shall have accuracy according to [5.1.2.6](#).

5.9.1.4 Test procedure

5.9.1.4.1 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.

5.9.1.4.2 Simulation of a total piping failure

5.9.1.4.2.1 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 tolerances of the closing valve shall be taken into account within the stated range of:

- a) flow;
- b) viscosity;

1) "Before the rupture valve" means between the cylinder and the rupture valve.

- c) pressure;
- d) ambient temperature.

This can be achieved by 2 test series with:

- maximum pressure, maximum ambient temperature, minimum adjustable flow and minimum viscosity;
- minimum pressure, minimum ambient temperature, maximum adjustable flow and maximum viscosity.

In each test series, at least 10 tests shall be carried out to evaluate the tolerances of operation of the rupture valve in these conditions.

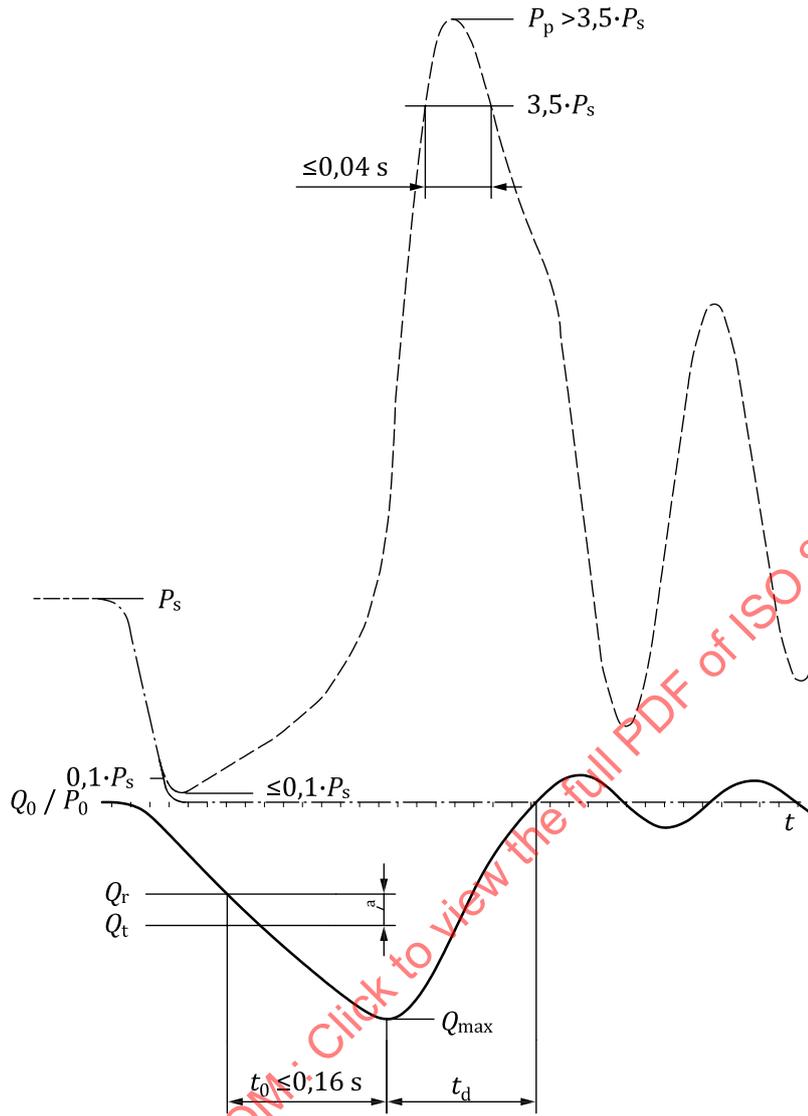
5.9.1.4.2.2 During the tests, the relation between:

- 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](#).

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Key

- P_0 pressure before test
- P_p pressure peak
- P_s pressure static
- 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

5.9.1.4.3 Resistance against pressure

Showing the resistance of the rupture valve against pressure, it shall be submitted to a pressure test with 5 times the maximum pressure over 2 min.

5.9.1.5 Interpretation of the tests

5.9.1.5.1 Closing operation

The rupture valve fulfils the requirements of this document if the curves recorded according to [5.9.1.4.2](#) 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 $3,5 \cdot P_S$, 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 + 0,30 m/s.

5.9.1.5.2 Pressure resistance

The rupture valve fulfils the requirements of the standard if, after the pressure test according to [5.9.1.4.3](#), it shows no permanent damage.

5.9.1.5.3 Readjustment

If the limits of flow decrease or pressure peaks are exceeded, the manufacturer may modify the adjustment of the rupture valve. After that, another series of tests shall be carried out.

5.9.1.6 Type examination certificate

The certificate shall indicate:

- a) the information according to [Annex A](#);
- b) the type and application of the rupture valve;
- c) 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.

The certificate shall be accompanied with a graph, according to [Figure 3](#), showing the relationship between the flow of hydraulic fluid and pressure from which Q_{\max} and t_d can be obtained.

5.10 Guide rails calculation

5.10.1 Range of calculation

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 buckling and bending;
- flange bending stress.

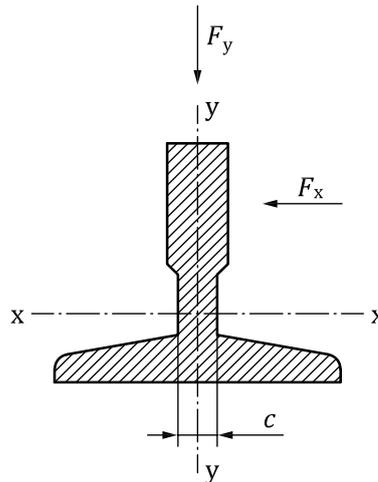
In addition, deflections shall be analysed.

NOTE An example for a calculation based on the following method is given in [Annex C](#).

5.10.2 Bending

5.10.2.1 Calculating the bending stresses in the different axis of the guide rail (see [Figure 4](#)), it can be assumed that:

- the guide rail is a continuous beam with flexible fixing points at distances of the length, l ;
- the resultant of forces causing bending stresses act in the middle between adjacent fixing points;
- bending moments act on the neutral axis of the profile of the guide rail.

**Key**

- 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
 x neutral axis in the x-x plane
 y neutral axis in the y-y plane

Figure 4 — Axis of the guide rail

Evaluating the bending stress, σ_m , from horizontal forces acting at right angles to the axis of the profile, [Formulae \(9\)](#) and [\(10\)](#) shall be used:

$$\sigma_m = \frac{M_m}{W} \quad (9)$$

$$\text{with } M_m = \frac{3 \cdot F_b \cdot l}{16} \quad (10)$$

where

- F_b 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.

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

If, for W_x and W_y , using the usual values of tables (respectively $W_{x,\min}$ and $W_{y,\min}$) does not exceed the permissible stresses, no further proof is necessary. Otherwise, it shall be analysed at which outer edge of the guide rail profile the tensile stresses have their maximum.

5.10.2.3 If more than two guide rails are used, an equal distribution of the forces between the guide rails may be assumed, provided that their profiles are identical.

5.10.2.4 If more than one safety gear is used, acting on different guide rails, it may be assumed that the whole braking force is equally distributed between the safety gears.

5.10.2.5 In the case of vertical multiplex safety gears acting on the same guide rail, it shall be assumed, that the braking force of a guide rail is acting on one point.

5.10.3 Buckling

Determining the buckling stresses the omega method shall be used with [Formula \(11\)](#):

$$\sigma_k = \frac{(F_v + k_3 \cdot M_{aux}) \cdot \omega}{A} \quad (11)$$

where

- A is the cross-sectional area of a guide rail in square millimetres;
- F_v is the vertical force on a guide rail of the car, counterweight or balancing weight in newtons;
- k_3 is the impact factor;
- M_{aux} is the force in a guide rail due to auxiliary equipment in newtons;
- σ_k is the buckling stress in newtons per square millimetre;
- ω is the omega value.

The omega values can be evaluated by using [Formulae \(12\)](#) and [\(13\)](#):

$$\lambda = l_k / i \quad (12)$$

$$l_k = l \quad (13)$$

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, $R_m = 370 \text{ N/mm}^2$:

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

For steel with tensile strength, $R_m = 520 \text{ N/mm}^2$:

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 \(14\)](#):

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

5.10.4 Combination of bending and compression/tension or buckling stresses

The combined bending and compression/tension or buckling stresses shall be evaluated using [Formulae \(15\) to \(17\)](#):

$$\text{Bending stresses: } \sigma = \sigma_m = \sigma_x + \sigma_y \leq \sigma_{perm} \quad (15)$$

$$\text{Bending and compression/tension: } \sigma = \sigma_m + \frac{F_v + k_3 \cdot M_{aux}}{A} \leq \sigma_{perm} \quad (16)$$

$$\text{Bending and buckling: } \sigma = \sigma_k + 0,9 \cdot \sigma_m \leq \sigma_{perm} \quad (17)$$

where

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

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

k_3 is the impact factor;

M_{aux} is the force in a guide rail due to auxiliary equipment 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, see the standards calling for the use of this document (e.g. ISO 8100-1:2019, 5.7.4.5);

σ_x is the bending stress in the x-axis in newtons per square millimetre;

σ_y is the bending stress in the y-axis in newtons per square millimetre.

5.10.5 Flange bending

Flange bending shall be taken into consideration. For T-shaped guide rails, [Formulae \(18\) and \(19\)](#) shall be used:

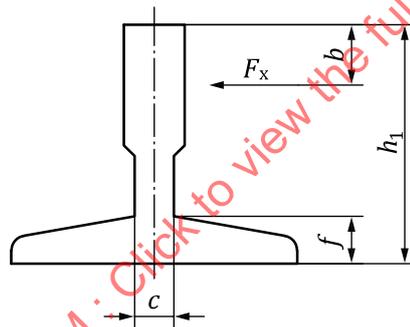
$$\sigma_F = \frac{1,85 \cdot F_x}{c^2} \leq \sigma_{perm} \quad \text{for roller guide shoes} \quad (18)$$

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

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

5.10.6 Deflections

The deflections shall be calculated by using [Formulae \(20\)](#) and [\(21\)](#):

$$\delta_y = 0,7 \frac{F_y \cdot l^3}{48 \cdot E \cdot I_y} \quad (20)$$

$$\delta_x = 1,0 \frac{F_x \cdot l^3}{48 \cdot E \cdot I_x} \quad (21)$$

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;
- $\delta_{\text{str-x}}$ is the deflection of the building structure in the x-axis in millimetres;
- $\delta_{\text{str-y}}$ is the deflection of the building structure 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 in the X-axis in fourth power millimetres;
- I_y is the second moment of area in the Y-axis in fourth power millimetres;
- l is the maximum distance between guide brackets in millimetres.

5.11 Evaluation of traction

5.11.1 General

Traction shall be ensured at all times taking into account:

- normal travel;
- loading the car at floor level; and
- retardation due to an emergency stop.

If the lift machine torque is sufficiently high to raise the car, considerations shall be given to allow slip to occur if the car or the counterweight is stalled in the well for any reason.

The following dimensioning procedure applies for the evaluation of traction in the traditional applications, which include steel wire ropes and steel/cast iron sheaves.

NOTE The results are, as shown by experience, safe due to built-in safety margins. Therefore, the following elements do not need to be taken into consideration in detail: rope construction, type and amount of lubrication, material of sheaves and ropes and manufacturing tolerances.

5.11.2 Traction calculation

5.11.2.1 General

For car loading and emergency braking conditions, [Formula \(22\)](#) shall be applied. For car/counterweight stalled conditions (car/counterweight resting on the buffers and the machine rotating in the “down/up” direction) where protection against raising of the car or counterweight is provided by limiting of traction, [Formula \(23\)](#) shall be applied.

$$\frac{T_1}{T_2} \leq e^{f\alpha} \quad (22)$$

$$\frac{T_1}{T_2} \geq e^{f\alpha} \quad (23)$$

where

α is the angle of wrap of the ropes on the traction sheave;

f is the friction factor;

T_1, T_2 are the forces in the portion of the ropes situated at either side of the traction sheave.

5.11.2.2 Evaluation of T_1 and T_2

5.11.2.2.1 Car loading condition

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.

Where handling devices which are not included in the rated load are used to load/unload the car, the weight of such devices shall be added to the rated load for the purpose of this calculation.

5.11.2.2.2 Emergency braking condition

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 ratio of the installation.

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

- 0,5 m/s² in normal cases;
- the minimum retardation to slow down the car and counterweight to a value not exceeding that for which the buffers are designed, in the case of reduced buffer stroke,.

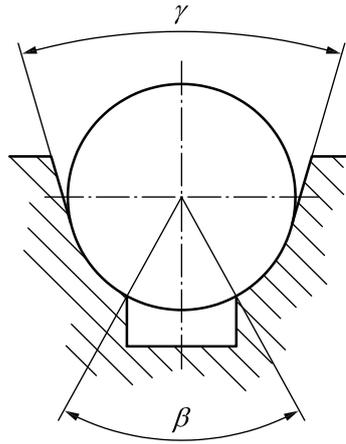
5.11.2.2.3 Car/counterweight stalled condition

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

5.11.2.3 Evaluation of the friction factor

5.11.2.3.1 Grooving considerations

5.11.2.3.1.1 Semi-circular and semi-circular undercut grooves (see [Figure 6](#))

**Key** β undercut angle γ groove angle**Figure 6 — Semi-circular groove, undercut**

[Formula \(24\)](#) shall be used:

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

where

β is the value of the undercut angle;

γ is the value of the groove angle;

μ is the friction coefficient;

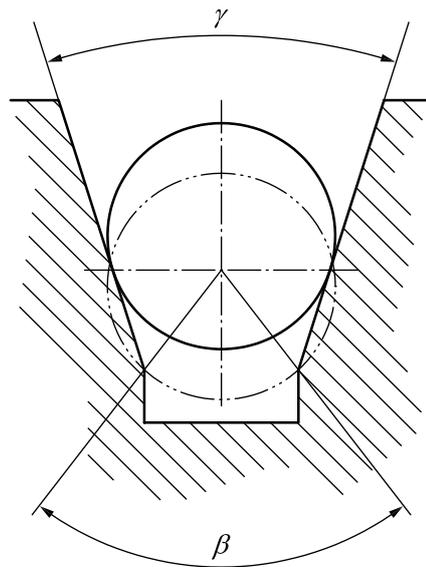
f is the friction factor.

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

The value of the groove angle, γ , shall be given by the manufacturer according to the grooving design. It should never be less than 25° (0,44 rad).

5.11.2.3.1.2 V-grooves (see [Figure 7](#))

Where the groove has not been submitted to an additional hardening process, in order to limit the deterioration of traction due to wear, an undercut is necessary.



Key

- β undercut angle
- γ groove angle

Figure 7 — V-groove

Formulae (25) to (27) apply:

- in the case of car loading and emergency braking:

$$f = \mu \cdot \frac{4 \left(1 - \sin \frac{\beta}{2} \right)}{\pi - \beta - \sin \beta} \quad \text{for non-hardened grooves} \quad (25)$$

$$f = \mu \cdot \frac{1}{\sin \frac{\gamma}{2}} \quad \text{for hardened grooves} \quad (26)$$

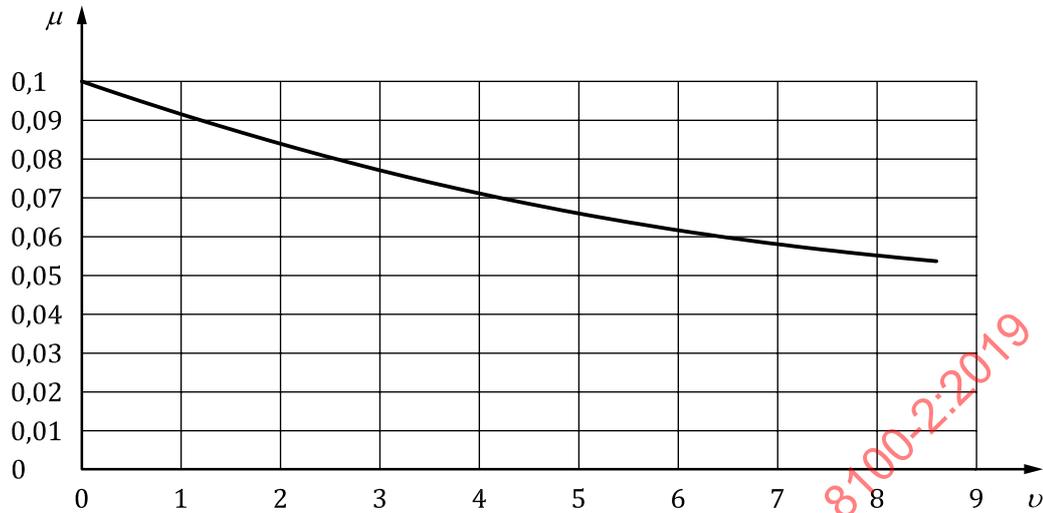
- in the case of counterweight stalled conditions:

$$f = \mu \cdot \frac{1}{\sin \frac{\gamma}{2}} \quad \text{for hardened and non-hardened grooves} \quad (27)$$

where

- β is the value of the undercut angle;
- γ is the value of the groove angle;
- μ is the friction coefficient;
- f is the friction factor.

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

5.11.2.3.2 Friction coefficient consideration (see [Figure 8](#))**Key**

- μ friction coefficient
 v speed in meters per second

Figure 8 — Minimum friction coefficient

The following values apply:

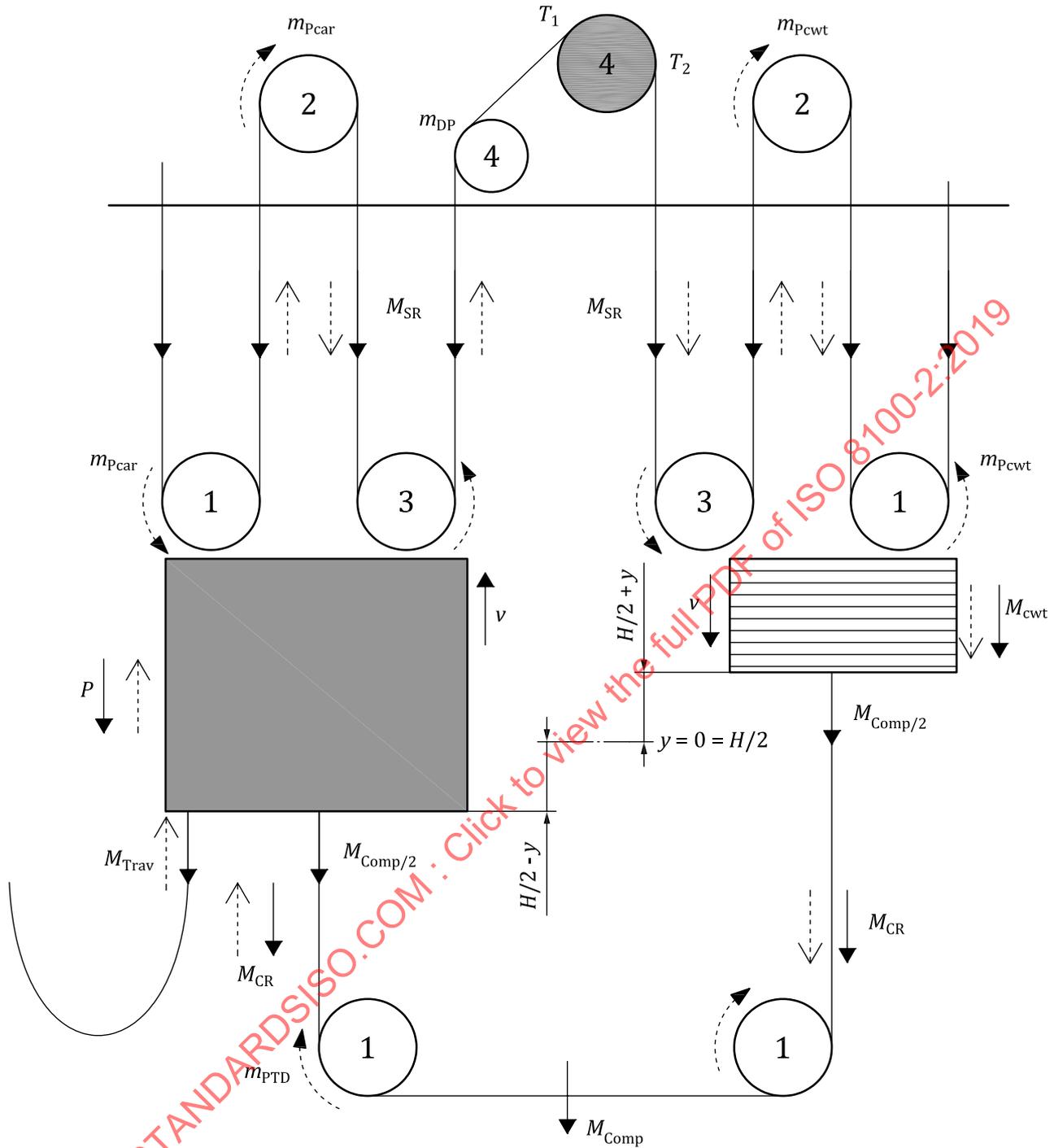
- $\mu = 0,1$ for loading conditions;
- $\mu = 0,2$ for counterweight stalled conditions;
- [Formula \(28\)](#) for emergency braking conditions:

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

where

- μ is the friction coefficient;
- v is the rope speed at rated speed of the car.

5.11.3 Formulae for a general case (see [Figure 9](#))



Key

H	travel height in metres	M_{CR}	actual mass of compensation ropes/chains in kilograms
m_{Pcar}	reduced mass (related to the car) of pulleys on car side in kilograms	M_{Comp}	mass of tension device including mass of pulleys in kg
m_{DP}	reduced mass (related to the car/counterweight) of deflection pulleys on car and/or counterweight side in kilograms	M_{cwt}	mass of counterweight including mass of pulleys in kg
m_{Pcwt}	reduced mass (related to the counterweight)	M_{SR}	actual mass of suspension ropes in kilograms
		M_{Trav}	actual mass of travelling cable in kilograms
		P	masses of the empty car in kilograms
		v	rotation speed of the pulley (rope speed) in m/s

	of pulleys on counterweight side	Y	level 0,5 H → y = 0 in metres;
	in kilograms	T ₁ , T ₂	force exerted on rope in newtons
m _{PTD}	reduced mass (related to car/ counterweight)	1, 2, 3, 4	speed factor of pulleys (example: 2 = 2 · v _{car})
	of one pulley on tensioning device		

Figure 9 — General case

Formulae (29) to (32) apply.

a) For machinery located above:

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

$$T_2 = \frac{(M_{Cwt} + M_{CRcwt})}{r} \cdot (g_n \mp a) + \frac{M_{Comp}}{2 \cdot r} \cdot g_n + M_{SRcwt} \left(g_n \pm a \cdot \frac{r^2 + 2}{3} \right) \mp \left(\frac{i_{PTD} \cdot m_{PTD}}{2 \cdot r} \cdot a \right) \mp \left[\frac{\sum_{i=1}^{r-1} (m_{Pcwt} \cdot i_{Pcwt} \cdot a)}{r} \right]^{III} \pm \frac{FR_{cwt}}{r} \quad (30)$$

b) For machinery located below:

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

$$T_2 = \frac{(M_{Cwt} + M_{trav})}{r} \cdot (g_n \mp a) + \frac{M_{Comp}}{2 \cdot r} \cdot g_n + M_{SR1car} \cdot (-g_n \pm a) + M_{SR2car} \left(g_n \mp a \cdot \frac{r^2 + 2}{3} \right) \mp \left(\frac{i_{PTD} \cdot m_{PTD}}{2 \cdot r} \cdot a \right) \mp \frac{(m_{DP} \cdot a)^I}{r} \mp \left[\frac{\sum_{i=1}^{r-1} (m_{Pcar} \cdot i_{Pcar} \cdot a)}{r} \right]^{III} \pm \frac{FR_{cwt}}{r} \quad (32)$$

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_{Pcar}	is the number of pulleys on car side with same rotation speed v_{pulley} (without deflection pulleys);
i_{Pcwt}	is the number of pulleys on counterweight side with same rotation speed v_{pulley} (without deflection pulleys);
i_{PTD}	is the number of pulleys for tensioning device;
m_{DP}	is the reduced mass (related to the car/counterweight) of deflection pulleys on car and/or counterweight side $J_{DP} \cdot (v_{pulley}/v)^2/R^2$ in kilograms;
m_{Pcar}	is the reduced mass (related to the car) of pulleys on car side $J_{Pcar} \cdot (v_{pulley}/v)^2/R^2$ in kilograms;
m_{Pcwt}	is the reduced mass (related to the counterweight) of pulleys on counterweight side $J_{Pcwt} \cdot (v_{pulley}/v)^2/R^2$ in kilograms;
m_{PTD}	is the reduced mass (related to car/counterweight) of one pulley on tensioning device J_{PTD}/R^2 in kilograms;
M_{Comp}	is the mass of tension device including mass of pulleys in kilograms;
M_{CR}	is the actual mass of compensation ropes/chains $[(0,5 \cdot H \pm y) \cdot n_c \cdot \text{rope weight per unit length}]$, 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 ropes $[(0,5 \cdot H \pm y) \cdot n_s \cdot \text{rope weight per unit length}]$, in kilograms;
M_{SRcar}	is the mass M_{SR} on car side.

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 the above formulae, the symbols \pm and \mp shall be used in such a way that:

- the upper operation is applicable in case the car with its rated load is retarding in the downward direction, and
- the lower operation in case the empty 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 $1,25 Q$ plus the weight of handling devices where used in case of goods passenger lifts.

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

NOTE 2 For calculation example, see [Annex D](#).

Conditions:

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

In the case of machine below, the rope leading from the machine to the pulley(s) in the headroom is M_{SR1car} and the rope leading from the pulley(s) in the headroom to the car is M_{SR2car} ($M_{SR2car} = 0$ if car at upmost landing);

M_{SRcwt} is the mass M_{SR} on counterweight side.

In the case of machine below, the rope leading from the machine to the pulley(s) in the headroom is M_{SR1cwt} and rope leading from pulley(s) in the headroom to the counterweight is M_{SR2cwt} ($M_{SR2cwt} = 0$ if counterweight at upmost landing);

- M_{Trav} is the actual mass of travelling cable $[(0,25H \pm 0,5y) \cdot n_t \cdot \text{travelling cable weight per unit length}]$, in kilograms;
- n_C is the number of compensating ropes/chains;
- n_S is the number of suspension ropes;
- n_t is the number of travelling cables;
- P is the masses of the empty car in kilograms;
- Q is the rated load in kilograms;
- T_1, T_2 is the force exerted on rope in newtons;
- r is the reeving factor;
- v_{pulley} is the rotation speed of the pulley (rope speed) in metres per second;
- y is on the level $0,5 \cdot H \rightarrow y = 0$, in metres;
- \rightarrow is the static force;
- \rightarrow is the dynamic force;

5.12 Evaluation of safety factor on suspension ropes for electric lifts

5.12.1 General

With reference to the requirements laid down in the standards calling for the use of this document (e.g. ISO 8100-1, 5.5.2.2), this clause describes the method of evaluation of the safety factor “ S_f ” for the suspension ropes. This evaluation method shall only be used for:

- Steel or cast iron traction sheaves;
- Steel wire ropes according to EN 12385-5 or ISO 4344.

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

5.12.2 Equivalent number, N_{equiv} , of pulleys

5.12.2.1 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 \(33\)](#):

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

where

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

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

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

Values of $N_{equiv(t)}$ can 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 the table may be determined by linear interpolation.

5.12.2.3 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, 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 [\(35\)](#)].

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

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.

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

where

D_t is the diameter of the traction sheave;

D_p is the average diameter of all pulleys, traction sheave excluded.

NOTE Examples for evaluation of equivalent number of pulleys are given in [Annex E](#).

5.12.3 Safety factor

For a given design of rope drive, the minimum value of safety factor can be selected from [Figure 10](#) taking into account the correct ratio of D_t/d_r and the calculated N_{equiv} for the worst-case section of ropes.

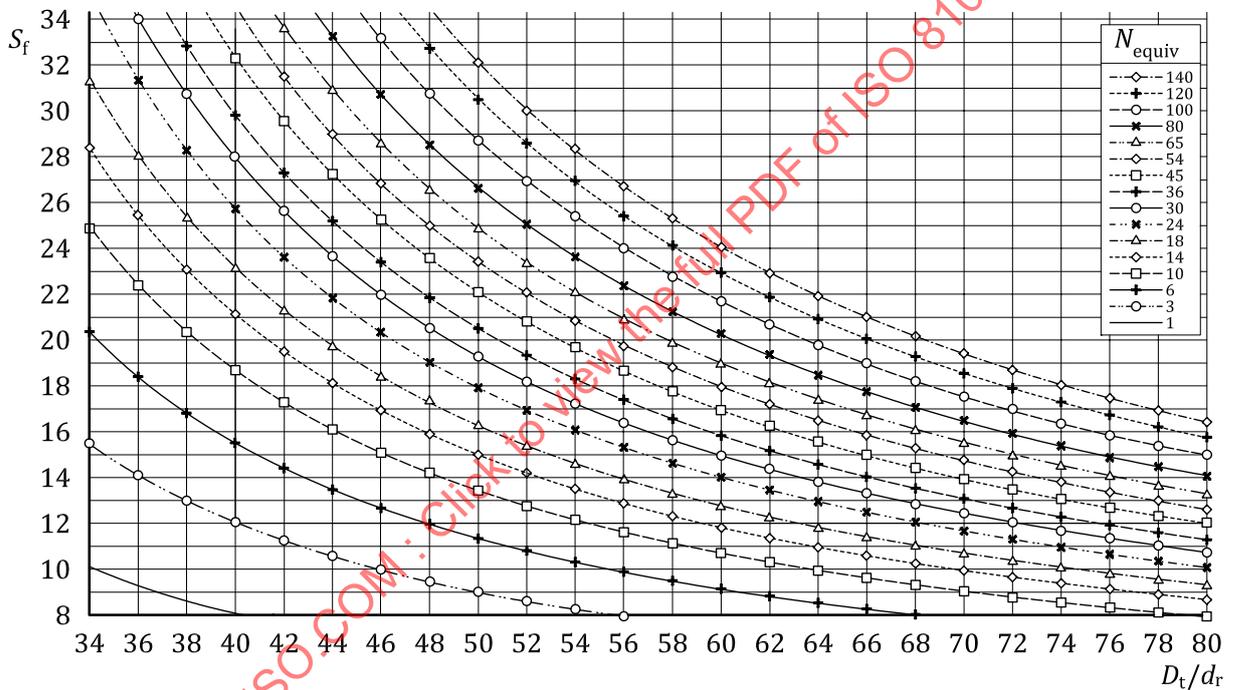


Figure 10 — Evaluation of minimum safety factor

The curves of the [Figure 10](#) are based on [Formula \(36\)](#):

$$S_f = 10 \left(\frac{\log \left(\frac{695,85 \cdot 10^6 \cdot N_{equiv}}{\left(\frac{D_t}{d_r} \right)^{8,567}} \right)}{2,6834 \cdot \log \left(77,09 \left(\frac{D_t}{d_r} \right)^{-2,894} \right)} \right) \tag{36}$$

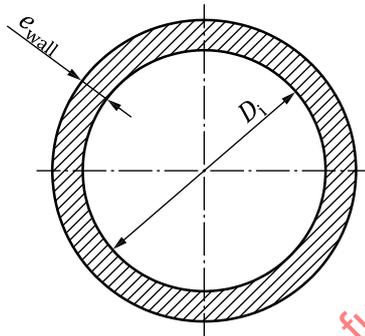
where

- 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.

5.13 Calculations of rams, cylinders, rigid pipes and fittings

5.13.1 Calculation against over pressure

5.13.1.1 Calculation of wall thickness of rams, cylinders, rigid pipes and fittings (see [Figure 11](#))



Key

- e_{wall} wall thickness of the cylinder/ram/rigid pipe in mm
- D_i inside diameter of the cylinder/ram/rigid pipe in mm

Figure 11 — Wall thickness calculation

Calculate wall thickness, e_{wall} , with [Formula \(37\)](#):

$$e_{wall} \geq \frac{2,3 \cdot 1,7 \cdot p \cdot D_i}{Rp_{0,2}} + e_o \tag{37}$$

where

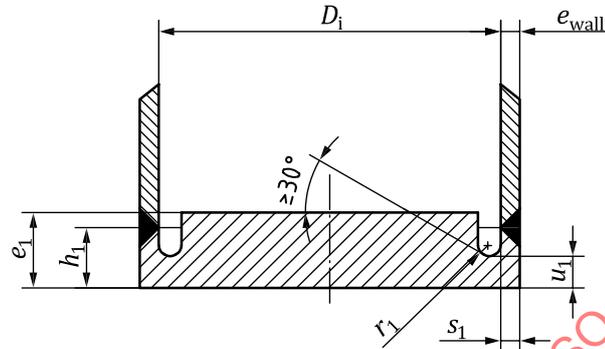
- D_i is the inside diameter of the cylinder in mm;
- $e_o = 1,0$ mm for wall and base of cylinders and rigid pipes between the cylinder and the rupture valve, if any;
- $e_o = 0,5$ mm for rams and other rigid pipes;
- p is the full load pressure in megapascals;
- $Rp_{0,2}$ is the proof stress (non-proportional elongation) 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 proof stress.

5.13.1.2 Calculation of the base thickness of cylinders (examples)

5.13.1.2.1 General

The examples shown do not exclude other possible constructions.

5.13.1.2.2 Flat bases with relieving groove (see Figure 12)



Key

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

Figure 12 — Flat bases with relieving groove

Conditions for the stress relief of the welding seam, see Formulae (38) to (43):

$$r_1 \geq 0,2 \cdot e_1 \tag{38}$$

$$\text{and } r_1 \geq 5 \text{ mm} \tag{39}$$

$$u_1 \leq 1,5 \cdot s_1 \tag{40}$$

$$h_1 \geq u_1 + r_1 \tag{41}$$

$$e_1 \geq 0,4 \cdot D_i \sqrt{\frac{2,3 \cdot 1,7 \cdot p}{R_{p0,2}}} + e_0 \tag{42}$$

$$u_1 \geq 1,3 \cdot \left(\frac{D_i}{2} - r_1 \right) \cdot \frac{2,3 \cdot 1,7 \cdot p}{R_{p0,2}} + e_0 \tag{43}$$

where

D_i is the inside diameter of the cylinder in mm;

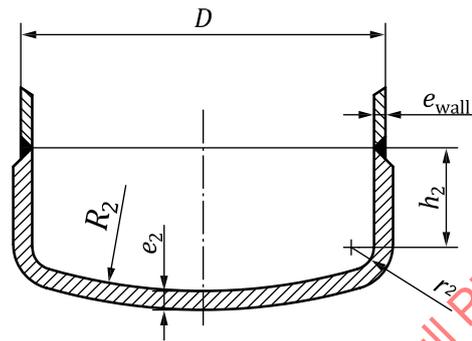
e_0 is 1,0 mm for wall and base of cylinders;

e_1 is the thickness of the flat base in mm;

h_1 is the height of the base wall in mm;

- p is the full load pressure in megapascals;
- r_1 is the inside radius of the base in mm;
- s_1 is the thickness of the base wall in mm;
- u_1 is the thickness of the base at the bottom of the relieving groove in mm;
- 2,3 is the factor for friction losses (1,15) and pressure peaks (2);
- 1,7 is the safety factor referred to the proof stress.

5.13.1.2.3 Cambered based (see [Figure 13](#))



Key

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

Figure 13 – Cambered based

Conditions, see [Formulae \(43\)](#) to [\(46\)](#):

$$h_2 \geq 3,0 \cdot e_2 \tag{44}$$

$$r_2 \geq 0,15 \cdot D \tag{44}$$

$$R_2 = 0,8 \cdot D \tag{45}$$

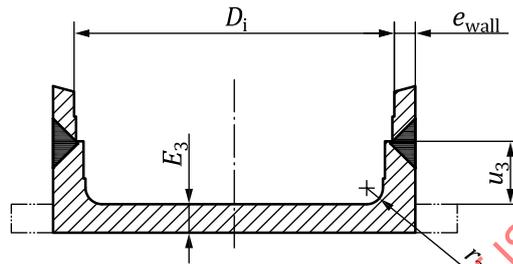
$$e_2 \geq \frac{2,3 \cdot 1,7 \cdot p \cdot D}{R_{p0,2}} + e_0 \tag{46}$$

where

- D is the outer diameter of the cylinder in mm;
- e_0 is 1,0 mm for wall and base of cylinders;
- e_2 is the thickness of the cambered base in mm;
- h_2 is the height of the base wall in mm;
- p is the full load pressure in megapascals;

- r_2 is the inside radius of the base in mm;
- R_2 is the inside radius of the cambered base in mm;
- $R_{P0,2}$ is the proof stress (non-proportional elongation) 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 proof stress.

5.13.1.2.4 Flat bases with welded flange (see Figure 14)



Key

- D_i inside diameter of the cylinder in mm
- E_3 thickness of the flat base in mm
- e_{wall} wall thickness of the cylinder in mm
- r_3 inside radius of the base in mm
- u_3 height base wall in mm

Figure 14 — Flat bases with welded flange

Conditions, see [Formulae \(47\)](#) to [\(50\)](#):

$$u_3 \geq e_3 + r_3 \tag{47}$$

$$r_3 \geq \frac{e_{wall}}{3} \tag{48}$$

$$\text{and } r_3 \geq 8 \text{ mm} \tag{49}$$

$$e_3 \geq 0,4 \cdot D_i \cdot \sqrt{\frac{2,3 \cdot 1,7 \cdot p}{R_{P0,2}}} + e_0 \tag{50}$$

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 proof stress (non-proportional elongation) in newtons per square millimetre;

e_0 is 1,0 mm for wall and base of cylinders;

2,3 is the factor for friction losses (1,15) and pressure peaks (2);

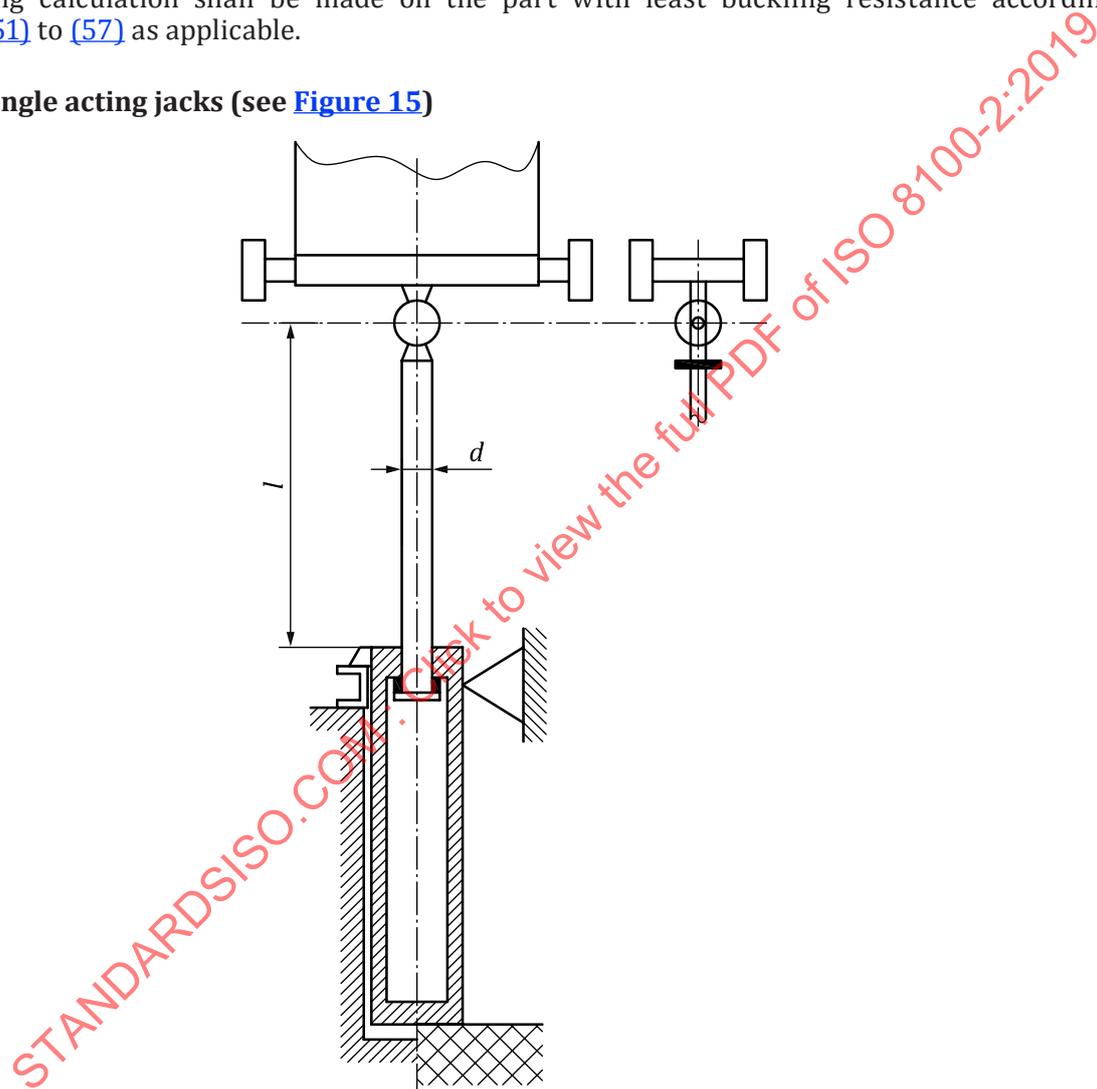
1,7 is the safety factor referred to the proof stress.

5.13.2 Calculations of the jacks against buckling

5.13.2.1 General

The buckling calculation shall be made on the part with least buckling resistance according to [Formulae \(51\) to \(57\)](#) as applicable.

5.13.2.2 Single acting jacks (see [Figure 15](#))



Key

d diameter of ram

l length of ram subject to buckling

Figure 15 — Single acting jacks

$$\text{For } \lambda_n \geq 100: F_s \leq \frac{\pi^2 \cdot E \cdot J_n}{2 \cdot l^2} \quad (51)$$

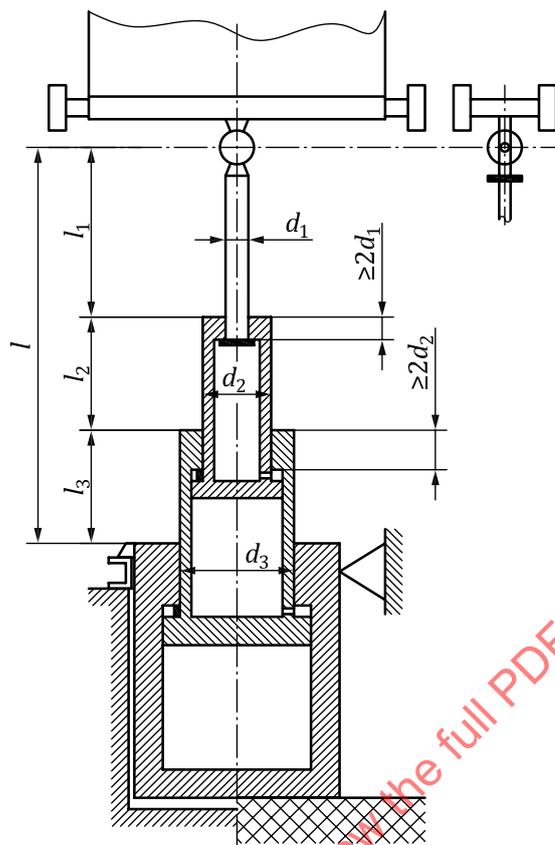
$$\text{For } \lambda_n < 100: F_s \leq \frac{A_n}{2} \left[R_m - (R_m - 210) \cdot \left(\frac{\lambda_n}{100} \right)^2 \right] \quad (52)$$

$$F_s = 1,4 \cdot g_n \cdot [c_m \cdot (P + Q) + 0,64 \cdot P_r + P_{rh}] \quad (\text{valid for rams extending in upward direction}) \quad (53)$$

where

- A_n is the cross-sectional area of the material of the ram to be calculated in square millimetres ($n = 1, 2, 3$);
- c_m is the reeving ratio;
- E is the modulus of elasticity in newtons per square millimetre (for steel: $E = 2,1 \times 10^5 \text{ N/mm}^2$);
- 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 ($n = 1, 2, 3$);
- l is the maximum length of rams subject to buckling 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 to be calculated in kilograms;
- P_{rh} is the mass of the ram head equipment, if any in kilograms;
- Q is the rated load (mass) displayed in the car in kilograms;
- R_m is the tensile strength of material in newtons per square millimetre;
- $\lambda_n = \frac{l}{i_n}$ is the coefficient of slenderness of the ram to be calculated;
- 1,4 is the over pressure factor;
- 2 is the safety factor against buckling.

5.13.2.3 Telescopic jacks without external guidance, calculation of ram (see Figure 16)



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 16 — Telescopic jacks without external guidance

$l = l_1 + l_2 + l_3, \quad l_1 = l_2 = l_3$ $v = \sqrt{\frac{J_1}{J_2}}; J_3 \geq J_2 > J_1$ <p>(assumption for simplified calculation: $J_3 = J_2$)</p> <p>for 2 sections: $\phi = 1,25 \cdot v - 0,2$ for $0,22 < v < 0,65$</p> <p>for 3 sections: $\phi = 1,5 \cdot v - 0,2$ for $0,22 < v < 0,65$ $\phi = 0,65 \cdot v + 0,35$ for $0,65 < v < 1$</p>	$\lambda_e = \frac{l}{i_e} \text{ with } i_e = \frac{d_m}{4} \sqrt{\phi \cdot \left[1 + \left(\frac{d_{mi}}{d_m} \right)^2 \right]}$ <p>For $\lambda_e \geq 100$</p> $F_s \leq \frac{\pi^2 \cdot E \cdot J_2 \cdot \phi}{2 \cdot l^2}$ <p>For $\lambda_e < 100$</p> $F_s \leq \frac{A_n}{2} \left[R_m - (R_m - 210) \cdot \left(\frac{\lambda_n}{100} \right)^2 \right]$
--	---

$$F_s = 1,4 \cdot g_n \cdot [c_m \cdot (P + Q) + 0,64 \cdot P_r + P_m + P_{rt}] \text{ (valid for rams extending in upward direction) } \quad (54)$$

where

- A_n is the cross-sectional area of the material of the ram to be calculated in square millimetres ($n = 1, 2, 3$);
- c_m is the reeving ratio;
- 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: $E = 2,1 \times 10^5 \text{ N/mm}^2$);
- 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 ($n = 1, 2, 3$);
- l is the maximum length of rams subject to buckling 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 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 the case of telescopic jacks) in kilograms;
- Q is the rated load (mass) displayed in the car in kilograms;

R_m is the tensile strength of material in newtons per square millimetre;

$R_{p0,2}$ is the proof stress (non-proportional elongation) in newtons per square millimetre;

$\lambda_e = \frac{l}{i_e}$ is the equivalent coefficient of slenderness of a telescopic jack;

$\lambda_n = \frac{l}{i_n}$ is the coefficient of slenderness of the ram to be calculated;

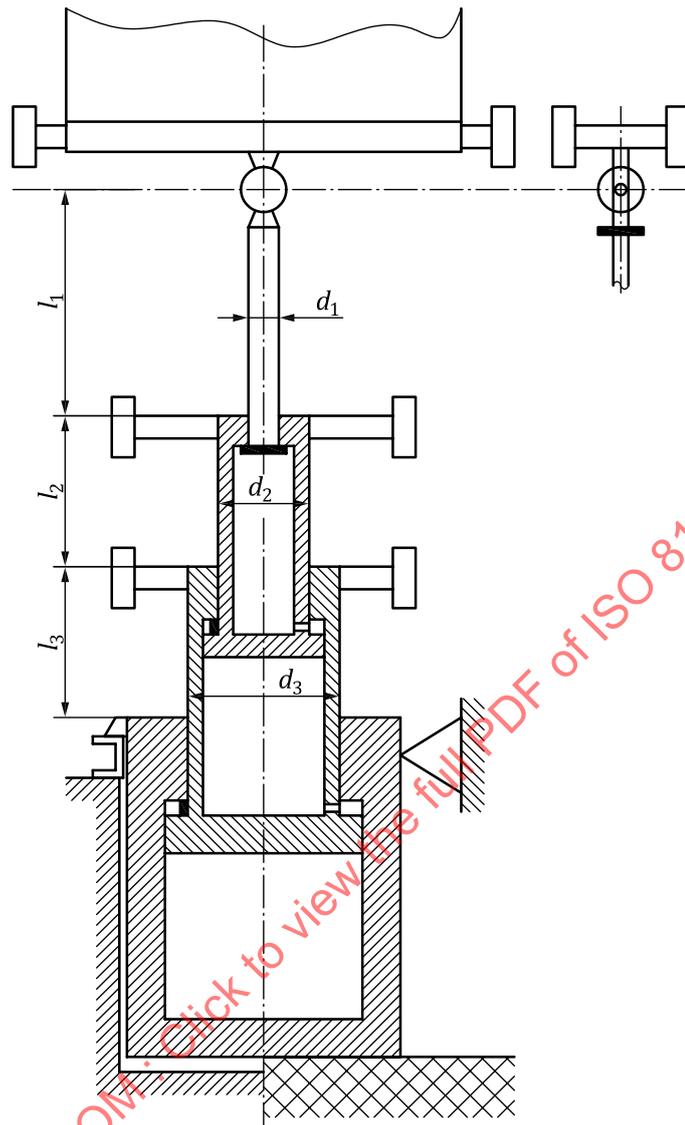
ν, ϕ are the factors used to represent approximate values given by experimentally determined diagrams;

1,4 is the over pressure factor;

2 is the safety factor against buckling.

5.13.2.4 Telescopic jacks with external guidance (see [Figure 17](#))

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**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 17 — Telescopic jacks with external guidance

$$\text{For } \lambda_n \geq 100: F_s \leq \frac{\pi^2 \cdot E \cdot J_n}{2 \cdot l_n^2} \quad (55)$$

$$\text{For } \lambda_n < 100: F_s \leq \frac{A_n}{2} \left[R_m - (R_m - 210) \cdot \left(\frac{\lambda_n}{100} \right)^2 \right] \quad (56)$$

$$F_s = 1,4 \cdot g_n \cdot [c_m \cdot (P + Q) + 0,64 \cdot P_r + P_{rh} + P_{rt}] \quad (\text{valid for rams extending in upward direction}) \quad (57)$$

where

A_n	is the cross-sectional area of the material of the ram to be calculated in square millimetres ($n = 1, 2, 3$);
c_m	is the reeving ratio;
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: $E = 2,1 \times 10^5 \text{ N/mm}^2$);
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 ($n = 1, 2, 3$);
l_n	is the length of ram subject to buckling 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 the case of telescopic jacks) in kilograms;
Q	is the rated load (mass) displayed in the car in kilograms;
R_m	is the tensile strength of material in newtons per square millimetre;
$R_{p0,2}$	is the proof stress (non-proportional elongation) in newtons per square millimetre;
$\lambda_n = \frac{l}{i_n}$	is the coefficient of slenderness of the ram to be calculated;
1,4	is the over pressure factor;
2	is the safety factor against buckling.

5.14 Pendulum shock tests

5.14.1 General

Pendulum shock tests shall be carried out according to the following prescriptions.

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

5.14.2 Test rig

5.14.2.1 Hard pendulum shock device

The hard pendulum shock device shall be a body according to [Figure 18](#). This body consists of a shock ring made of steel S 235 JR, according to EN 10025 and a case made of steel E 295, according to EN 10025. The overall mass of this body will be brought up to $10 \text{ kg} \pm 0,01 \text{ kg}$ by filling with lead balls of a diameter of $3,5 \text{ mm} \pm 0,5 \text{ mm}$.

5.14.2.2 Soft pendulum shock device

The soft pendulum shock device shall be a small shot bag according to [Figure 19](#) made of leather, which is filled with lead balls of a diameter of $3,5 \text{ mm} \pm 0,5 \text{ mm}$ up to an overall mass of $45 \text{ kg} \pm 0,5 \text{ kg}$.

5.14.2.3 Suspension of the pendulum shock device

The pendulum shock device shall be suspended by a wire rope of approximately 3 mm diameter 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 $15 \text{ mm} \pm 10 \text{ mm}$.

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

5.14.2.4 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 falling height required in [5.14.3.2](#) and [5.14.3.3](#). 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 should be realized by a triangle hooking keeping the shocking device's centre of gravity in line with the hoisting wire at triggering position.

5.14.2.5 Test samples

5.14.2.5.1 The test samples shall be complete and shall have the intended size and fixations according to 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).

5.14.2.5.2 The samples shall be submitted to the tests in the intended manufacturing finish (machined edges, holes, etc.).

5.14.3 Tests

5.14.3.1 The tests shall be carried out at a temperature of $23 \text{ °C} \pm 5 \text{ °C}$. The panels shall be stored directly before the tests for at least 4 hours at that temperature.

5.14.3.2 The hard pendulum shock test shall be carried out with the device according to [5.14.2.1](#) with a falling height and test arrangement according to [Figure 18](#) and [Figure 20](#).

5.14.3.3 The soft pendulum shock test shall be carried out with the device according to [5.14.2.2](#) with a falling height and test arrangement according to [Figure 19](#) and [Figure 20](#).

5.14.3.4 The pendulum shock device shall be brought to the required falling height according to the standard calling for this test (e.g. ISO 8100-1:2019, 5.3.5.3.2) and released.

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 as close as possible to the striking point (see the requirements laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2019).

5.14.3.5 Only one test for each striking point is required with each of the devices called for in [5.14.2.1](#) and [5.14.2.2](#).

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.

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

5.14.4 Interpretation of the results

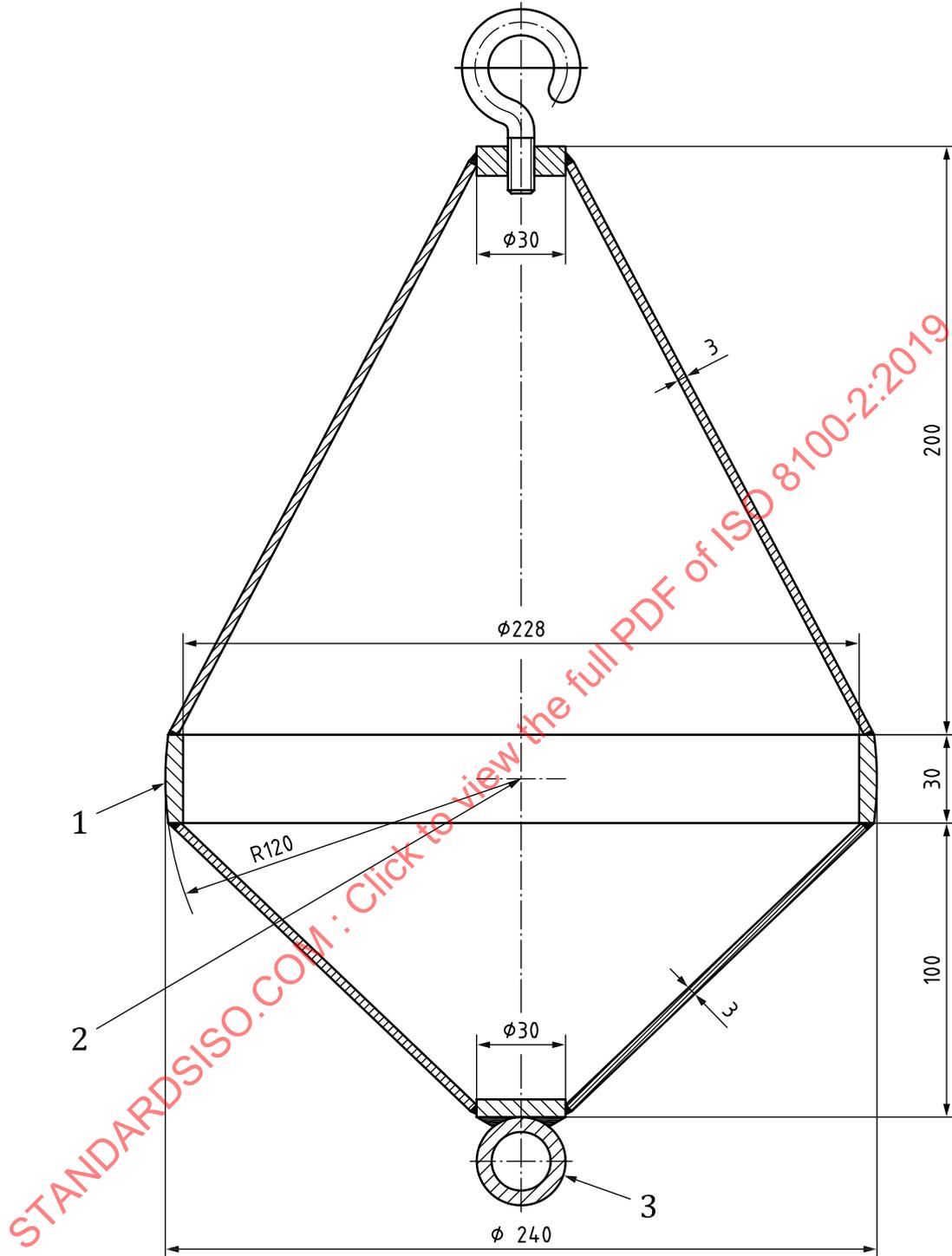
Checks shall be carried out after the test according to the standard calling for this test for the following:

- a) loss of integrity;
- b) permanent deformation;
- c) cracks or chips.

5.14.5 Test report

The test report shall contain at least the following information:

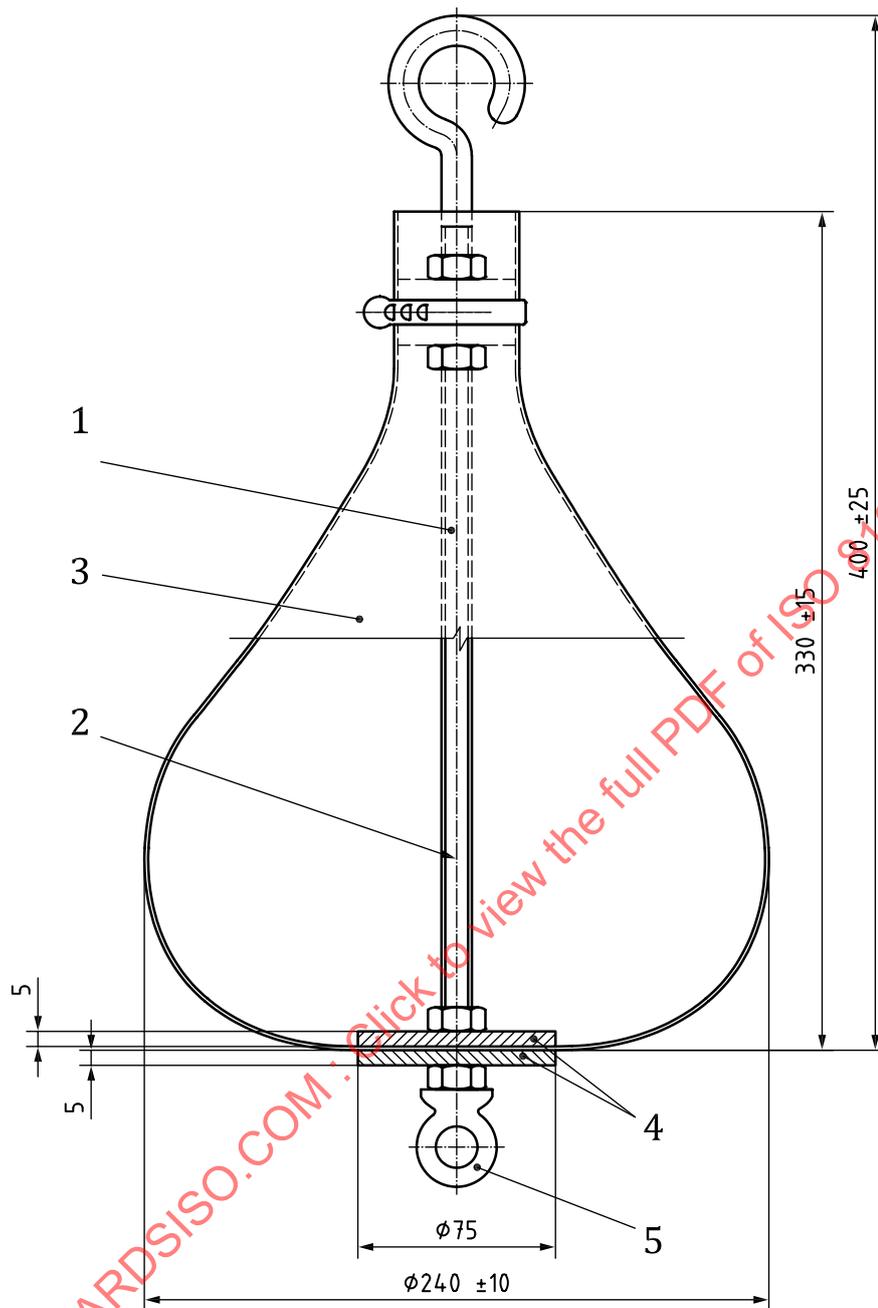
- a) name and address of the organization having made the tests;
- b) date of the tests;
- c) dimensions and construction of the panel;
- d) fixation of the panel;
- e) falling height of the tests;
- f) number of tests carried out;
- g) test results;
- h) signature of the person responsible for these tests.



Key

- 1 shocking ring
- 2 reference point for measuring the falling height
- 3 triggering device attachment

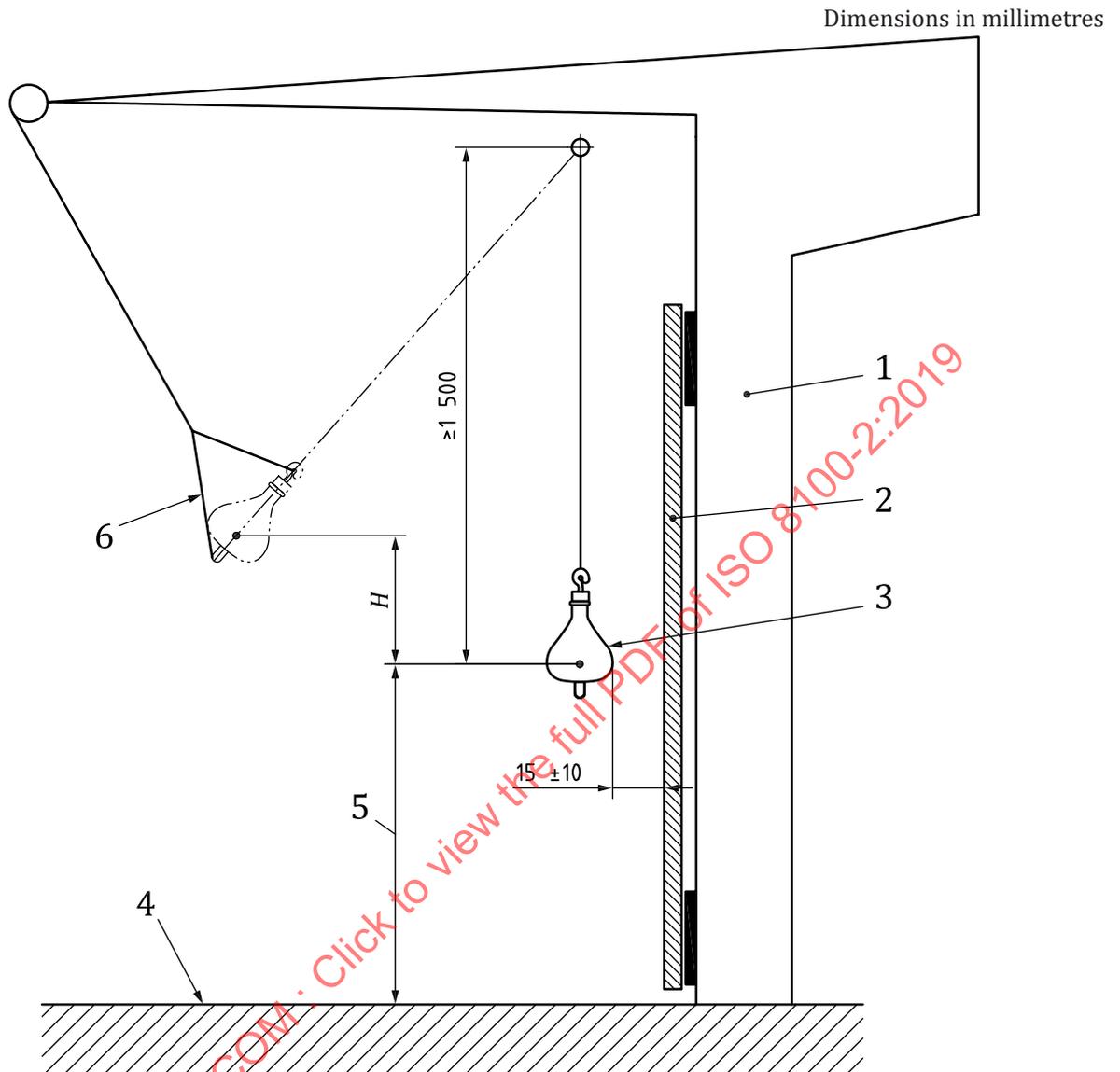
Figure 18 — Hard pendulum shock device



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 19 — Soft pendulum shock device

**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 [5.14.2.4](#)
- H falling height

Figure 20 — Test rig falling height**5.15 Electronic components — Failure exclusion**

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

[Table 3](#) describes the conditions under which certain faults can be excluded.

Table 3 — Exclusions of failures

Component	Possible failure exclusion					Change of function	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)			(a) Only for film resistors with varnished or sealed resistance film and axial connection according to applicable IEC standards, and for wire wound resistors if they are made of a single layer winding protected by enamel or sealed.	
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	NO	NO	NO				
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.
"NO" in the cell means: failure not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.								

Table 3 (continued)

Component	Possible failure exclusion					Change of function	Conditions	Remarks
	Open circuit	Short circuit	Change to higher value	Change to lower value				
2.4 Optocoupler	NO	(a)			NO	(a) Can be excluded on condition that the optocoupler is according to IEC 60747-5-5, and the isolation voltage is at least according to table below, IEC 60664-1:2007, Table F.1.	Open circuit means open circuit in one of the two basic components (LED and photo transistor). Short circuit means short circuit between them.	
						Voltage phase-to-earth derived from rated system voltage up to and including V_{rms} and D.C. Preferred series of impulse withstand voltages in volts for installation Category III 800 1 500 2 500 4 000 6 000 8 000		
2.5 Hybrid circuit	NO	NO	NO	NO	NO			
2.6 Integrated circuit	NO	NO	NO	NO	NO		Change in function to oscillation, "and" gates becoming "or" gates, etc.	
3 Miscellaneous								
"NO" in the cell means: failure not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.								

Table 3 (continued)

Component	Possible failure exclusion					Remarks
	Open circuit	Short circuit	Change to higher value	Change to lower value	Change of function	
3.1 Connectors — Terminals — Plugs	NO	(a)				(a) The short circuits of connectors can be excluded if the minimum values are according to the tables (taken over from IEC 60664-1) with the conditions: — the pollution degree is 3; — the material group is III; — inhomogeneous field. The column "printed wiring material" of Table F.4 is not used. 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 5X or better, the creepage distances can be reduced to the clearance value, e.g. 3 mm for 250 V _{rms} .
3.2 Neon bulb	NO	NO				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.
3.3 Transformer	NO	(a)	(b)	(b)		(a) (b) Can be excluded on condition that transformer complies with IEC 61558-1:2005, Clause 18 for double or reinforced insulation between windings and between windings and core.
<p>"NO" in the cell means: failure not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.</p>						

Table 3 (continued)

Component	Possible failure exclusion					Remarks	
	Open circuit	Short circuit	Change to higher value	Change to lower value	Change of function		
3.4 Fuse		(a)				(a) Can be excluded if the fuse is correctly rated, and constructed according to 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 8100-1:2019, 5.10.3.2.2). (b) Welding of contacts cannot be excluded. However, if the relay is constructed to have mechanically forced interlocked contacts, and made according to IEC 60947-5-1:2003, the assumptions laid down in the standards calling for the use of this document (e.g. ISO 8100-1:2019, 5.10.3.1.2 and 5.10.3.1.3) apply.	

“NO” in the cell means: failure not excluded, i.e. shall be considered;

The unmarked cell means: the identified fault type is not relevant.

Table 3 (continued)

Component	Possible failure exclusion					Remarks
	Open circuit	Short circuit	Change to higher value	Change to lower value	Change of function	
3.6 Printed circuit board (PCB)	NO	(a)				(a) The short circuit can be excluded provided: <ul style="list-style-type: none"> — The general specifications of PCB are in accordance with IEC 62326-1; — The base material is in accordance to the specifications of IEC 61249 series; — The PCB is constructed according to the above requirements and the minimum values are according to the tables (taken over from IEC 60664-1) with the conditions: <ul style="list-style-type: none"> — The pollution degree is 3; — The material group is III; — Inhomogeneous field.
“NO” in the cell means: failure not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.						

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Table 3 (continued)

Component	Possible failure exclusion					Remarks
	Open circuit	Short circuit	Change to higher value	Change to lower value	Change of function	
						<p>The column "printed wiring material" of Table 4 is not used. That means that the creepage distances are 4 mm and the clearances 3 mm at 2000 m altitude for 250 V_{rms}. For other voltages and higher altitude see IEC 60664-1.</p> <p>If the protection of the PCB is IP 54 or better, and the printed side(s) is (are) coated with an ageing-resistant varnish or protective layer covering all conductor paths and for the inner layers of multilayer PCB, pollution degree 2 can be used.</p> <p>NOTE Experience has shown that solder masks are satisfactory as a protective layer.</p> <p>For multi-layer boards comprised of at least 3 prepreg or other thin sheet insulating materials, short circuit can be excluded (see EN 60950-1:2006, 2.10.6.4)</p>
4 Assembly of components on printed circuit board (PCB)	NO	(a)				<p>(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 acceptable values as listed in 3.1 and 3.6 of this table, neither by the mounting technique nor by the PCB itself.</p>
<p>"NO" in the cell means: failure not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.</p>						

5.16 Design rules for programmable electronic systems (PESSRAL)

Programmable electronic systems shall comply with the minimum requirements of the safety functions common to all SIL's listed in [Tables B.1, B.2](#) and [B.3](#). In addition, specific measures required for SIL's 1, 2 and 3 are listed respectively in [Tables B.4, B.5](#) and [B.6](#).

See also the requirements in the standard calling for the use of this document.

NOTE The IEC 61508-7:2010 clauses listed in [Tables B.1](#) to [B.6](#) refer to the relevant requirements in IEC 61508-2 and IEC 61508-3.

6 Use of ISO/TS 8100-3

ISO/TS 8100-3:2019, Clause 4, includes requirements that shall be followed when applicable for use in combination with this document.

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Annex A
(normative)

Model form of type examination certificate

The examination certificate shall contain the following information.

MODEL TYPE-EXAMINATION CERTIFICATE

Name of the approved body

.....

Type-examination number

1 Type and make or trade name

2 Name and address of manufacturer

.....

3 Name and address of certificate holder

.....

4 Date of submission for type-examination

5 Certificate issued on the basis of the following requirement

.....

6 Test laboratory

7 Date and number of laboratory report

8 Date of type-examination

9 The following documents, bearing the type-examination number shown above, are annexed to this certificate

.....

10 Any additional information

.....

Place Date

Name and position of person signing the certificate

(Signature)

Annex B (normative)

Programmable electronic systems in safety related applications for lifts (PESSRAL)

B.1 Common measures

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

No.	Object	Measure	Reference to IEC 61508-7:2010
1	Processing unit	Use of watch dog.	A.9
2	Component selection	Use of components only within their specifications	
3	I/O units and interfaces incl. Communication links	Defined safe state in the event of power failure or reset	
4	Power supply	Defined safe shut-off state in case of over-voltage or under-voltage	A.8.2
5	Variable memory ranges	Use of only solid state memories.	
6	Variable memory ranges	Read/write test of variable data memory during boot procedure	
7	Variable memory ranges	Remote access only to informative data (e.g. statistics)	
8	Invariant memory ranges	No possibility to change the program code, either automatically by the system or remote intervention	
9	Invariant memory ranges	Test of program code memory and fixed data memory during boot procedure with a method at least equivalent to sum check	A.4.2

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

No.	Object	Measure	Reference to IEC 61508-7:2010
1	Structure	Program structure (i.e. modularity, data handling, interface definition) according to the state of the art (see IEC 61508-3).	B.3.4/C.2.1 C.2.9/C.2.7
2	Boot procedure	During boot procedures a safe state of the lift shall be maintained.	
3	Interrupts	Limited use of interrupts: Use of nested interrupts only if all possible sequences of interrupts are predictable.	C.2.6.5
4	Interrupts	No triggering of watchdog by interrupt procedure except in combination with other program sequence conditions.	A.9.4
5	Power down	No power down procedures, such as saving of data, for safety related functions.	
6	Memory management	Stack manager in the hardware and/or software with appropriate reaction procedure.	C.2.6.4/ C.5.4

Table B.2 (continued)

No.	Object	Measure	Reference to IEC 61508-7:2010
7	Program	Iteration loops shorter than system reaction time, e.g. by limiting number of loops or checking execution time.	
8	Program	Array pointer offset checks, if not included in the used programming language.	C.2.6.6
9	Program	Defined handling of exceptions (e.g. divisions by zero, overflow, variable range checking etc.) which forces the system into a defined safe state.	
10	Program	No recursive programming, except in well tried standard libraries, in approved operating systems, or in high-level language compilers. For these exceptions separate stacks for separate tasks shall be provided and controlled by a memory management unit.	C.2.6.7
11	Program	Documentation of programming library interfaces and operating systems at least as complete as the user program itself.	
12	Program	Plausibility checks on data relevant to safety functions e.g. input patterns, input ranges, and internal data.	C.2.5/C.3.1
13	Program	If any operational mode can be invoked for testing or validation purposes normal operation of the lift shall not be possible until this mode has been terminated.	IEC 61508-1:2010, 7.7.2.1
14	Communication system (external and internal)	Reach a safe state with due consideration to the system reaction time in a bus communication system with safety functions in case of loss of communication or a fault in a bus participant.	A.7/A.9
15	Bus system	No reconfiguration of the CPU-bus system, except during the boot procedure. NOTE Periodical refresh of the CPU-bus system is not considered as being reconfiguration.	C.3.13
16	I/O handling	No reconfiguration of I/O lines, except during the boot procedures. NOTE Periodical refresh of the I/O configuration registers is not considered as being reconfiguration.	C.3.13

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

No.	Measure	Reference to IEC 61508-7:2010
1	Assessment of the functional, environmental and interface aspects of the application	A.14/B.1
2	Requirement specification including the safety requirements	B.2.1
3	Reviews of all specifications	B.2.6
4	Design documentation as required in 5.6.1 and in addition: — function description including system architecture and hardware/software interaction; — software documentation including function and program flow description	C.5.9
5	Design review reports	B.3.7/B.3.8, C.5.16
6	Check of reliability using a method such as failure mode and effect analysis (FMEA)	B.6.6
7	Manufacturer's test specification, manufacturer's test reports and field test reports	B.6.1

Table B.3 (continued)

No.	Measure	Reference to IEC 61508-7:2010
8	Instruction documents incl. limits for intended use	B.4.1
9	Repeat and update of above mentioned measures if the product is modified	C.5.23
10	Implementation of version control of hardware and software and its compatibility.	C.5.24

B.2 Specific measures

Table B.4 — Specific measures according to SIL 1

Components and functions	Requirements	Measures	see No. in B.7	Reference to IEC 61508-7:2010
Structure	The structure shall be such that any single random failure is detected and the system shall go into a safe state.	One channel structure with self-test, or	M 1.1	A.3.1
		two channels or more with comparison.	M 1.3	A.2.5
Processing units	Failures in processing units, which can lead to incorrect results, shall be detected. If such a failure can lead to a dangerous situation the system shall go into a safe state.	Failure correcting hardware, or	M 2.1	A.3.4
		self-test by software, or comparator for two-channel structure, or	M 2.2 M 2.4	A.3.1 A.1.3
		reciprocal comparison by software for 2-channel structure.	M 2.5	A.3.5
Invariant memory ranges	Incorrect information modification, i.e. all odd bit-or 2-bit failures and some 3-bit and multi-bit failures shall be detected at the latest before the next travel of the lift.	The following measures refer only to a one-channel structure:		
		one-bit redundancy (parity bit), or block safety with one-word redundancy.	M 3.5 M 3.1	A.5.5 A.4.3
Variable memory ranges	Global failures during addressing, writing, storing and reading as well as all odd bit and 2-bit failures and some 3-bit failures and multi-bit failures shall be detected at the latest before the next travel of the lift.	The following measures refer only to a one-channel structure:		
		Word-saving with multi-bit redundancy, or check via test pattern against static or dynamic faults.	M 3.2 M 4.1	A.5.6 A.5.2

NOTE As a consequence of the detection of a failure, a safe state of the lift shall be maintained.

Table B.4 (continued)

Components and functions	Requirements	Measures	see No. in B.7	Reference to IEC 61508-7:2010
I/O units and interfaces incl. communication links	Static failures and cross talk on I/O lines as well as random and systematic failures in the data flow shall be detected at the latest before the next travel of the lift.	Code safety, or test pattern.	M 5.4 M 5.5	A.6.2 A.6.1
Clock	Failures in clock generation for processing units like frequency modification or break down shall be detected at the latest before the next travel of the lift.	Watchdog with separate time base, or reciprocal monitoring.	M 6.1 M 6.2	A.9.4
Program sequence	Wrong program sequence and inappropriate execution time of the safety related functions shall be detected at the latest before the next travel of the lift.	Combination of timing and logical monitoring of program sequence	M 7.1	A.9.4
NOTE As a consequence of the detection of a failure, a safe state of the lift shall be maintained.				

Table B.5 — Specific measures according to SIL 2

Components and functions	Requirements	Measures	see No. in B.7	Reference to IEC 61508-7:2010
Structure	The structure shall be such that any single random failure is detected with due consideration to the system reaction time and that the system goes into a safe state.	One channel with self-test and monitoring, or	M 1.2	A.3.3
		two channels or more with comparison.	M 1.3	A.2.5
Processing units	Failures in processing units, which can lead to incorrect results, shall be detected with due consideration to the system reaction time. If such a failure can lead to a dangerous situation the system shall go into a safe state.	Failure correcting hardware, and	M 2.1	A.3.4
		software self-test supported by hardware for one-channel structure, or	M 2.3	A.3.3
		comparator for 2-channel structure, or	M 2.4	A.1.3
Invariant memory ranges	Incorrect information modification, i.e. all odd bit-or 2-bit failures and some 3-bit and multi-bit failures shall be detected with due consideration to the system reaction time.	The following measures refer only to a one-channel structure:		
		Block safety with one-word redundancy, or word saving with multi-bit redundancy.	M 3.1 M 3.2	A.4.3 A.5.6
NOTE As a consequence of the detection of a failure, a safe state of the lift shall be maintained.				