भारतीय मानक
Indian Standard

IS 17900 (Part 2) : 2022

[*Superseding* IS 14665 (Part 1) : 2000,
IS 14665 (Part 2/Sec 1) : 2000,
IS 14665 (Part 3/Sec 1) : 2000,
IS 14665 (Part 4/Sec 1 to 9) : 2001,
IS 14671 : 1999, IS 15785 : 2007]

यात्री एवम सामान के परिवहन के लिए लिफ्ट्स

भाग 2 लिफ्ट घटक के डिजाइन नियम, गणना, जाँच एवम परीक्षण

Lifts for the Transport of Persons and Goods

Part 2 Design Rules, Calculations, Examinations and Tests of Lift Components

ICS 91.140.90

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Lifts, Escalators and Moving Walks Sectional Committee, ETD 25

FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards, after the draft finalized by the Lifts, Escalators and Moving Walks Sectional Committee had been approved by the Electrotechnical Division Council.

The requirements for traction lifts were earlier covered in IS 14665 (Parts 1 to 4) which were published in the years 2000 and 2001. IS 14671 published in 1999 provided the 'Code of practice for installation and maintenance of hydraulic lift' and IS 15785 published in 2007 provided the 'Code of practice for installation and maintenance of lift without conventional machine rooms'.

This Part and Part 1 of this series of standards supersedes IS 14665 (Part 1), IS 14665 (Part 2/Sec 1), IS 14665 (Part 3/Sec 1), IS 14665 (Part 4/Sec 1 to 9), IS 14671 and IS 15785.

This Indian Standard is a part of series of Indian Standards on 'Lifts for the transport of persons and goods'. Other parts of this series of standards cover various requirements like specifications for control devices, buttons, signals, indicators, and other fittings; specifications for planning and selection, guide for inspection and maintenance of lifts, lifts for special applications, dumbwaiters etc. Other parts of this series are under development.

This standard is to be read in conjunction with IS 17900 (Part 1) : 2022.

This standard and its part 1 introduces major changes to the existing standards that will bring more safety to the passengers, service engineers, and public in general, in connection with the use of lifts and lift installations This part of the standard introduces the type testing requirements for safety components of lifts, such as:

a) Overspeed governor;
b) Buffer;
c) Landing and car door locking devices;
d) Safety gear;
e) PESSRAL component;
f) Ascending car overspeed protection means;
g) Unintended car movement protection means;
h) Rupture valve/one-way restrictor.

Following calculations are also made available for use:

1) Guide rail;
2) Evaluation of traction;
3) Evaluation of safety factor on suspension ropes;
4) Rams, cylinders, rigid pipes, and fittings;
5) Calculation against over pressure;
6) Calculation of jacks against buckling.

This standard is largely based on ISO 8100-2 : 2019 'Lifts for the transport of persons and goods — Part 2 : Design rules, calculations, examinations and tests of lift components'. In order to suit the Indian market requirements and considering provisions of enhanced safety, changes have been made in the standard ISO 8100-2. However, the structure of ISO 8100-2 : 2019 has been retained. Clauses from ISO 8100-2 which have not been accepted as part of this standard have been indicated as "Not Used" keeping the clause numbering same as the original ISO 8100-2. Clauses with major modifications/additions/deletions can be identified with a vertical line placed against them.

Main changes with regard to the ISO 8100-2 include:

a) Formulae for various calculations have been corrected;
b) Deletion of Annex A (model form of type examination certificate).

The composition of the Committee, responsible for the formulation of this standard is given at Annex F.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'.

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INTRODUCTION

The object of this standard 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 [for example, IS 17900 (Part 1)] calling for the use of this standard with regard to persons and objects to be safeguarded, assumptions, principles, etc.

Indian Standard

LIFTS FOR THE TRANSPORT OF PERSONS AND GOODS

PART 2 DESIGN RULES, CALCULATIONS, EXAMINATIONS AND TESTS OF LIFT COMPONENTS

1 SCOPE

This Indian Standard (Part 2) 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 REFERENCES

The standards listed below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards.

IS No./ International Publication	*Title*
2824 : 2007	Method for the determination of the proof and the comparative tracking indices of solid insulating materials (*second revision*)
9000 (Part 7/Sec 1) : 2018	Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 1 Shock (Test Ea) (*second revision*)
13252 (Part 1) : 2010	Information technology equipment — Safety: Part 1 General requirements (*second revision*)
15382 (Part 1) : 2014	Insulation coordination for equipment within low — Voltage systems: Part 1 Principles, requirements and tests (*first revision*)
16819 : 2018	Safety of machinery — General principles for design — Risk assessment and risk reduction
17806 : 2022	Passenger lifts and service lifts — Guide rails for lift cars and counterweights — T-type
17900 (Part 1) : 2022	Lifts for the transport of persons and goods: Part 1 Safety rules
IS/IEC 60068-2-6 : 2007	Environmental testing — Part 2-6: Tests — Test Fc: Vibration (sinusoidal)
IS/IEC 60947-4-1 : 2012	Low -voltage switchgear and controlgear: Part 4 Contactors and motor — Starters, Section 1 Electromechanical contactors and motor — Starters (*first revision*)
IS/IEC 60947-5-1 : 2009	Low-Voltage switchgear and controlgear: Part 5 Control circuit devices and switching elements, Section 1 Electromechanical control circuit devices (*first revision*)
IS/IEC 61508-1 : 2010	Functional safety of electrical/ electronic/programmable electronic safety-related systems: Part 1 General requirements (*first revision*)
IS/IEC 61508-2 : 2010	Functional safety of electrical/electronic/programmable electronic safety — Related systems: Part 2 Requirements for electrical/electronic/programmable electronic safety related systems (*first revision*)
IS/IEC 61508-3 : 2010	Functional safety of electrical/ electronic/programmable electronic safety-related systems: Part 3 Software requirements (*first revision*)
IS/IEC 61508-7 : 2010	Functional safety of electrical/ electronic/programmable electronic safety-related systems: Part 7 Overview of techniques and measures (*first revision*)
IS/IEC 62326-1 : 2002	Printed boards: Part 1 Generic specification

IS No./ International Publication	*Title*
IEC 60068-2-14 : 2009	Environmental testing — Part 2-14: Tests — Test N: Change of temperature
IEC 60747-5-5 : 2020	Semiconductor devices — Part 5-5: Optoelectronic devices — Photocouplers
IEC 61249 series	Materials for printed boards and other interconnecting structures
IEC 61558-1 : 2005	Safety of power transformers, power supplies, reactors and similar products — Part 1: General requirements and tests
ISO 4344 : 2004	Steel wire ropes for lifts — Minimum requirements
ISO 22559-1: 2014	Safety requirements for lifts (elevators) — Part 1: Global essential safety requirements (GESRs)
EN 10025 series	Hot rolled products of structural steels

3 TERMINOLOGY

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

3.1 Certifying Entity — Organization or manufacturer, operating a 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 certifying entity (**3.1**) carrying out a type-examination in which it certifies that the product example under consideration complies with the provisions applicable to it as noted in the certificate.

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 standard, identified by risk assessment as significant for this type of machinery, and they require action to eliminate or reduce the risk (*see* Table 1).

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 standard. 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 This clause number has not been used.

5.1.2.2 This clause number has not been used.

5.1.2.3 This clause number has not been used.

5.1.2.4 This clause number has not been used.

5.1.2.5 This clause number has not been used.

5.1.2.6 Unless specified otherwise, the precision of the instruments shall allow measurements to be made within the following accuracy:

a) ± 1 percent for masses, forces, distances, speeds;
b) ± 2 percent for accelerations, retardations;
c) ± 5 percent 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) ± 2.5 percent for flow rate;
g) ± 1 percent for pressure, P, up to and including 200 kPa;
h) ± 5 percent 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.

Table 1 List of Significant Hazards

(*Clause* 4)

Sl No.	Hazards (as listed in Annex B of IS 16819)	Relevant Clauses
(1)	(2)	(3)
1	**Mechanical hazards due to:**	
	i) Acceleration, deceleration (kinetic energy)	**5.3; 5.4; 5.5; 5.7; 5.8; 5.9**
	ii) Approach of a moving element to a fixed part	**5.2**
	iii) Elastic elements	**5.10; 5.11; 5.12; 5.13**
	iv) Falling objects	**5.3; 5.4; 5.5; 5.9**
	v) Gravity (stored energy)	**5.3; 5.4; 5.5; 5.9**
	vi) Height from the ground	**5.3; 5.4; 5.5; 5.9**
	vii) High pressure	**5.13**
	viii) 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**
	ix) Rotating elements	**5.4; 5.11; 5.12**
	x) Stability	**5.10; 5.11; 5.12; 5.13; 5.14**
	xi) Strength	**5.10; 5.11; 5.12; 5.13; 5.14**
2	**Electrical hazards**	
	xii) Arc	**5.2; 5.4; 5.6; 5.7; 5.8; 5.15; 5.16**
	xiii) Electrostatic phenomena	**5.2; 5.4; 5.6; 5.7; 5.8; 5.15; 5.16**
	xiv) Live parts	**5.2; 5.4; 5.6; 5.7; 5.8; 5.15; 5.16**
	xv) Not enough distance to live parts under high voltage	**5.2; 5.4; 5.6; 5.7; 5.8; 5.15; 5.16**
	xvi) Overload	**5.2; 5.4; 5.6; 5.7; 5.8; 5.15; 5.16**
	xvii) Parts which have become live under faulty conditions	**5.2; 5.4; 5.6; 5.7; 5.8; 5.15; 5.16**
	xviii) Short-circuit	**5.2; 5.4; 5.6; 5.7; 5.8; 5.15; 5.16**
3	**Hazards generated by radiation**	
	xix) Low frequency electromagnetic radiation	**5.6; 5.15; 5.16**
	xx) Radio frequency electromagnetic radiation	**5.6; 5.15; 5.16**
4	**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**

5.2.1.2 *Documents required*

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 tested.

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:

a) the mechanical and electrical components of the locking device are operating correctly with respect to safety, and in conformity with:
   1) the requirements of this standard;
   2) the standard calling for this locking device;
b) the device is in conformity with the particulars provided by the manufacturer.

In particular, it shall be verified that:

1) there is at least 7 mm engagement of the locking elements before the electric safety device operates;
2) 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 (*see* **5.2.2.2.2**) 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 percent) 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 percent) 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 percent) cycles.

The driving of the device shall be smooth, without shocks, and at a rate of 60 (± 10 percent) 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 *Acceptance 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 IS/IEC 60947-4-1 and IS/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 percent 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 ± 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 percent 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 percent of the steady-state value of the test current in 300 ms.

The test current shall be 110 percent 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 IS 2824. 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 standard [for example, **5.11.2.2.4** of IS 17900 (Part 1)].

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 standard, the devices providing direct mechanical linkage between panels [for example, **5.3.14.1** of IS 17900 (Part 1)] or indirect mechanical linkage [for example, **5.3.14.2** of IS 17900 (Part 1)] 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) type and application of locking device;
b) type (a.c. and/or d.c.) and values of the rated voltage and rated current;
c) 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 range of use provided shall be stated, that is:

a) minimum and maximum masses;
b) 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 submitted by the manufacturer:

1) detailed and assembly drawings showing the construction, operation, materials used, dimensions and tolerances of the construction components;

2) 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 for testing.

The arrangement and the fixing details for the samples shall be in accordance with the equipment that is used.

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 declared by the manufacturer. 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 over speed governor fixed in the requirements laid down in the standards calling for the use of this standard [for example, **5.6.2.2.1.2** of IS 17900 (Part 1)], shall be adopted.

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

$$h = \frac{v_1^2}{2 \times g_n} + 0 \cdot 1 + 0.03 \qquad ...(1)$$

where

g_n = the standard acceleration of free fall, in metres per square second;
v_1 = 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):

$$2 \times K = (P + Q)_1 \times g_n \times h \qquad ...(2)$$

$$(P + Q)_1 = \frac{2 \times K}{g_n \times h} \qquad ...(3)$$

where

K = 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, that is, part of the travelling cable, compensation means (if any), etc., in kilograms;
Q = the rated load, in kilograms;
$(P + Q)_1$ = 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):

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

where

K = calculated by the integration of the area defined in **5.3.2.2.3.2 a)**;

2 = 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.

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

where

K_1 = calculated by the integration of the area defined in **5.3.2.2.3.2 b) 1)**;

2 = taken as the dividing safety coefficient.

$$(P+Q)_1 = \frac{2 \times K_2}{3.5 \times g_n \times h} \quad ...(6)$$

where

K_2 = calculated by the integration of the area defined in **5.3.2.2.3.2 b) 2)**;

3.5 = taken as the dividing safety coefficient.

5.3.3 *Progressive Safety Gear*

5.3.3.1 *Statement and test sample*

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

The manufacturer 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, together with the number of brake shoes necessary for all the tests, shall be made available. 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 for testing shall also be made available.

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 the:

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

5.3.3.2.2 *Test procedure*

5.3.3.2.2.1 *Safety gear for a single mass*

Four tests with the mass $(P + Q)_1$ shall be performed. 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 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 manufacturer shall supply a formula, or a chart, showing the variation of the braking force as a function of a given parameter.

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

5.3.3.2.3 *Determination of the braking force of the safety gear*

5.3.3.2.3.1 *Safety gear for a single mass*

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

A check shall be made that the average values determined during the tests lie within a range of ± 25 percent 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 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 declared by the manufacturer;
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 for a single mass*

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

$$(P+Q)_1 = \frac{F_B}{16} \qquad \text{...(7)}$$

where

F_B = the braking force in newtons, determined in accordance with **5.3.3.2.3**;
P = the masses of the empty car and components supported by the car, i.e. part of the travelling cable, compensation means (if any), etc, in kilograms;
Q = the rated load, in kilograms;
$(P + Q)_1$ = 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 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 percent from those declared by the manufacturer, other tests may be made 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 ± 7.5 percent. It is accepted, in these conditions, that the requirements laid down in the standards calling for the use of this standard [for example, **5.6.2.1** of IS 17900 (Part 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 type and application of safety gear;
b) the limits of the permissible masses [*see* **5.3.4 a)**];
c) the tripping speed of the overspeed governor;
d) the type of guide rail;
e) the permissible thickness of the guide rail blade;
f) the minimum width of the gripping areas; and, for progressive safety gear only:
g) the surface condition of the guide rails (drawn, milled, ground);
h) 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 following shall be indicated for testing:

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 submitted and declared by the manufacturer.

5.4.2 *Check on the Characteristics of the Overspeed Governor*

5.4.2.1 *Test samples*

The following shall be submitted for testing:

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;

   Adequate length shall be supplied for testing;
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 declared by the manufacturer;
b) the operation of the electric safety device called for in the standards calling for the use of this standard [for example, **5.6.2.2.1.6 a)** of IS 17900 (Part 1)] 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 standard [for example, **5.6.2.2.1.6 b)** of IS 17900 (Part 1)] 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 standard.

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 standard [for example, **5.6.2.2.1.6 a)** and **5.6.2.2.1.6 b)** of IS 17900 (Part 1)].

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

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 type and application of overspeed governor;
b) the maximum and minimum rated speeds of the lift for which the overspeed governor may be used;
c) the diameter of the rope to be used and its construction;
d) in the case of an overspeed governor with traction pulley, the minimum tensioning force;
e) the tensile force in the rope which can be produced by the overspeed governor when tripped.

5.5 Type Examination of Buffers

5.5.1 *General Provisions*

The range of use provided, i.e. maximum impact speed, minimum and maximum masses shall be stated. Following information shall be submitted with the sample:

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 for testing:

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 by the manufacturer.

The retardation shall conform to the requirements of the standard calling for this device [for example, **5.8.2.2.3** of IS 17900 (Part 1)].

The creeping at the end of the buffer stroke for calculation of the average retardation shall be ignored where the retardation is below 0.5 m/s^2.

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

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

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 This clause number has not been used.

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 declared by the manufacturer, equal to 50 percent of the real height of the buffer, shall not vary by more than 5 percent. 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*" [for example, **5.8.2.1.2.1** of IS 17900 (Part 1)], shall conform to the following requirements:

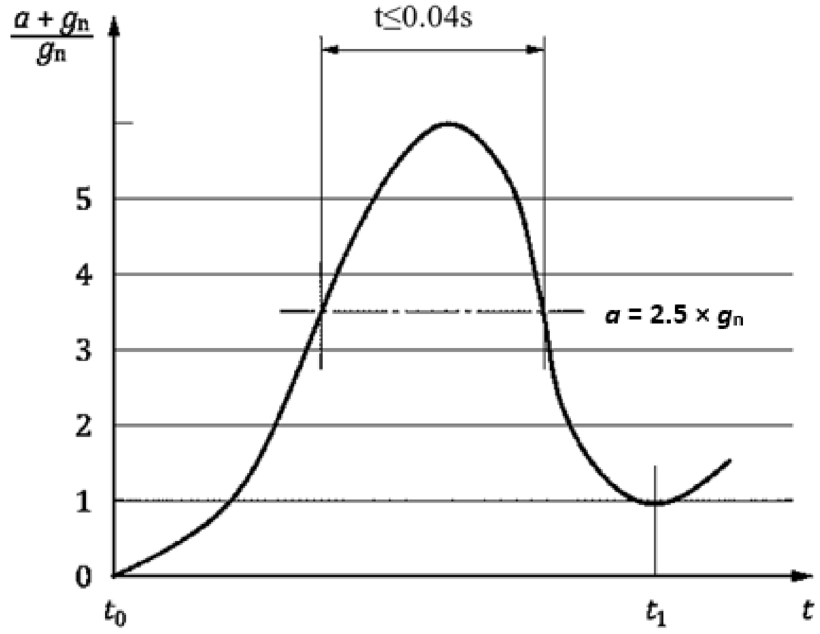
a) The retardation will be evaluated taking into account the time between the first two absolute minima of the retardation (*see* Fig. 1). The retardation shall not exceed the maximum as required by the standard calling for this device.
b) Peaks of retardation above a value specified by the standard calling for this device shall not exceed the maximum duration of these peaks as required by the standard calling for this device [for example, **5.8.2.1.2.1 b)** of IS 17900 (Part 1)]
c) The maximum peak retardation shall not exceed the maximum as required in the standard calling for this device [for example, **5.8.2.1.2.1 e)** of IS 17900 (Part 1)].
d) The return speed shall not exceed the maximum as required in the standard calling for this device.

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 declared by the manufacturer, the testing is to be carried out with acceptable limits which may be determined with additional testing.



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

FIG. 1 RETARDATION GRAPH — EXAMPLE USING IS 17900 (PART 1) REQUIREMENTS

5.5.4 *Type Examination Certificate*

The certificate shall indicate the following:

a) type and application of buffer;
b) dimensions of the buffer;
c) maximum impact speed;
d) maximum mass;
e) minimum mass;
f) kind of fixation;
g) specification of the liquid in the case of hydraulic buffers;
h) 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, type 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 following shall be indicated for testing:

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 A;
b) general description of the software used (for example, 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 for testing:

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) IS/IEC 60068-2-6, Table C.2: 20 sweep cycles in each axis, at amplitude 0.35 mm, and in the frequency range 10 Hz–55 Hz;
b) Table 1 of IS 9000 (Part 7/Sec 1) - the combination of:
   1) peak acceleration 294 m/s^2 or 30 g_n;
   2) corresponding duration of pulse 11 ms;
   3) 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 [IS 9000 (Part 7/Sec 1)]*

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:

a) the printed circuit board shall be in operational position;
b) the printed circuit board shall be supplied with rated operational voltage;
c) 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);
d) tests shall be carried out for minimum and maximum temperature (0°C + 65°C). Tests shall last a minimum of four hours;
e) 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 standard shall be validated. [for example, **5.11.2.3** of IS 17900 (Part 1)].

5.6.3.4 *Functional and safety test of PESSRAL*

In addition to the verification of the measures defined in Tables A-1 to A-6, the following shall be validated:

a) Software design and coding: Inspect all code statements using methods such as formal design reviews, PAGAN, test cases etc.;
b) Software and hardware inspection: Verify all measures of Tables A-1 and A-2 and the measures chosen, for example, from Table A-7 by using fault insertion testing (based on IS/IEC 61508-2 and IS/IEC 61508-7).

5.6.4 *Type Examination Certificate*

The certificate shall indicate:

a) the type and application of the circuitry;
b) the design for pollution degree according to IS 15382 (Part 1);
c) the operating voltages;
d) 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:

a) ascending car overspeed protection means which are not using overspeed governors, or
b) 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 manufacturer 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 for testing:

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

5.7.2.2 Either:

a) a complete assembly consisting of both elements, braking device and speed monitoring device; or
b) only that device which was not subject to verifications according to **5.3, 5.4** and **5.6**; shall be provided by the manufacturer as required.

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 proper dimensions for testing.

5.7.3 *Test*

5.7.3.1 *Test method*

The test method shall be as per mutual agreement between the manufacturer and the user, depending on the device and its function to achieve a realistic function of the system. Measurements shall be made of the:

a) acceleration and speed;
b) braking distance;
c) 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 for a single mass*

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

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

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

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 standard [for example, **5.6.6.1** of IS 17900 (Part 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 declared by the manufacturer;
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 1 g_n.

5.7.4 *Possible Modification to the Adjustments*

If, during the tests, the values found differ by more than 20 percent from those expected by the manufacturer, other tests may be made, 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:

a) method of test defined;
b) description of the testing arrangement;
c) location of the device to be tested in the testing arrangement;
d) number of tests carried out;
e) record of measured values;
f) report of observations during the test;
g) evaluation of the test results to show compliance with the requirements.

5.7.6 *Type Examination Certificate*

The certificate shall indicate the:

a) type and application of overspeed protection means;
b) limits of the permissible masses;
c) tripping speed range of the overspeed monitoring device;
d) 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 key parameters for use of the system or subsystem that form part of the type examination shall be stated:

a) minimum and maximum masses;
b) minimum and maximum force or torque or fluid pressure, if applicable;
c) individual response times of detector, control circuit and stopping element(s);
d) highest speed anticipated before deceleration occurs (*see* Note 1);
e) distance from the floor at which the detector device will be installed;
f) test speed(s) (*see* Note 2);
g) limits of temperature and humidity of the design and any other relevant.

NOTE 1 — As an example and indication, for traction lifts, where the natural acceleration is 1.5 m/s^2 and without any torque contribution from the motor, the maximum speed attainable would be in the magnitude of 2 m/s. This is based on the speed attained at start of deceleration, for example, being the result of a “natural” acceleration of 1.5 m/s^2 through the response times of the unintended car movement protection device, control circuit and stopping elements, assuming that the movement detector operates when the car reaches the limit of the unlocking zone.

In case of electric failure, it can be assumed that, for traction lifts due to internal control means, the acceleration which can be achieved is not greater than 2.5 m/s^2.

NOTE 2 — Test speed(s): a speed stated by the manufacturer, used 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 for testing requirements.

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 standard [for example, **5.6.7.5** of IS 17900 (Part 1)].

The following documents shall be submitted:

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 It shall be stated for what duty the means is intended.

5.8.2.2 Test samples shall be supplied for testing 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 for testing requirements.

5.8.3 *Test*

5.8.3.1 *Test method*

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

Measurements shall be made of:

a) the stopping distance;
b) the average retardation;
c) the response time of the detection, actuation, stopping element and control circuits (*see* Fig. 2);
d) the total distance travelled (sum of acceleration and stopping distances).

The test shall also include:

1) the operation of the unintended car movement detection device;
2) any automatic monitoring system, if applicable.

5.8.3.2 *Test procedure*

5.8.3.2.1 *General*

Twenty tests shall be made on the stopping element with:

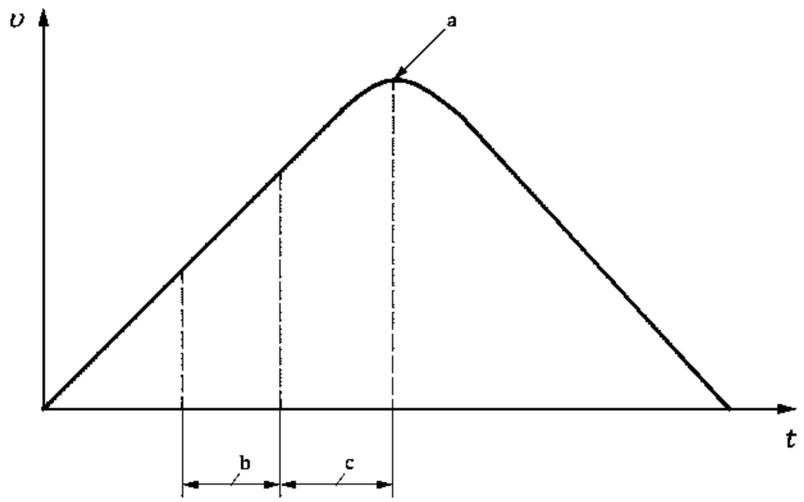
a) no result outside the specification;
b) each result within ± 20 percent of the average value.

Average value shall be stated on the certificate.

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

The following shall be carried out:

a) 10 tests with the system mass or torque or fluid pressure representing an empty car in the upward direction;
b) 10 tests with the system mass or torque or fluid pressure representing a car carrying the rated load in the downward direction.



Key

υ 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.

FIG. 2 RESPONSE TIMES

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 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.

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

The validity of the formula or chart shall be verified.

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 declared by the manufacturer. Other analyses may be carried out in special cases;
b) it shall be checked that there are no fractures, deformations or any other changes (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.

5.8.4 *Possible Modification to the Adjustments*

If, during the tests, the values found differ by more than 20 percent from those expected by the manufacturer, another series of tests may be made 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:

a) method of test defined;
b) description of the testing arrangement;
c) location of the device to be used when installed in the testing arrangement;
d) number of tests carried out;
e) record of all measured values;
f) report of observations during the test;
g) evaluation of the test results to show compliance with the requirements.

5.8.6 *Type Examination Certificate*

The certificate shall indicate:

a) the type and application of the unintended car movement protection system/subsystem;
b) the limits of the key parameters (as defined for testing);
c) the test speed with relevant parameters for final inspection use;
d) the type of parts on which the stopping elements act;
e) the combination of "detecting" device and "stopping" element of the means in the case of complete systems;
f) the interface conditions in case of subsystems.

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*

Following shall be stated for getting the component tested:

a) the range of:
   1) flow;
   2) pressure;
   3) viscosity;
   4) ambient temperature;
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 also be submitted.

5.9.1.2 *Samples to be submitted*

The following shall be submitted for testing:

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.

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 before and behind the rupture valve can be recorded;

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

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

The system shall allow recording of the flow over time. To determine the values of flow, the measurement of another figure, that is, 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 percent.

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

a) flow;
b) viscosity;
c) pressure;
d) ambient temperature.

This can be achieved by 2 test series with:

1) maximum pressure, maximum ambient temperature, minimum adjustable flow and minimum viscosity;
2) 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:

a) flow and time;
b) pressure before the rupture valve and time;
c) pressure behind the rupture valve and time, shall be recorded.

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

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 standard if the curves recorded according to **5.9.1.4.2** show that:

a) the time, t_0, between the rated flow (100 percent 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):

$$\frac{|Q_{max}|}{6\times A\times 9.81} < t_d \leq \frac{|Q_{max}|}{6\times A\times 1.96} \qquad ...(8)$$

where

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

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

t_d = the braking time, in seconds;

c) a pressure of more than $3.5 \times P_S$, 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.

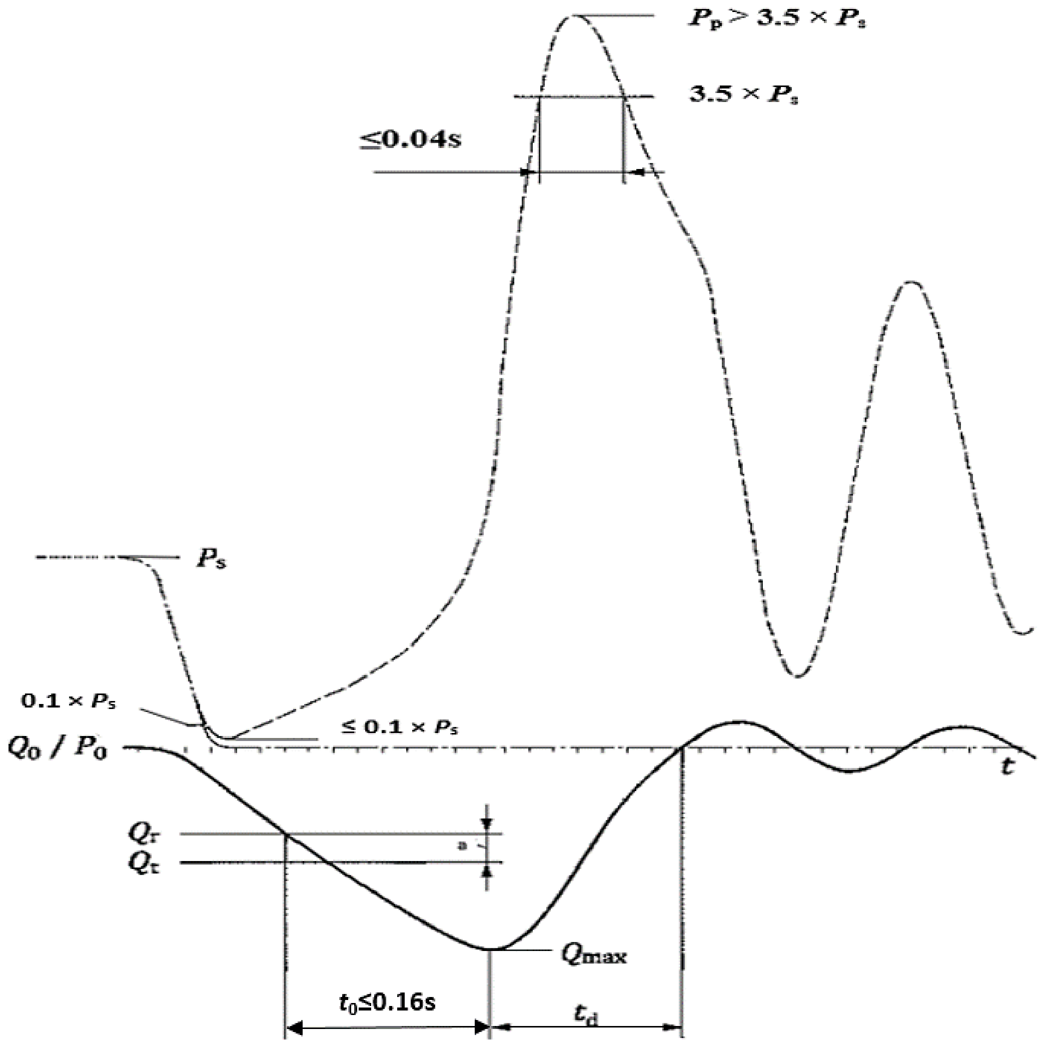
5.9.1.5.3 *Readjustment*

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 type and application of the rupture valve;
b) the range of:



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.

FIG. 3 HYDRAULIC FLUID FLOW THROUGH PRESSURE BEFORE AND BEHIND THE RUPTURE VALVE

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 Fig. 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:

a) bending stress;
b) combined bending;
c) buckling stress;
d) compression stress/tension stress;
e) combined bending and compression/tension stress;
f) combined buckling and bending;
g) flange bending stress.

In addition, deflections shall be analyzed.

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

5.10.2 *Bending*

5.10.2.1 Calculating the bending stresses in the different axes of the guide rail (*see* Fig. 4), it can be assumed that:

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

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

$$\text{with } M_m = \frac{3 \times F_b \times l}{16} \qquad ...(10)$$

where

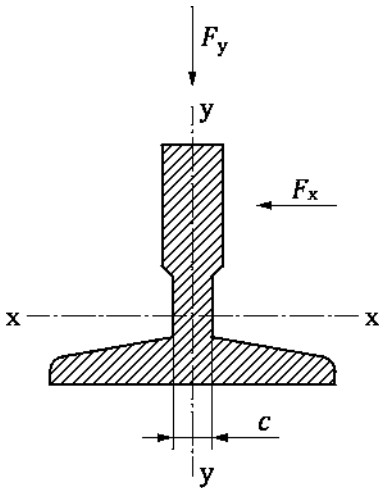
F_b = the horizontal force applied to the guide rail by the guide shoes in the different load cases, in newtons;

l = the maximum distance between guide brackets, in millimetres;

M_m = the bending moment, in newtons millimetres;

σ_m = the bending stress, in newtons per square millimetre;

W = the cross-sectional area modulus, in cubic millimetres.



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

FIG. 4 AXES OF THE GUIDE RAIL

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, the usual values of tables given in IS 17806 (respectively $W_{x,\ min}$ and $W_{y,\ min}$) does not exceed the permissible stresses, no further proof is necessary. Otherwise, it shall be analyzed at which outer edge of the guide rail profile the tensile stresses have their maximum values.

5.10.2.3 If more than two guide rail lines are used, an equal distribution of the forces between the guide rail lines 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):

$$\sigma_k = \frac{(F_V + k_3 + M_{aux}) \times \omega}{A} \qquad ...(11)$$

where

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

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

k_3 = the impact factor;

M_{aux} = the force in a guide rail due to auxiliary equipment, in newtons;

σ_k = the buckling stress in newtons per square millimetre;

ω = the omega value.

The omega values can be evaluated by using Formulae (12) and (13):

$$A = l_k / i \qquad ...(12)$$

$$l_k = l \qquad ...(13)$$

where

A = the slenderness;

i = the minimum radius of gyration, in millimetres;

l = the maximum distance between guide brackets, in millimetres;

l_k = the buckling length, in millimetres.

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

Value of λ	Value of ω
$20 \le \lambda \le 60$	$\omega = 0.000\,129\,20 \times \lambda^{1.89} + 1$
$60 < \lambda \le 85$	$\omega = 0.000\,046\,27 \times \lambda^{2.14} + 1$
$85 < \lambda \le 115$	$\omega = 0.000\,017\,11 \times \lambda^{2.35} + 1.04$
$115 < \lambda \le 250$	$\omega = 0.000\,168\,87 \times \lambda^{2.00}$

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

Value of λ	Value of ω
$20 \le \lambda \le 50$	$\omega = 0.000\,082\,40 \times \lambda^{2.06} + 1.021$
$50 < \lambda \le 70$	$\omega = 0.000\,018\,95 \times \lambda^{2.41} + 1.05$
$70 < \lambda \le 89$	$\omega = 0.000\,024\,47 \times \lambda^{2.36} + 1.03$
$89 < \lambda \le 250$	$\omega = 0.000\,253\,30 \times \lambda^{2.00}$

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):

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

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):

Bending stresses:

$$\sigma = \sigma_m = \sigma_x + \sigma_y \le \sigma_{perm} \qquad ...(15)$$

Bending and compression/tension:

$$\sigma = \sigma_m + \frac{F_v + k_3 \times M_{aux}}{A} \le \sigma_{perm} \qquad ...(16)$$

Bending and buckling:

$$\sigma = \sigma_k + 0.9 \times \sigma_m \le \sigma_{perm} \qquad ...(17)$$

where

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

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

k_3 = the impact factor;

M_{aux} = the force in a guide rail due to auxiliary equipment, in newtons;

σ = the combined stress, in newtons per square millimetre;

σ_k = the buckling stress, in newtons per square millimetre

σ_m = the bending stress, in newtons per square millimetre;

σ_{perm} = the permissible stress, in newtons per square millimetre, see the standards calling for the use of this document [for example, **5.7.4.5** of IS 17900 (Part 1)];

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

σ_y = 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:

$$\sigma_F = \frac{1.85 \times F_x}{c^2} \le \sigma_{perm} \quad \text{for roller guide shoes} \qquad ...(18)$$

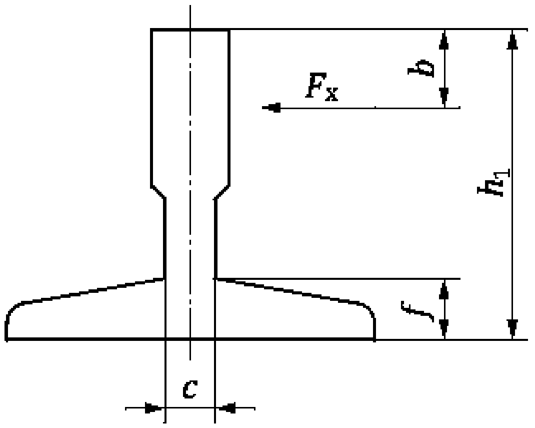
$$\sigma_F = \frac{F_x \times (h_1 - b - f) \times 6}{c^2 \times [l + 2 \times (h_1 - f)]} \le \sigma_{perm}$$

for sliding guide shoes ...(19)

where

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

NOTE — Dimensions are shown in Fig. 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

FIG. 5 DIMENSIONS FOR FLANGE BENDING CALCULATION

5.10.6 *Deflections*

$$\delta_y = 0.7 \times \frac{F_y \times l^3}{48 \times E \times I_x} \leq \delta_{perm} \quad ...(20)$$

$$\delta_x = 0.7 \times \frac{F_x \times l^3}{48 \times E \times I_y} \leq \delta_{perm} \quad ...(21)$$

where

- δ_{perm} = the maximum permissible deflection, in millimetres;
- δ_x = the deflection in the X-axis, in millimetres;
- δ_y = the deflection in the Y-axis, in millimetres;
- E = the modulus of elasticity, in newtons per square millimetre;
- F_x = the supporting force in the X-axis, in newtons;
- F_y = the supporting force in the Y-axis, in newtons;
- I_x = the second moment of area in the X-axis, in fourth power millimetres;
- I_y = the second moment of area in the Y-axis, in fourth power millimetres;
- l = 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:

a) normal travel;
b) loading the car at floor level;
c) 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.

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

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

where

α = the angle of wrap of the suspension means on the traction sheave;

f = the friction factor;

T_1, T_2 = 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 percent 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:

a) 0.5 m/s^2 in normal cases;

b) 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.

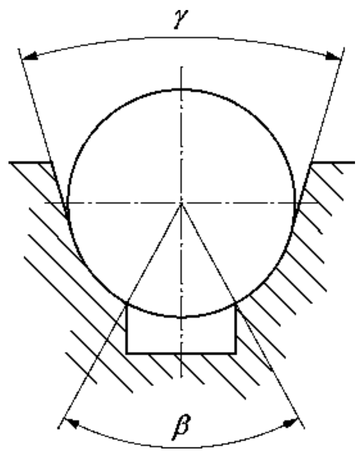
5.11.2.2.3 *Car/counterweight stalled condition*

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 Fig. 6)*



Key

β undercut angle

γ groove angle

FIG. 6 SEMI-CIRCULAR GROOVE, UNDERCUT

Formula (24) shall be used:

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

where

β = the value of the undercut angle;

γ = the value of the groove angle;

μ = the friction coefficient;

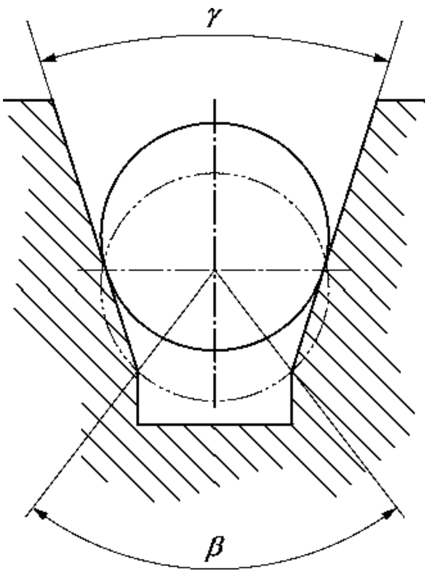
f = the friction factor.

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 Fig. 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

FIG. 7 V-GROOVE

Formulae (25) to (27) apply:

a) in the case of car loading and emergency braking:

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

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

b) in the case of counterweight stalled conditions:

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

where

β = the value of the undercut angle;

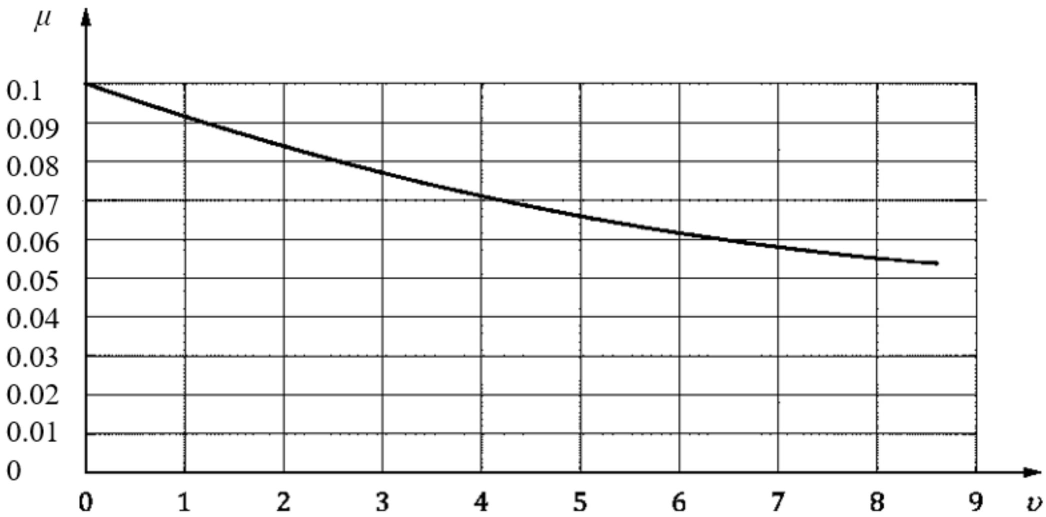
γ = the value of the groove angle;

μ = the friction coefficient;

f = 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 Fig. 8)*



Key

μ friction coefficient

v speed in meters per second

FIG. 8 MINIMUM FRICTION COEFFICIENT

The following values apply:

a) $\mu = 0.1$ for loading conditions;

b) $\mu = 0.2$ for counterweight stalled conditions;

c) Formula (28) for emergency braking conditions:

$$\mu = \frac{0.1}{1+\frac{v}{10}} \quad ...(28)$$

where

μ = the friction coefficient;

v = the rope speed at rated speed of the car.

5.11.3 *Formulae for a General Case (see Fig. 9)*

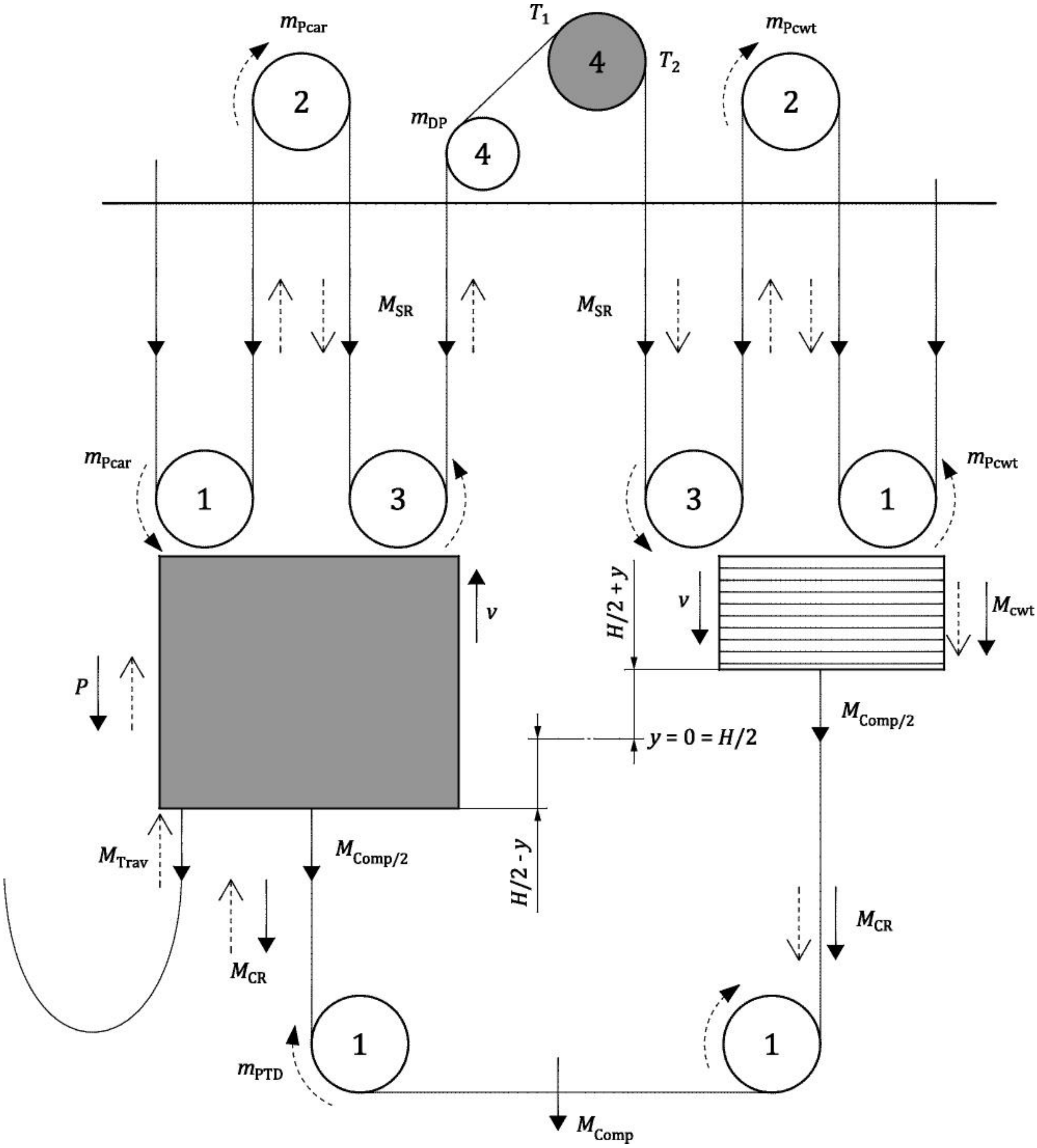


FIG. 9 GENERAL CASE (*Continued*)

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) of pulleys on counterweight side, in kilograms	M_{SR}	actual mass of suspension ropes, in kilograms
m_{PTD}	reduced mass (related to car/counterweight) of one pulley on tensioning device	M_{Trav}	actual mass of travelling cable, in kilograms
Y	level 0.5 H → y = 0, in metres	P	masses of the empty car, in kilograms
T_1, T_2	force exerted on rope, in newtons	v	rotation speed of the pulley (rope speed), in m/s
1, 2, 3, 4	speed factor of pulleys (example: 2 = 2 × v_{car})		

FIG. 9 GENERAL CASE (*Concluded*)

Formulae (29) to (32) apply.

a) For machinery located above:

$$\text{T}_1 = \frac{\left(P+Q+M_{CRcar}+M_{Trav}\right)}{r}\times\left(g_n \pm a\right)+\frac{M_{Comp}}{2\times r}\times g_n + M_{SRcar}\times\left(g_n \pm a\times\frac{r^2+2}{3}\right)\pm\left(\frac{i_{PTD}\times m_{PTD}}{2\times r}\times a\right)\pm \frac{(m_{DP}\times a)^I}{r}\pm\left[\frac{\left[\ \sum_{i=1}^{r-1}\left(m_{Pcar}\times i_{Pcar}\times a\right)\ \right]}{r}\right]^{III}\mp\frac{FR_{car}}{r} \quad ...(29)$$

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

b) For machinery located below:

$$\text{T}_1 = \frac{\left(P+Q+M_{\text{CRcar}}+M_{\text{Trav}}\right)}{r}\times(g_{\text{n}} \pm a)\frac{M_{\text{Comp}}}{2\times r}\times g_{\text{n}} + M_{\text{SR1car}}\times\left(-g_{\text{n}} \pm a\right)+M_{\text{SR2car}}\times\left(g_{\text{n}} \pm a\times\frac{r^2+2}{3}\right)\pm\left(\frac{i_{\text{PTD}}\times m_{\text{PTD}}}{2\times r}\times a\right)\pm\frac{(m_{\text{DP}}\times a)^I}{r}\pm\left[\frac{\sum_{i=1}^{r-1}\left(m_{\text{Pcar}}\times i_{\text{Pcar}}\times a\right)}{r}\right]^{III}\mp\frac{FR_{\text{car}}}{r} \quad ...(31)$$

$$\text{T}_2 = \frac{(M_{Cwt}+M_{Trav})}{r}\times(g_{\text{n}} \mp a)+\frac{M_{Comp}}{2\times r}\times g_{\text{n}} + M_{\text{SR1car}}\times\left(-g_n \pm a\right)+M_{\text{SR2car}}\times\left(g_n \mp a\times\frac{r^2+2}{3}\right)\mp\left(\frac{i_{PTD}\times m_{PTD}}{2\times r}\times a\right)\mp\frac{(m_{DP}\times a)^I}{r}\mp\left[\frac{\left[\sum_{i=1}^{r-1}\left(m_{Pcar}\times i_{Pcar}\times a\right)\right]}{r}\right]^{III}\pm\frac{FR_{cwt}}{r} \quad ...(32)$$

where,

a	=	the braking retardation (positive value) of the car, in metres per square second;
FR_{car}	=	the frictional force in the well (efficiency of bearings car side and friction on guide rails, etc.), in newtons;
FR_{cwt}	=	the frictional force in the well (efficiency of bearings counterweight side and friction on guide rails, etc.), in newtons;
g_{n}	=	the standard acceleration of free fall, in metres per square second;
H	=	the travel height, in metres;
i_{Pcar}	=	the number of pulleys on car side with same rotation speed v_{pulley} (without deflection pulleys);

i_{Pcwt} = the number of pulleys on counterweight side with same rotation speed v_{pulley} (without deflection pulleys);

i_{PTD} = the number of pulleys for tensioning device;

m_{DP} = the reduced mass (related to the car/counterweight) of deflection pulleys on car and/or counterweight side $J_{DP} \times (v_{pulley}/v)^2/R^2$, in kilograms;

m_{Pcar} = the reduced mass (related to the car) of pulleys on car side $J_{Pcar} \times (v_{pulley}/v)^2/R^2$, in kilograms;

m_{Pcwt} = the reduced mass (related to the counterweight) of pulleys on counterweight side $J_{Pcwt} \times (v_{pulley}/v)^2/R^2$, in kilograms;

m_{PTD} = the reduced mass (related to car/counterweight) of one pulley on tensioning device J_{PTD}/R^2, in kilograms;

M_{Comp} = the mass of tension device including mass of pulleys, in kilograms;

M_{CR} = the actual mass of compensation ropes/chains [$(0.5 \times H \pm y) \times n_c \times$ *rope weight per unit length*], in kilograms;

MCR_{car} = the mass M_{CR} on the car side;

MCR_{cwt} = the mass M_{CR} on the counterweight side;

M_{cwt} = the mass of counterweight including mass of pulleys, in kilograms;

M_{SR} = the actual mass of suspension ropes [$(0.5 \times H \pm y) \times n_s \times$ *rope weight per unit length*], in kilograms;

M_{SRcar} = the mass M_{SR} on car side.

NOTE — 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 ± and R shall be used in such a way that:

a) the upper operation is applicable in case the car with its rated load is retarding in the downward direction,

b) 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 — For calculation example, *see* Annex C.

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 [$(0.25H \pm 0.5y) \times n_t \times$ *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 $0.5 \times H \rightarrow y = 0$, in metres;

→ is the static force;

— → 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 [for example, **5.5.2.2** of IS 17900 (Part 1)], 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:

a) Steel or cast iron traction sheaves;

b) Steel wire ropes according to 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):

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

where

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

$N_{equiv(p)}$ = 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.

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)].

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

where

N_{ps} = the number of pulleys with simple bends;

N_{pr} = the number of pulleys with reversed bends;

K_p = the factor of ratio between sheave and pulley diameters.

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

where

D_t = the diameter of the traction sheave;

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

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

5.12.3 *Safety Factor*

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

The curves of the Fig. 10 are based on Formula (36):

$$S_f = 10^{\left(2.6834 - \frac{\log\left(\frac{695.85 \times 10^6 \times N_{equiv}}{\left(\frac{D_t}{d_r}\right)^{8.567}}\right)}{\log\left(77.09 \times \left(\frac{D_t}{d_r}\right)^{-2.894}\right)}\right)} \quad ...(36)$$

where

D_t = the diameter of traction sheave;

d_r = the diameter of the ropes;

N_{equiv} = the equivalent number of pulleys;

S_f = 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 Fig. 11)*

Table 2 Evaluation of Equivalent Number of Traction Sheaves $N_{equiv(t)}$

(*Clauses* 5.12.2.2, Fig. D-1 *and* Fig. D-2)

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

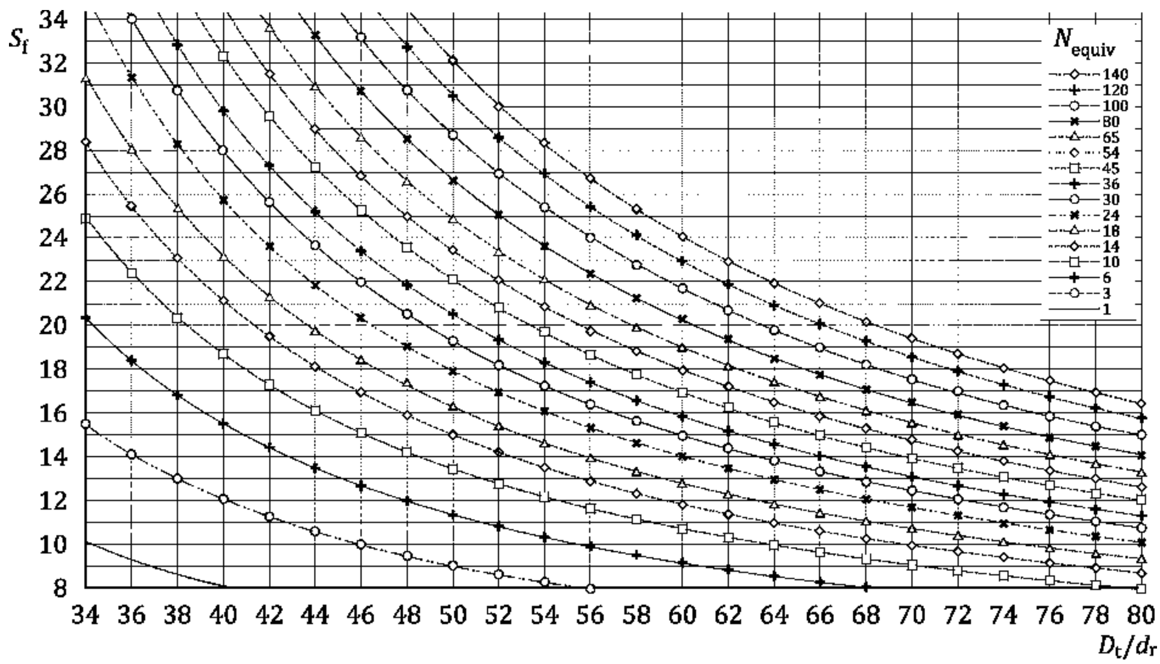
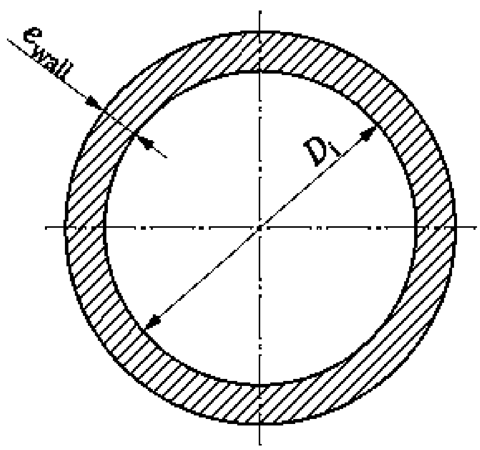


FIG. 10 EVALUATION OF MINIMUM SAFETY FACTOR



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

FIG. 11 WALL THICKNESS CALCULATION

Calculate wall thickness, e_{wall}, with Formula (37):

$$e_{wall} \geq \frac{2.3 \times 1.7 \times p}{R_{p0.2}} \times \frac{D_i}{2} + e_0 \qquad ...(37)$$

where

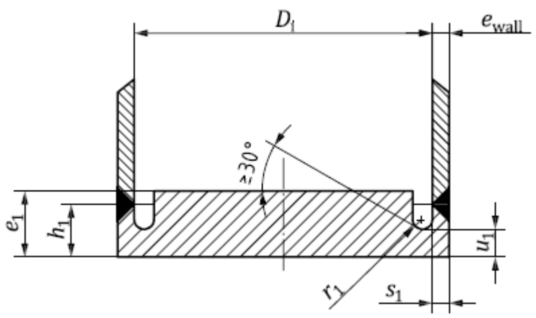
- D_i = the inside diameter of the cylinder, in mm;
- e_o = 1.0 mm for wall and base of cylinders and rigid pipes between the cylinder and the rupture valve, if any;
- e_o = 0.5 mm for rams and other rigid pipes;
- p = the full load pressure, in megapascals;
- $R_{p0.2}$ = the proof stress (non-proportional elongation), in newtons per square millimetre;
- 2.3 = the factor for friction losses (1.15) and pressure peaks (2);
- 1.7 = 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 Fig. 12)*



Key

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

FIG. 12 FLAT BASES WITH RELIEVING GROOVE

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

$$r_1 \geq 0.2 \times e_1 \qquad ...(38)$$

$$\text{and } r_1 \geq 5 \text{ mm} \qquad ...(39)$$

$$u_1 \leq 1.5 \times s_1 \qquad ...(40)$$

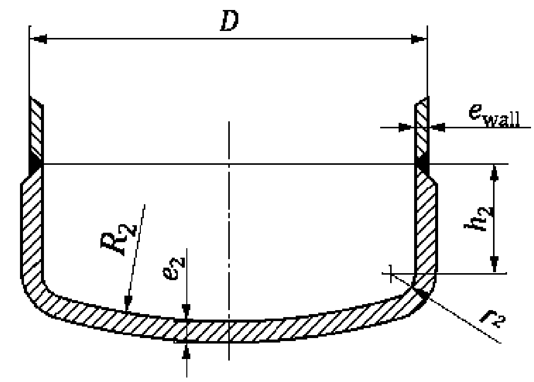
$$h_1 \geq u_1 + r_1 \qquad ...(41)$$

$$e_1 \geq 0.4 \times D_i \sqrt{\frac{2.3 \times 1.7 \times p}{R_{P0.2}}} + e_0 \qquad ...(42)$$

$$u_1 \geq 1.3 \times \left(\frac{D_i}{2} - r_1\right) \times \frac{2.3 \times 1.7 \times p}{R_{P0.2}} + e_0 \qquad ...(43)$$

- D_i = the inside diameter of the cylinder, in mm;
- e_o = 1.0 mm for wall and base of cylinders;
- e_1 = the thickness of the flat base, in mm;
- h_1 = the height of the base wall, in mm;
- p = the full load pressure, in megapascals;
- r_1 = the inside radius of the base, in mm;
- s_1 = the thickness of the base wall, in mm;
- u_1 = the thickness of the base at the bottom of the relieving groove, in mm;
- 2.3 = the factor for friction losses (1.15) and pressure peaks (2);
- 1.7 = the safety factor referred to the proof stress.

5.13.1.2.3 *Cambered based (see Fig. 13)*



Key

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

FIG. 13 CAMBERED BASED

Conditions, see Formulae (43) to (46):

$$h_2 \geq 3.0 \times e_2 \quad ...(44)$$

$$r_2 \geq 0.15 \times \mathrm{D} \quad ...(44)$$

$$R_2 = 0.8 \times D \quad ...(45)$$

$$e_2 \geq \frac{2.3 \times 1.7 \times p}{R_{P0.2}} \times \frac{D}{2} + e_0 \quad ...(46)$$

where

D = the outer diameter of the cylinder, in mm;

e_0 = 1.0 mm for wall and base of cylinders;

e_2 = the thickness of the cambered base, in mm;

h_2 = the height of the base wall, in mm;

p = the full load pressure, in mega pascals;

r_2 = the inside radius of the base, in mm;

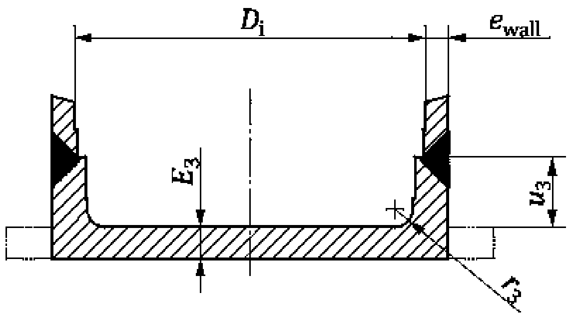
R_2 = the inside radius of the cambered base, in mm;

$R_{P0.2}$ = the proof stress (non-proportional elongation), in newtons per square millimeter;

2.3 = the factor for friction losses (1.15) and pressure peaks (2);

1.7 = the safety factor referred to the proof stress.

5.13.1.2.4 *Flat bases with welded flange (see Fig. 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

FIG. 14 FLAT BASES WITH WELDED FLANGE

Conditions, *see* Formulae (47) to (50):

$$u_3 \geq e_3 + r_3 \quad ...(47)$$

$$r_3 \geq \frac{e_{wall}}{3} \quad ...(48)$$

$$and\ r_3 \geq 8 \text{ mm} \quad ...(49)$$

$$e_3 \geq 0.4 \times D_i \sqrt{\frac{2.3 \times 1.7 \times p}{R_{P0.2}}} + e_0 \quad ...(50)$$

where

u_3 = the height base wall, in mm;

e_3 = the thickness of the flat base, in mm;

r_3 = the inside radius of the base, in mm;

e_{wall} = the wall thickness of the cylinder, in mm;

D_i = the inside diameter of the cylinder, in mm;

p = the full load pressure, in megapascals;

$R_{P0.2}$ = the proof stress (non-proportional elongation), in newtons per square millimetre;

e_o = 1.0 mm for wall and base of cylinders;

2.3 = the factor for friction losses (1.15) and pressure peaks (2);

1.7 = the safety factor referred to the proof stress.

5.13.2 *Calculations of the Jacks against Buckling*

5.13.2.1 *General*

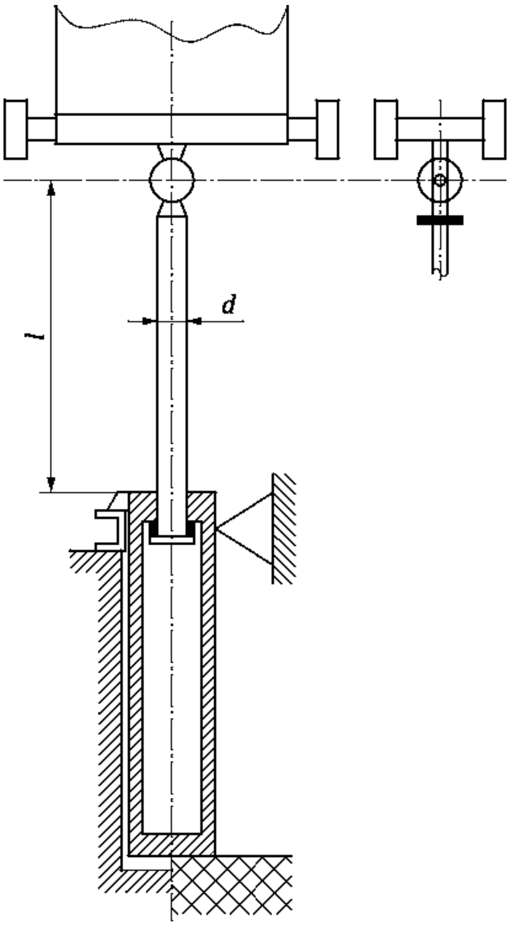
The buckling calculation shall be made on the part with least buckling resistance according to Formulae (51) to (57) as applicable.

5.13.2.2 *Single acting jacks (see Fig. 15)*

For $\lambda_n \geq 100$: $F_s \leq \dfrac{\pi^2 \times E \times J_n}{2 \times l^2}$ ...(51)

For $\lambda_n < 100$: $F_s \leq \dfrac{A_n}{2}\left[R_m - (R_m - 210) \times \left(\dfrac{\lambda_n}{100}\right)^2\right]$ ... (52)

$F_s = 1.4 \times g_n \times [c_m \times (\mathrm{P} + \mathrm{Q}) + 0.64 \times P_r + P_{rh}]$ (valid for rams extending in upward direction) ...(53)



Key

d diameter of ram

l length of ram subject to buckling

FIG. 15 SINGLE ACTING JACKS

where

A_n = 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 = the modulus of elasticity, in newtons per square millimetre (for steel: $E = 2.1 \times 10^5$ N/mm^2);

F_s = the actual buckling force applied, in newtons;

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

i_n = the radius of gyration of the ram to be calculated, in millimetres (n = 1, 2, 3);

J_n = the second moment of area of the ram to be calculated, in fourth power millimetres (n = 1, 2, 3);

l = the maximum length of rams subject to buckling, in millimetres;

P = 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 = the mass of the ram to be calculated, in kilograms;

P_{rh} = the mass of the ram head equipment, if any, in kilograms;

Q = the rated load (mass) displayed in the car, in kilograms;

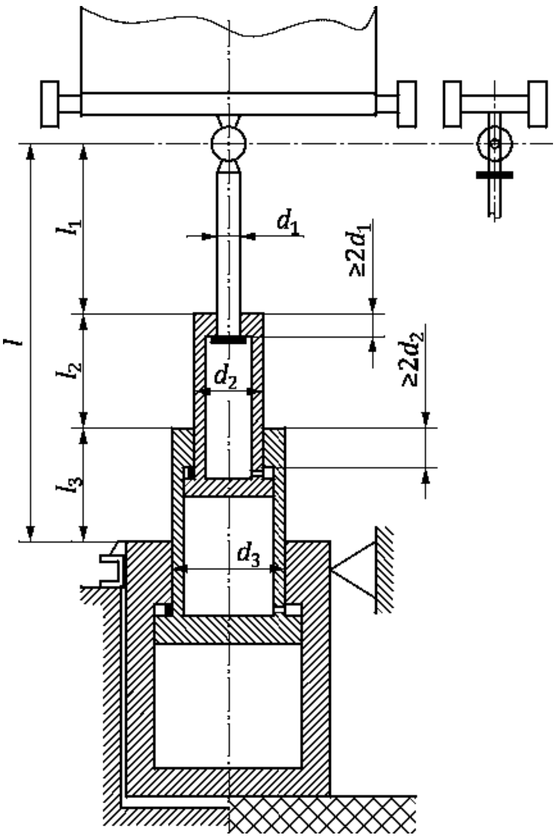
R_m = the tensile strength of material, in newtons per square millimetre;

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

1.4 = the over pressure factor;

2 = the safety factor against buckling.

5.13.2.3 *Telescopic jacks without external guidance, calculation of ram (see Fig. 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

FIG. 16 TELESCOPIC JACKS WITHOUT EXTERNAL GUIDANCE

<table>
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$l = l_1 + l_2 + l_3$, $\quad l_1 = l_2 = l_3$

$v = \sqrt{\frac{J_1}{J_2}}; J_3 \geq J_2 > J_1$

(assumption for simplified calculation: $J_3 = J_2$

for 2 sections:

$\phi = 1.25 \times v - 0.2$ for $0.22 < v < 0.65$

for 3 sections:

$\phi = 1.5 \times v - 0.2$ for $0.22 < v < 0.65$

$\phi = 0.65 \times v + 0.35$ for $0.65 < v < 1$

</td>
<td>

$\lambda_e = \frac{l}{i_e}$ with $i_e = \frac{d_m}{4}\sqrt{\phi \times \left[1 + \left(\frac{d_{mi}}{d_m}\right)^2\right]}$

For $\lambda_e \geq 100$

$F_s \leq \frac{\pi^2 \times E \times J_2}{2 \times l^2} \times \phi$

For $\lambda_e < 100$

$F_s \leq \frac{A_n}{2}\left[R_m - (R_m - 210) \times \left(\frac{\lambda_n}{100}\right)^2\right]$

</td>
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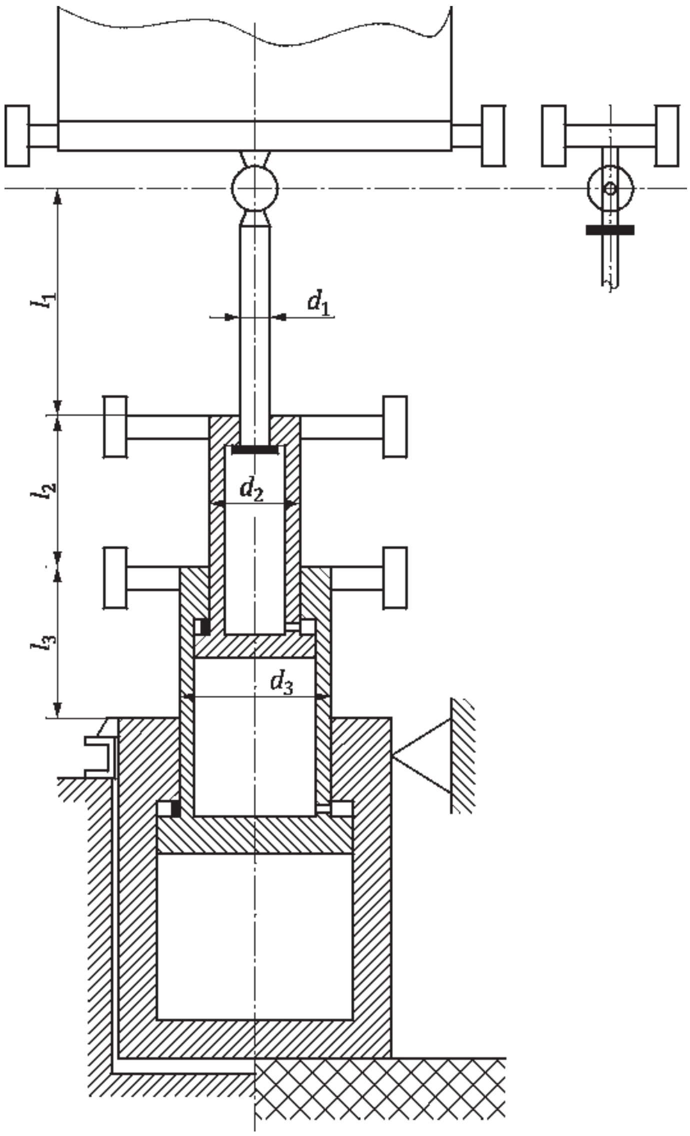
$F_s = 1.4 \times g_n \times [c_m \times (P+Q) + 0.64 \times P_r + P_m + P_{rt}]$ (valid for rams extending in upward direction) ...(54)

where

A_n	=	the cross-sectional area of the material of the ram to be calculated, in square millimetres (n = 1, 2, 3);
c_m	=	the reeving ratio;
d_m	=	the outside diameter of the biggest ram of a telescopic jack, in millimetres;
d_{mi}	=	the inner diameter of the biggest ram of a telescopic jack, in millimetres;
E	=	the modulus of elasticity, in newtons per square millimetre (for steel: $E = 2.1 \times 10^5$ N/mm²);
F_s	=	the actual buckling force applied, in newtons;
g_n	=	the standard acceleration of free fall, in metres per square second;
i_e	=	the equivalent radius of gyration of a telescopic jack, in millimetres;
in	=	the radius of gyration of the ram to be calculated, in millimetres (n = 1, 2, 3);
J_n	=	the second moment of area of the ram to be calculated, in fourth power millimetres (n = 1, 2, 3);
l	=	the maximum length of rams subject to buckling, in millimetres;
P	=	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	=	the mass of the ram to be calculated, in kilograms;
P_{rh}	=	the mass of the ram head equipment, if any, in kilograms;
P_{rt}	=	the mass of the rams acting on the ram to be calculated (in the case of telescopic jacks), in kilograms;
Q	=	the rated load (mass) displayed in the car, in kilograms;
R_m	=	the tensile strength of material, in newtons per square millimetre;
$R_{P0.2}$	=	the proof stress (non-proportional elongation), in newtons per square millimetre;
$\lambda_e = \frac{l}{i_e}$	=	the equivalent coefficient of slenderness of a telescopic jack;
$\lambda_n = \frac{l}{i_n}$	=	the coefficient of slenderness of the ram to be calculated;
v, ϕ	=	the factors used to represent approximate values given by experimentally determined diagrams;
1.4	=	the over pressure factor;
2	=	the safety factor against buckling.

5.13.2.4 *Telescopic jacks with external guidance (see Fig. 17)*



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

FIG. 17 TELESCOPIC JACKS WITH EXTERNAL GUIDANCE

For $\lambda_n \geq 100$: $F_s \leq \dfrac{\pi^2 \times E \times J_n}{2 \times l_n^2}$ ...(55)

For $\lambda_n < 100$: $F_s \leq \dfrac{A_n}{2}\left[R_m - \left(R_m - 210\right) \times \left(\dfrac{\lambda_n}{100}\right)^2\right]$ ...(56)

$F_s = 1.4 \times g_n \times [c_m \times (P + Q) + 0.64 \times P_r + P_{rh} + P_{rt}]$ (valid for rams extending in upward direction) ...(57)

where

A_n = the cross-sectional area of the material of the ram to be calculated, in square millimetres (n = 1, 2, 3);

c_m = the reeving ratio;

D_m = the outside diameter of the biggest ram of a telescopic jack, in millimetres;

D_{mi} = the inner diameter of the biggest ram of a telescopic jack, in millimetres;

E	=	the modulus of elasticity, in newtons per square millimetre (for steel: $E = 2.1 \times 10^5$ N/mm^2);
F_s	=	the actual buckling force applied, in newtons;
g_n	=	the standard acceleration of free fall, in metres per square second;
i_n	=	the radius of gyration of the ram to be calculated, in millimetres (n = 1, 2, 3);
J_n	=	the second moment of area of the ram to be calculated, in fourth power millimetres (n = 1, 2, 3);
l_n	=	the length of ram subject to buckling, in millimetres (n = 1, 2, 3);
P	=	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	=	the mass of the ram to be calculated, in kilograms;
P_{rh}	=	the mass of the ram head equipment, if any, in kilograms;
P_{rt}	=	the mass of the rams acting on the ram to be calculated (in the case of telescopic jacks), in kilograms;
Q	=	the rated load (mass) displayed in the car, in kilograms;
R_m	=	the tensile strength of material, in newtons per square millimetre;
$R_{P0.2}$	=	the proof stress (non-proportional elongation), in newtons per square millimetre;
$\lambda_n = \frac{l}{i_n}$	=	the coefficient of slenderness of the ram to be calculated;
1.4	=	the over pressure factor;
2	=	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 Fig. 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 kg ± 0.01 kg by filling with lead balls of a diameter of 3.5 mm ± 0.5 mm.

5.14.2.2 *Soft pendulum shock device*

The soft pendulum shock device shall be a small shot bag according to Fig. 19 made of leather, which is filled with lead balls of a diameter of 3.5 mm ± 0.5 mm up to an overall mass of 45 kg ± 0.5 kg.

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 mm ± 10 mm. The pendulum length (lower end of the hook to reference point of the shock device) shall be at least 1.5 m.

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*

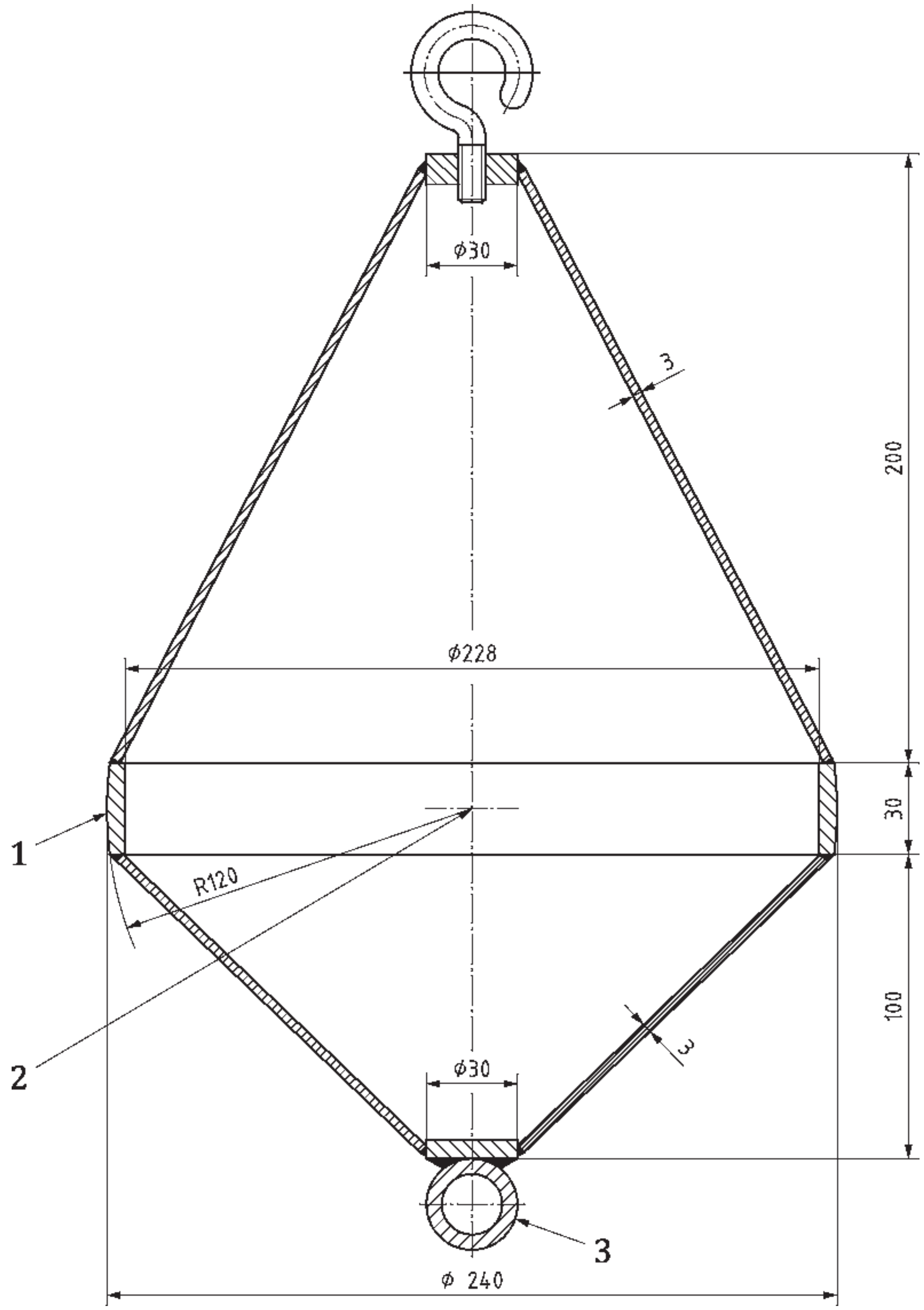
5.14.2.5.1 The test samples shall be complete and shall have the intended size and fixations according to the specific application. The test samples shall be fixed to the test frame in such a way that at the fixation points, no deformations under test conditions are possible (stiff fixation).

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°C ± 5°C. The panels shall be stored directly before the tests for at least 4 hours at that temperature.

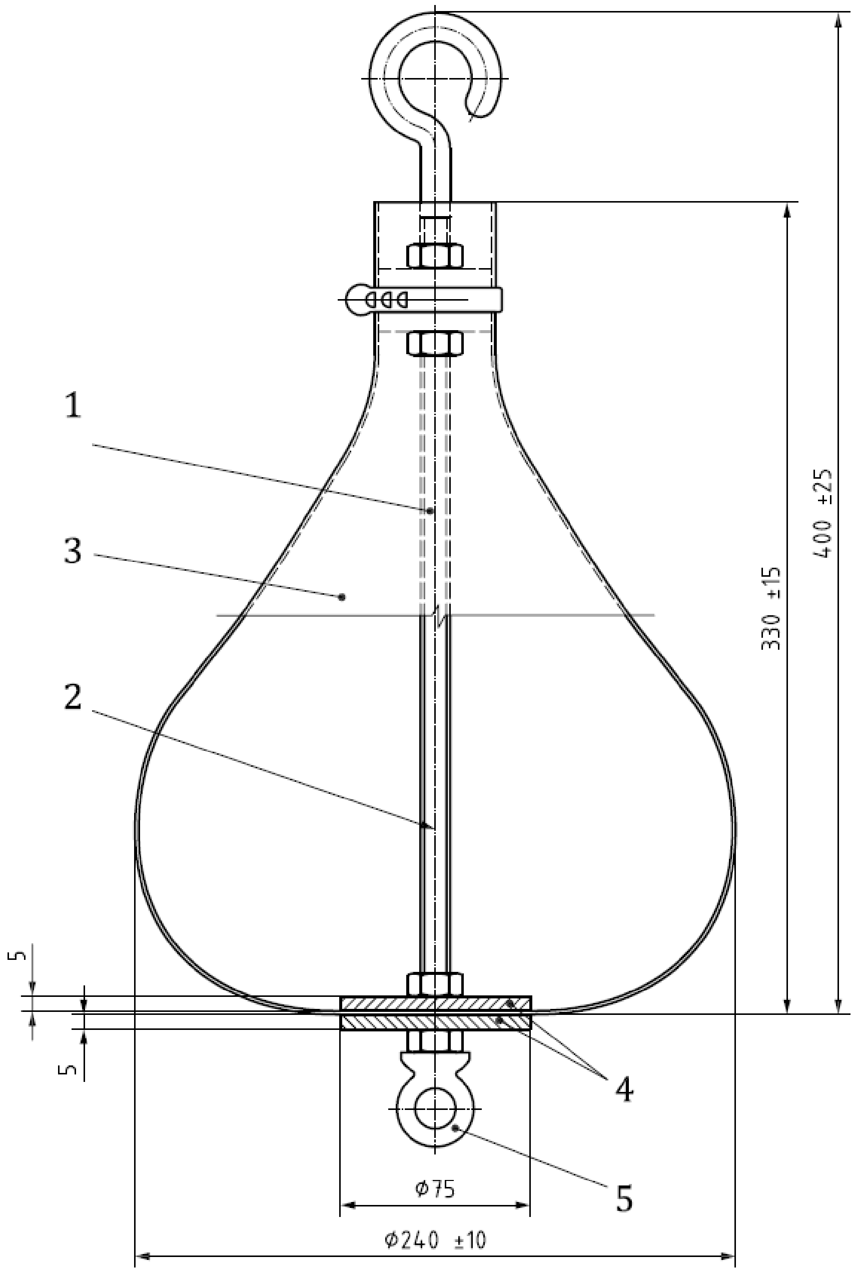
5.14.3.2 The hard pendulum shock test shall be carried out with the device according to **5.14.2.1** with a falling height and test arrangement according to Fig. 18 and Fig. 20.



Key

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

FIG. 18 HARD PENDULUM SHOCK DEVICE



Key

1 screwed rod

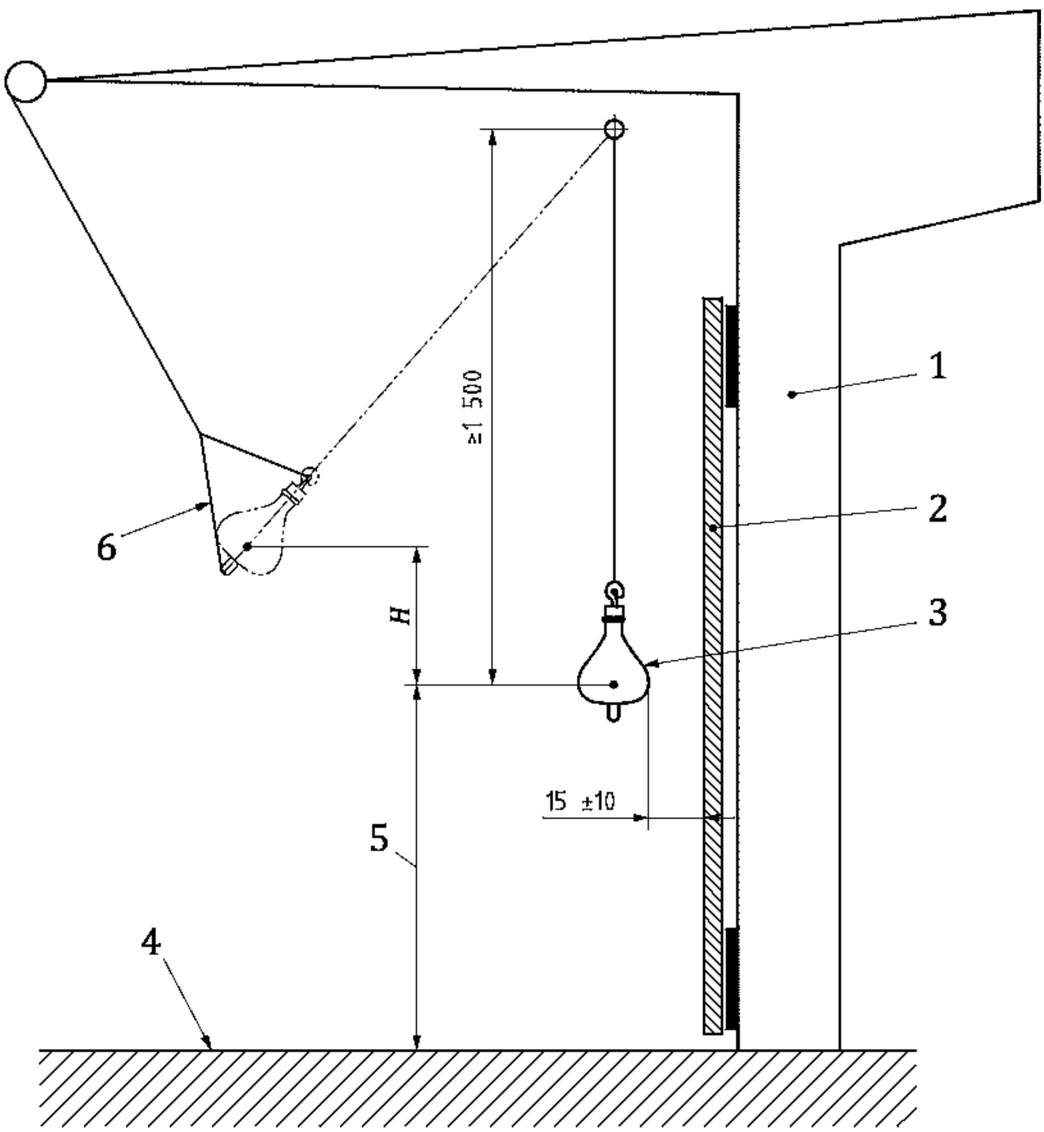
2 reference point for measuring the falling height in the plane of the maximum diameter

3 leather bag

4 steel disk

5 triggering device attachment

FIG. 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

All dimensions in millimetres.

FIG. 20 TEST RIG FALLING HEIGHT

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 Fig. 19 and Fig. 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 [for example, **5.3.5.3.2** of IS 17900 (Part 1)] and released.

If it is not possible to hit the specified striking point of the relevant part of the test sample (for example, 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 standard [for example, IS 17900 (Part 1)].

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.

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

(*Clause* 5.15)

	Possible failure exclusion						
Component	**Open circuit**	**Short circuit**	**Changeto higher value**	**Change to lowervalue**	**Change of function**	**Conditions**	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
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 IS/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			
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*)

<table>
<tr><th></th><th colspan="5">Possible failure exclusion</th><th colspan="2"></th><th></th></tr>
<tr><th>Component</th><th>Open circuit</th><th>Short circuit</th><th>Changeto higher value</th><th>Change to lowervalue</th><th>Change of function</th><th colspan="2">Conditions</th><th>Remarks</th></tr>
<tr><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td><td>(6)</td><td colspan="2">(7)</td><td>(8)</td></tr>
<tr><td rowspan="9">2.4 Optocoupler</td><td rowspan="9">NO</td><td rowspan="9">(a)</td><td rowspan="9"></td><td rowspan="9"></td><td rowspan="9">NO</td><td colspan="2">(a) Can be excluded on condition that the optocoupler is according to IEC 60747-5-5 and the isolation voltage is atleast according to table below, Table F.1 of IS 15382 (Part 1).</td><td rowspan="10">Open circuit means open circuitinoneof the two basic components (LED and photo transistor). Shortcircuit means short circuit between them.</td></tr>
<tr><td rowspan="2">Voltage phase-to-earth derived from rated system voltage up to and including Vrms and D.C.</td><td>Preferred series of impulse withstand voltages in volts for installation</td></tr>
<tr><td>Category III</td></tr>
<tr><td>50</td><td>800</td></tr>
<tr><td>100</td><td>1500</td></tr>
<tr><td>150</td><td>2500</td></tr>
<tr><td>300</td><td>4000</td></tr>
<tr><td>600</td><td>6000</td></tr>
<tr><td>1000</td><td>8000</td></tr>
<tr><td>2.5Hybridcircuit</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td colspan="2"></td></tr>
<tr><td>2.6Integratedcircuit</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td colspan="2"></td><td>Change in function to oscillation, “and” gates becoming “or”gates,etc.</td></tr>
<tr><td>3 Miscellaneous</td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td></tr>
<tr><td colspan="9">“NO”in the cell means: failure not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.</td></tr>
</table>

Table 3 (*Continued*)

	Possible failure exclusion						
Component	**Open circuit**	**Short circuit**	**Changeto higher value**	**Change to lowervalue**	**Change of function**	**Conditions**	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
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 from IS 15382 (Part1)] with the conditions: - the pollution degree is 3; - the material group is III; - in homogeneous 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 connectoris IP 5X or better, the creepage distances can be reduced to the clearance value,for example, 3 mm for 250 V_{rms}.	
3.2 Neon bulb	NO	NO					
3.3 Transformer	NO	(a)	(b)	(b)		(a) (b) Can be excluded on condition that transformer complies with Clause 18 of IEC 61558-1 for double or reinforced insulation between windings and between windings and core.	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.
"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*)

	Possible failure exclusion						
Component	**Open circuit**	**Short circuit**	**Changeto higher value**	**Change to lower value**	**Change of function**	**Conditions**	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3.4 Fuse		(a)				(a) Can be excluded if the fuse is correctly rated, and constructed according to the applicable IE/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 standard [for example, **5.10.3.2.2** of IS 17900 (Part 1)]. (b) Welding of contacts cannot be excluded. However, if the relay is constructed to have mechanically forced interlocked contacts, and made according to IS/IEC 60947-5-1, the assumptions laid down in the standards calling for the use of this standard [for example, **5.10.3.1.2** and **5.10.3.1.3** of IS 17900 (Part 1)] apply.	
"NO" in the cellmeans: failure not excluded, i.e. shall be considered; The unmarked cell means: the identified fault type is not relevant.							
3.6 Printed circuit board (PCB)	NO	(a)				(a) The short circuit can be excluded provided: - The general specifications of PCB are in accordance with IS/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 IS 15382 (Part1)] with the conditions: - The pollution degree is 3; - The material group is III; - In homogeneous 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.							

Table 3 (*Concluded*)

Component	Possible failure exclusion					Conditions	Remarks
	Open circuit	**Short circuit**	**Changeto higher value**	**Change to lower value**	**Change of function**		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
						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 2 000 m altitude for 250 Vrms. For other voltages and higher altitude, *see* IS 15382 (Part 1) 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. NOTE — Experience has shown that solder masks are satisfactory as a protective layer. For multi-layer boards comprised of at least 3 prepreg or other thin sheet insulting materials, short-circuit can be excluded [*see* 2.10.6.4 of IS 13252 (Part1)].	
4 Assembly of componentson printed circuit board (PCB)	NO	(a)				(a) Short circuit can be excluded under circumstances where the short circuit of the component itself can be excluded and the component is mounted in a way that the creepage distances and clearances are not reduced below the minimum acceptable values as listed in 3.1 and 3.6 of this table, neither by the mounting technique nor by the PCB itself.	
"NO"inthecellmeans:failurenotexcluded,i.e.shallbeconsidered; The unmarked cell means: the identified fault type is not relevant.							

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 A-1, A-2 and A-3. In addition, specific measures required for SIL's 1, 2 and 3 are listed respectively in Tables A-4, A-5 and A-6.

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

NOTE — The IS/IEC 61508-7 clauses listed in Tables A-1 to A-6 refer to the relevant requirements in IS/IEC 61508-2 and IS/IEC 61508-3.

6 BIS CERTIFICATION MARKING

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.

ANNEX A

(*Normative*)

(*Clause* 5.6.1.3)

PROGRAMMABLE ELECTRONIC SYSTEMS IN SAFETY RELATED APPLICATIONS FOR LIFTS (PESSRAL)

A-1 COMMON MEASURES

See Table A-1, A-2 and A-3.

Table A-1 Common Measures to Avoid and Detect Failures — Hardware Design

(*Clauses* 5.6.3.4, 5.16 *and* A-1)

Sl No.	Object	Measure	Reference to IS/IEC 61508–7
(1)	(2)	(3)	(4)
i)	**Processing unit**	Use of watch dog.	A.9
ii)	**Component selection**	Use of components only within their specifications	
iii)	**I/O units and interfaces incl. Communication links**	Defined safe state in the event of power failure or reset	
iv)	**Power supply**	Defined safe shut-off state in case of over-voltage or under-voltage	A.8.2
v)	**Variable memory ranges**	Use of only solid-state memories.	
vi)	**Variable memory ranges**	Read/write test of variable data memory during boot procedure	
vii)	**Variable memory ranges**	Remote access only to informative data (for example, statistics)	
viii)	**Invariant memory ranges**	No possibility to change the program code, either automatically by the system or remote intervention	
ix)	**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 A-2 Common Measures to Avoid and Detect Failures — Software Design

(*Clauses* 5.6.3.4, 5.16 *and* A-1)

Sl No.	Object	Measure	Reference to IS/IEC 61508–7
(1)	(2)	(3)	(4)
i)	**Structure**	Program structure (i.e. modularity, data handling, interface definition) according to the state of the art (*see* IS/IEC 61508–3).	B.3.4/C.2.1 C.2.9/C.2.7
ii)	**Boot procedure**	During boot procedures a safe state of the lift shall be maintained.	
iii)	**Interrupts**	Limited use of interrupts: Use of nested interrupts only if all possible sequences of interrupts are predictable.	C.2.6.5
iv)	**Interrupts**	No triggering of watchdog by interrupt procedure except in combination with other program sequence conditions.	A.9.4
v)	**Power down**	No power down procedures, such as saving of data, for safety related functions.	
vi)	**Memory management**	Stack manager in the hardware and/or software with appropriate reaction procedure.	C.2.6.4/C.5.4
vii)	**Program**	Iteration loops shorter than system reaction time, for example, by limiting number of loops or checking execution time.	
viii)	**Program**	Array pointer offset checks, if not included in the used programming language.	C.2.6.6
ix)	**Program**	Defined handling of exceptions (for example, divisions by zero, overflow, variable range checking etc.) which forces the system into a defined safe state.	
x)	**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

Table A-2 (*Concluded*)

Sl No.	Object	Measure	Reference to IS/IEC 61508–7
(1)	(2)	(3)	(4)
xi)	**Program**	Documentation of programming library interfaces and operating systems at least as complete as the user program itself.	
xii)	**Program**	Plausibility checks on data relevant to safety functions, for example, input patterns, input ranges, and internal data.	C.2.5/C.3.1
xiii)	**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.	IS/IEC 61508–1, 7.7.2.1
xiv)	**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
xv)	**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
xvi)	**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 A-3 Common Measures for the Design and Implementation Process

(*Clauses* 5.6.3.4, 5.16 *and* A-1)

Sl No.	Measure	Reference to IS/IEC 61508–7
(1)	(2)	(3)
i)	Assessment of the functional, environmental and interface aspects of the application	A.14/B.1
ii)	Requirement specification including the safety requirements	B.2.1
iii)	Reviews of all specifications	B.2.6
iv)	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
v)	Design review reports	B.3.7/B.3.8, C.5.16
vi)	Check of reliability using a method such as failure mode and effect analysis (FMEA)	B.6.6
vii)	Manufacturer's test specification, manufacturer's test reports and field test reports	B.6.1
viii)	Instruction documents incl. limits for intended use	B.4.1
ix)	Repeat and update of above-mentioned measures if the product is modified	C.5.23
x)	Implementation of version control of hardware and software and its compatibility.	C.5.24

A-2 SPECIFIC MEASURES

Table A-4 Specific Measures According to SIL 1

(*Clauses* 5.6.3.4, 5.16 *and* A-2)

Sl No.	Components and Functions	Requirements	Measures	See No. in A-7	Reference to IS/IEC 61508–7
(1)	(2)	(3)	(4)	(5)	(6)
i)	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
ii)	Processing units	Failures in processing units, which can lead to incorrect results, shall be detected.	Failure correcting hardware, or	M 2.1	A.3.4
			self-test by software,	M 2.2	A.3.1
		If such a failure can lead to a dangerous situation the system shall go into a safe state.	or comparator for two-channel structure, or	M 2.4	A.1.3
			reciprocal comparison by software for 2-channel structure.	M 2.5	A.3.5
iii)	Invariant memory Ranges	Incorrect information modification, that is, 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 meas- ures refer only to a one-channel structure:		
			one-bit redundancy (parity bit), or	M 3.5	A.5.5
			block safety with one- word redundancy.	M 3.1	A.4.3
iv)	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	M 3.2	A.5.6
			check via test pattern against static or dynamic faults.	M 4.1	A.5.2
v)	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	M 5.4	A.6.2
			test pattern.	M 5.5	A.6.1
vi)	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	M 6.1	A.9.4
			reciprocal monitoring.	M 6.2	
vii)	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 A-5 Specific Measures According to SIL 2

(*Clauses* 5.6.3.4, 5.16 *and* A-2)

Sl No.	Components and Functions	Requirements	Measures	See No. in A-7	Reference to IS/IEC 61508–7
(1)	(2)	(3)	(4)	(5)	(6)
i)	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
ii)	Processing units	Failures in processing units, which can lead to incorrect results, shall be detected with	Failure correcting hardware, and	M 2.1	A.3.4
		due consideration to the system reaction time. If such a failure can lead to a	software self-test supported by hardware for one-channel structure, or	M 2.3	A.3.3
		dangerous situation the system shall go into a safe state.	comparator for 2-channel structure, or	M 2.4	A.1.3
			reciprocal comparison by soft- ware for 2-channel structure.	M 2.5	A.3.5
iii)	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	M 3.1	A.4.3
			word saving with multi-bit redundancy.	M 3.2	A.5.6
iv)	Variable memory Ranges	Global failures during ad-dressing, 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 with due consideration to the system reaction time.	The following measures refer only to a one-channel structure:		
			Word-saving with multi-bit redundancy, or	M 3.2	A.5.6
			check via test pattern against static or dynamic faults.	M 4.1	A.5.2
v)	I/O units and interfaces incl. communication links	Static failures and cross talk on I/O lines as well as random	Code safety, or	M 5.4	A.6.2
		and systematic failures in the data flow, shall be detected with due consideration to the system reaction time.	test pattern.	M 5.5	A 6.1
vi)	Clock	Failures in clock generation for processing units like frequency modification or	Watchdog with separate time base, or	M 6.1	A 9.4
		break down shall be detected with due consideration to the system reaction time.	reciprocal monitoring.	M 6.2	
vii)	Program sequence	Wrong program sequence and inappropriate execution time of the safety function shall be detected with due consideration to the system reaction time.	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 A-6 Specific Measures According to SIL 3

(*Clauses* 5.6.3.4, 5.16 *and* A-2)

Sl No.	Components and functions	Requirements	Measures	*See* No. in A-7	IS/IEC 61508–7 reference
(1)	(2)	(3)	(4)	(5)	(6)
i)	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.	2 channels or more with comparison.	M 1.3	A.2.5
ii)	Processing units	Failures in processing units, which can lead to incorrect results, shall be detected with due consideration to the system reaction time.	Comparator for two channels, or	M 2.4	A.1.3
		If such a failure can lead to a dangerous situation the system shall go into a safe state.	reciprocal comparison by software for 2-channel structure.	M 2.5	A.3.5
iii)	Invariant memory Ranges	Incorrect information modification, that is, all 1-bit or multi-bit failures, shall be detected with due consideration to the system reaction time.	Block safety procedure with block replication, or	M 3.3	A.4.5
			block safety with multi-word redundancy.	M 3.4	A.4.4
iv)	Variable memory ranges	Global failures during addressing, writing, storing and reading as well as static bit failures and dynamic couplings shall be detected with due consideration to the system reaction time.	Block safety procedure with block replication, or	M 4.2	A.5.7
			inspection checks, such as “Galpat”.	M 4.3	A.5.3
v)	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 with due consideration to the system reaction time.	Multi-channel parallel input and	M 5.1	A.6.5
			multi-channel parallel output, or	M 5.3	A.6.3
			output read back, or	M 5.2	A.6.4
			code safety, or	M 5.4	A.6.2
			test pattern.	M 5.5	A.6.1
vi)	Clock	Failures in clock generation for processing units like frequency modification or break down shall be detected with due consideration to the system reaction time.	Watchdog with separate time base, or.	M 6.1	A.9.4
			reciprocal monitoring	M 6.2	
vii)	Program sequence	Wrong program sequence and in-appropriate execution time of the safety function shall be detected with due consideration to the system reaction time.	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.					

A-3 DESCRIPTIONS OF POSSIBLE MEASURES

Table A-7 contains descriptions of possible measures which are considered to be helpful when fulfilling the requirements laid down in the standards calling for the use of this document [for example, **5.11.2.6** of IS 17900 (Part 1)].

Table A-7 Description of Possible Measures to Failure Control

(*Clauses* 5.6.3.4 *and* A-3)

Sl No.	Components and Functions	Measure No.	Description of Measures
(1)	(2)	(3)	(4)
i)	**Structure**	**M-1.1**	**One channel structure with self-test** Description: Even though the structure consists of a single channel, redundant output paths shall be provided to ensure a safe shutdown. Self-tests (cyclical) are applied to the sub-units of the PESSRAL at time intervals which may be application dependent. These tests (for example, CPU tests or memory tests) are designed to detect latent failures which are independent of the data flow. A detected failure shall cause the system to go into a safe state.
		M-1.2	**One channel structure with self-test and monitoring** Description: A one channel structure with self-test and monitoring consists of a separate hardware monitoring unit which, independent of the application, periodically receives test data from the system which might result from self-test procedures. In case of incorrect data, the system shall go into a safe state. At least two independent shut down paths are needed so that a shutdown can be caused either by the processing unit itself or by the monitoring unit.
		M-1.3	**Two channels or more with comparison** Description: Two-channel safety-related design consists of two independent and feedback-free functional units. This allows the specified functions to be processed independently in each channel. For a two-channel PESSRAL exclusively designed for the function of one safety device the design of the channels may be identical in terms of hardware and software. In the case of a two-channel PESSRAL used for complex solutions (for example, combinations of several safety functions) and where the processes or conditions are not definitely verifiable, diversity for hardware and software should be considered. The structure includes a function which compares internal signals (for example, bus comparison) and/or output signals which are relevant to safety functions in order to aid failure detection. At least two independent shut down paths are needed so that a shutdown can be caused either by the channels themselves or by the comparator. The comparison itself also shall be subject to the failure recognition.
ii)	**Processing Units**	**M-2.1**	**Failure correcting hardware** Description: Such units can be realized using special failure recognizing or failure correcting circuit techniques. These techniques are known for simple structures.
		M-2.2	**Self-test by software** Description: All the functions of the processing unit, which are used in the safety related application shall be tested cyclically. These tests can be combined with the test of the sub-components, for example, memories, I/O’s etc.
		M-2.3	**Software self-test supported by hardware** Description: A special hardware facility is used for the failure detection which supports the self-test functions. For example, a monitoring unit which checks the periodic output of certain bit patterns.

Table 7 (*Continued*)

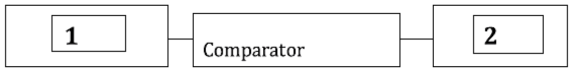
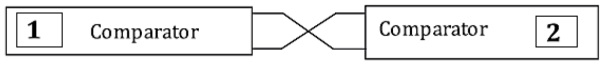
Sl No.	Components and Functions	Measure No.	Description of Measures
(1)	(2)	(3)	(4)
		M-2.4	**Comparator for 2 channel structures** Description:  Two channels with hardware comparator: a) The signals of both processing units are compared using a hardware unit cyclically or continuously. The comparator can be an externally tested unit or designed as a self-monitoring device or b) The signals of both channels are compared using a processing unit. The comparator can be an externally tested unit or designed as a self-monitoring device.
		M-2.5	**Reciprocal comparison of 2 channels** Description:  Two redundant processing units are used which exchange safety relevant data reciprocally. A comparison of the data are carried out by each unit.
iii)	**Invariant memory ranges (ROM, EPROM..)**	**M-3.1**	**Block safety procedure with one-word-redundancy (for example, signature formation via ROM with single word width)** Description: In this test, the contents of the ROM are compressed by a certain algorithm to at least one memory word. The algorithm, for example, cyclic redundancy check (CRC), can be realized using hardware or using software.
		M-3.2	**Word saving with multi-bit-redundancy (for example, modified hamming code)** Description: Every word of the memory is extended by several redundant bits to produce a modified hamming code with a hamming distance of at least 4. Every time a word is read, one can determine whether a corruption has taken place by checking the redundant bits. If a difference is found, the system shall go into a safe state.
		M-3.3	**Block safety procedure with block replication** Description: The address space is equipped with two memories. The first memory is operated in the normal manner. The second memory contains the same information and is accessed in parallel to the first. The outputs are compared and a failure is assumed if a difference is detected. In order to detect certain kinds of bit errors, the data shall be stored inversely in one of the two memories and inverted once again when read. In the software procedure, the contents of both memory areas are compared cyclically using a program.
		M-3.4	**Block safety procedure with multiword redundancy** Description: This procedure calculates a signature using a CRC algorithm, but the resulting value is at least two words in size. The extended signature is stored, recalculated and compared as in a single-word case. A failure message is produced if a difference occurs.
		M-3.5	**Word saving one-bit redundancy (for example, ROM monitoring with parity bit)** Description: Every word of the memory is extended by one bit (the “parity” bit) which completes each word to an even or odd number of logical 1’s. The parity of the data word is checked each time it is read. If the wrong number of 1’s is found, a failure message is produced. The choice of even or odd parity should be made such that whichever of zero word (nothing but 0s) and the one word (nothing but 1’s) is the more unfavourable in the event of failure, then that word is not a valid code. Parity can also be used to detect addressing failure, when the parity is calculated for the concatenation of the data word and its address.

Table 7 (*Continued*)

Sl No.	Components and Functions	Measure No.	Description of Measures
(1)	(2)	(3)	(4)
iv)	**Variable memory ranges**	**M-4.1**	**Check *via* test pattern against static or dynamic faults, for example, RAM test "walkpath"** Description: The memory range to be tested is initialized by a uniform bit stream. The first cell is then inverted and the remaining memory area is inspected to ensure that the background is correct. After this, the first cell is re-inverted to return to its original value and the whole process is repeated for the next. A second run of the "wandering bit model" is carried out with an inverse background pre-assignment. If a difference occurs the system shall go into a safe state.
		M-4.2	**Block safety procedures with block replication, for example, double RAM with hardware or software comparison** Description: The address space is equipped with two memories. The first memory is operated in the normal manner. The second memory contains the same information and is accessed in parallel to the first. The outputs are compared and a failure is assumed if a difference is detected. In order to detect certain kinds of bit errors, the data shall be stored inversely in one of the two memories and inverted once again when read. In the software procedure, the contents of both memory areas are compared cyclically using a program.
		M-4.3	**Inspection to check for static and dynamic failures, for example, "GALPAT"** Description: a) RAM test "galpat": An inverse element is written into the standard pre-assigned memory and then all the remaining cells are inspected to ensure that their contents are correct. After every reading access to one of the remaining cells, the inversely described cell is also inspected and read in addition to this. This process is repeated for every cell. A second run is carried out with an inverse pre-assignment. A failure is assumed if there is a difference; or b) Transparent "galpat" test: At the beginning of the test, a "signature" is formed using software or also hardware regarding the content of the memory range to be tested and this is stored in the register; this corresponds to the pre-assignment of the memory in the galpat test. The contents are now written into the test cell in an inverted way and inspect the contents of the remaining cells. The contents of the test cell are also read after every reading access to one of these cells. Since the contents of the remaining cells is indeed unknown, their contents are not inspected individually, but by forming a signature once again. After this first run for the first cell, a second run for this cell takes place with contents which have been inverted several times — therefore contents which are real again. Thus, the original contents of the memory are re-established. All the other memory cells are tested in the same manner. A failure is assumed if there is a difference.
v)	**I/O units and interfaces**	**M-5.1**	**Multi-channel parallel input** Description: This is a data flow dependent comparison of independent inputs complying with a defined tolerance area (time value).
		M-5.2	**Output read back (monitored output)** Description: This is a data flow dependent comparison of outputs with independent inputs complying with a defined tolerance area (time, value). The failure cannot always be related to the defective output.
		M-5.3	**Multi-channel parallel output** Description: This is a data flow dependent output redundancy. Failure recognition takes place directly via the technical process or via external comparators.

Table 7 (*Concluded*)

Sl No.	Components and Functions	Measure No.	Description of Measures
(1)	(2)	(3)	(4)
		M-5.4	**Code safety** Description: This procedure protects the input and output information with regard to coincident failures and systematic failures. It provides data flow dependent failure recognition of the input and output units with information redundancy or/and time redundancy.
		M-5.5	**Test pattern (model)** Description: This is a data flow independent cyclical test of input and output units carried out with the aid of defined testing pattern to compare observations with the corresponding expected values. The testing pattern information, the testing pattern reception and testing pattern evaluation shall be independent from each other. It shall be assumed that all possible input patterns are tested.
vi)	**Clock**	**M-6.1**	**Watch dog with separate time base** Description: Hardware timer with separate time base triggered by correct operation of the program.
		M-6.2	**Reciprocal monitoring** Description: Hardware timer with separate time base triggered by the correct operation of the program of the other processor
vii)	**Program sequence**	**M-7.1**	**Combination of timing and logical monitoring of program sequence** Description: A time-based facility monitoring the program sequence is retriggered only if the sequence of the program sections is executed correctly.

ANNEX B

(*Informative*)

(*Clause* 5.10.1)

EXAMPLE FOR CALCULATION OF GUIDE RAILS

B-1 GENERAL

B-1.1 The following example is used to explain the calculation of the guide rails.

B-1.2 The following symbols for the dimensions in the lift are used with a Cartesian coordinates system for all possible geometrical cases:

C	is the car centre;
D_x	is the car dimension in X-direction, car depth;
Dy	is the car dimension in Y-direction, car width;
h	is the distance between car guide shoes;
l	is the distance between brackets;
P	are the masses of the empty car and components supported by the car, i.e. part of travelling cable, compensating ropes/chains (if any), etc., in kilograms;
Q	is the rated load, in kilograms;
S	is the car suspension;
x_C, y_C	is the position of the car centre (C) in relation to the guide rail cross coordinates;
x_i, y_i	is the position of the car door, i = 1, 2, 3 or 4;
x_P, y_P	is the position of the car mass (P) in relation to the guide rail cross coordinates;
x_Q, y_Q	is the position of the rated load (Q) in relation to the guide rail cross coordinates;
x_S, y_S	is the position of the suspension (S) in relation to the guide rail cross coordinates;
1, 2, 3, 4	is the centre of the car door 1, 2, 3 or 4;
$\longrightarrow$	is the direction of loading.

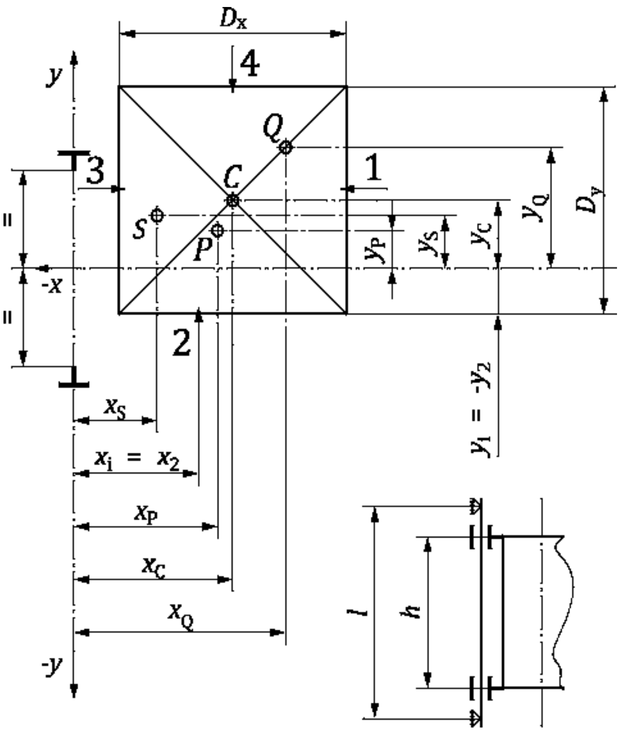


FIG. B-1 LOAD DISTRIBUTION IN LIFT CAR — GENERAL CASE

B-1.3 The following symbols are used in Formulae (B.1) to (B.30), *see* B-2 and Fig. B-1:

- A is the cross-sectional area of a guide rail, in square millimetres;
- c is the width of the connecting part of the foot to the blade, in millimetres;
- δ_{perm} is the maximum permissible deflection, in millimetres;
- δ_x is the deflection in the X-axis, in millimetres;
- δy is the deflection in the Y-axis, in millimetres;
- E is the modulus of elasticity, in newtons per square millimetre;
- F_p is the push through forces of all brackets at one guide rail (due to normal settling of the building or shrinkage of concrete), in newtons;
- F_s is the vertical force acting on the car sill due to loading and unloading, in newtons;
- F_v is the vertical force on a guide rail of the car, counterweight or balancing weight, in newtons;
- F_x is the supporting force in the X-axis, in newtons;
- F_y is the supporting force in the Y-axis, in newtons;
- g_n is the standard acceleration of free fall, in metres per square second;
- I_x is the second moment of area in the X-axis, in fourth power millimetres;
- I_y is the second moment of area in the Y-axis, in fourth power millimetres;
- k_1 is the impact factor for the type of safety gear used;
- k_2 is the impact factor for the running condition;
- k_3 is the impact factor for auxiliary parts and other operational scenarios;
- M_{aux} is the force in a guide rail due to auxiliary equipment, in newtons;
- M_g is the mass of one line of guide rails, in kilograms;
- M_m is the bending moment, in newtons millimetres;
- M_x is the bending moment in the x-axis, in newtons millimetres;
- M_y is the bending moment in the y-axis, in newtons millimetres;
- n is the number of guide rails;
- σ is the combined stress, in newtons per square millimetre;
- σ_k is the buckling stress, in newtons per square millimetre;
- σ_m is the bending stress, in newtons per square millimetre;
- σ_F is the local flange bending stress, in newtons per square millimetre;
- σ_{perm} is the permissible stress, in newtons per square millimetre;
- σ_x is the bending stress in the x-axis, in newtons per square millimetre;
- σ_y is the bending stress in the y-axis, in newtons per square millimetre;
- W_x is the modulus of cross sectional area in the x-axis in cubic millimeters;
- W_y is the modulus of cross sectional area in the y-axis in cubic millimeters;
- ω is the omega value.

B-2 GENERAL CONFIGURATION FOR LIFTS WITH SAFETY GEAR

B-2.1 Safety Gear Operation

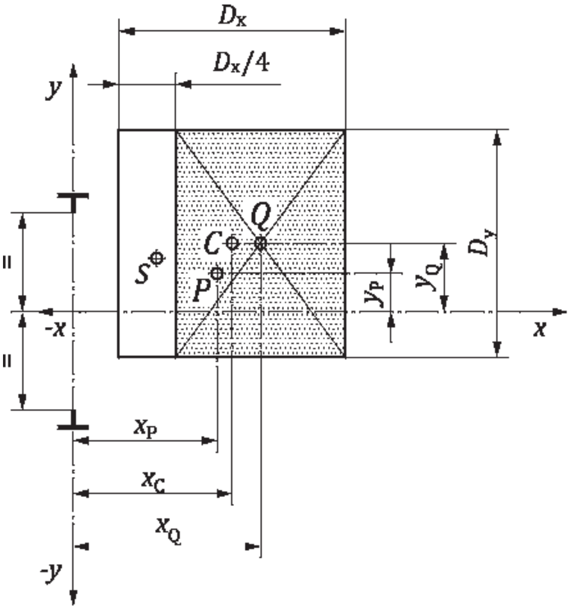
B-2.1.1 *Bending Stress*

a) Bending stress relative to the y-axis of the guide rail due to guiding force:

$$F_x = \frac{k_1 \times g_n \times \left(Q \times x_Q + P \times x_P\right)}{n \times h}, \quad M_y = \frac{3 \times F_x \times l}{16}, \quad \sigma_y = \frac{M_y}{W_y} \tag{B.1}$$

b) Bending stress relative to the x-axis of the guide rail due to guiding force:

$$F_y = \frac{k_1 \times g_n \times \left(Q \times y_Q + P \times y_P\right)}{\frac{n}{2} \times h}, \quad M_x = \frac{3 \times F_y \times l}{16}, \quad \sigma_x = \frac{M_x}{W_x} \tag{B.2}$$

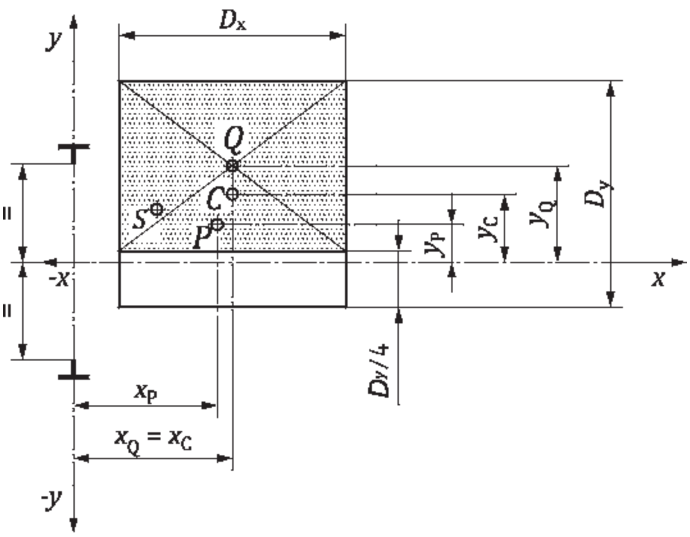


NOTES

1 $x_Q = x_C + D_x/8$.

2 $y_Q = y_C$.

FIG. B-2 SAFETY GEAR OPERATION — LOAD DISTRIBUTION IN LIFT CAR — CASE 1 RELATIVE TO X-AXIS



NOTES

1 $x_Q = x_C$

2 $y_Q = y_C + D_y/8$.

FIG. B-3 SAFETY GEAR OPERATION — LOAD DISTRIBUTION IN LIFT CAR — CASE 2 RELATIVE TO Y-AXIS

B-2.1.2 *Buckling*

$$F_v = \frac{k_1 \times g_n \times (P+Q)}{n} + M_g \times g_n + F_p \quad \text{(B.3)}$$

$$\sigma_k = \frac{(F_v + k_3 \times M_{aux}) \times \omega}{A} \quad \text{(B.4)}$$

B-2.1.3 *Combined Stress*[2)]

$$\sigma = \sigma_m = \sigma_x + \sigma_y \le \sigma_{perm} \quad \text{(B.5)}$$

$$\sigma = \sigma_m + \frac{F_v + k_3 \times M_{aux}}{A} \le \sigma_{perm} \quad \text{(B.6)}$$

$$\sigma = \sigma_k + 0.9 \times \sigma_m \le \sigma_{perm} \quad \text{(B.7)}$$

B-2.1.4 *Flange Bending*[3)]

$$\sigma_F = \frac{1.85 \times F_x}{c^2} \le \sigma_{perm}, \text{ or} \quad \text{(B.8)}$$

$$\sigma_F = \frac{6 \times F_x \times (h_1 - b - f)}{c^2 \times [l + 2 \times (h_1 - f)]} \le \sigma_{perm} \quad \text{(B.9)}$$

B-2.1.5 *Deflections*[4)]

$$\delta_x = 0.7 \times \frac{F_x \times l^3}{48 \times E \times I_y} \le \delta_{perm} \quad \text{(B.10)}$$

$$\delta_y = 0.7 \times \frac{F_y \times l^3}{48 \times E \times I_x} \le \delta_{perm} \quad \text{(B.11)}$$

Key:

2) - These figures apply to both load distribution cases 1 and 2, *see* **B-2.1.1**. If $\sigma_{perm} < \sigma_m$, the figures for **5.10.2.2** can be used in the interest of minimum guide rail dimensions.

3) - These figures apply to both load distribution cases **B-2.1.1**.

4) - These figures apply to both load distribution cases **B-2.1.1**.

B-2.2 Normal Operation, Running

B-2.2.1 *Bending Stress*

a) Bending stress relative to the y-axis of the guide rail due to guiding force:

$$F_x = \frac{k_2 \times g_n \times [Q \times (x_Q - x_s) + P \times (x_p - x_s)]}{n \times h},$$

$$M_y = \frac{3 \times F_x \times l}{16}, \sigma_y = \frac{M_y}{W_y} \quad \text{(B.12)}$$

b) Bending stress relative to the x-axis of the guide rail due to guiding force:

$$F_y = \frac{k_2 \times g_n \times [Q \times (y_Q - y_s) + P \times (y_p - y_s)]}{\frac{n}{2} \times h},$$

$$M_x = \frac{3 \times F_y \times l}{16}, \ \sigma_x = \frac{M_x}{W_x} \quad \text{(B.13)}$$

Load distribution:

Case 1 relative to the x-axis (*see* **B-2.1.1**).

Case 2 relative to the y-axis (*see* **B-2.1.1**).

B-2.2.2 *Buckling*

$$F_v = M_g \times g_n + F_p \quad \text{(B.14)}$$

$$\sigma_k = \frac{F_v + k_3 \times M_{aux}}{A} \quad \text{(B.15)}$$

B-2.2.3 *Combined Stress*[5)]

$$\sigma_m = \sigma_x + \sigma_y \le \sigma_{perm} \quad \text{(B.16)}$$

$$\sigma = \sigma_m + \frac{F_v + k_3 \times M_{aux}}{A} \le \sigma_{perm} \quad \text{(B.17)}$$

B-2.2.4 *Flange Bending*[6)]

$$\sigma_F = \frac{1.85 \times F_x}{c^2} \le \sigma_{perm}, \text{ or} \quad \text{(B.18)}$$

$$\sigma_F = \frac{6 \times F_x \times (h_1 - b - f)}{c^2 \times [l + 2 \times (h_1 - f)]} \le \sigma_{perm} \quad \text{(B.19)}$$

B-2.2.5 *Deflections*[7)]

$$\delta_x = 0.7 \times \frac{F_x \times l^3}{48 \times E \times I_y} \le \delta_{perm} \quad \text{(B.20)}$$

$$\delta_y = 0.7 \times \frac{F_y \times l^3}{48 \times E \times I_x} \le \delta_{perm} \quad \text{(B.21)}$$

Key:

5) - These figures apply to both load distribution cases **B-2.2.1**. If $\sigma_{perm} < \sigma_m$, the figures for **5.10.2.2** can be used in the interest of minimum guide rail dimensions.

6) - These figures apply to both load distribution cases **B-2.1.1**.

7) - These figures apply to both load distribution cases **B-2.1.1**.

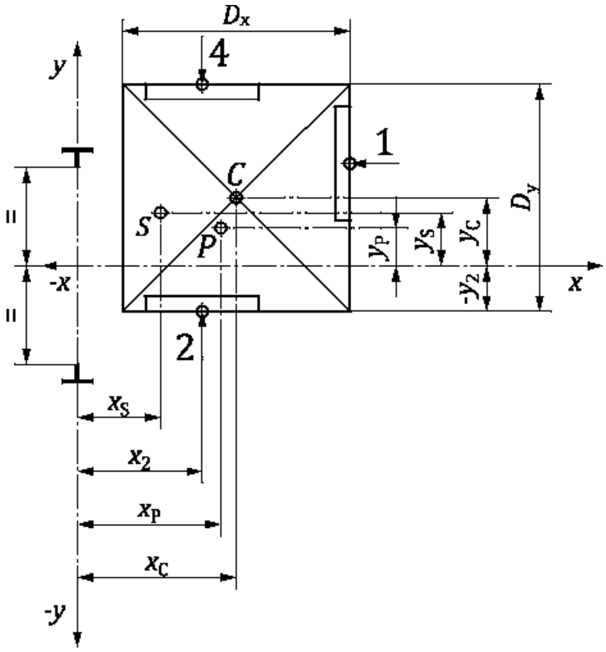


FIG. B-4 NORMAL OPERATION — LOADING DISTRIBUTION

B-2.3 Normal Operation, Loading

B-2.3.1 *Bending Stress*

(a) Bending stress relative to the y-axis of the guide rail due to guiding force:

$$F_x = \frac{g_n \times P \times (x_P - x_S) + F_s \times (x_i - x_s)}{n \times h}, M_y = \frac{3 \times F_x \times l}{16}$$

$$\sigma_y = \frac{M_y}{W_y} \quad \text{(B.22)}$$

(b) Bending stress relative to the x-axis of the guide rail due to guiding force:

$$F_y = \frac{g_n \times P \times (y_p - y_s) + F_s \times (y_i - y_s)}{\frac{n}{2} \times h}, M_x = \frac{3 \times F_y \times l}{16}$$

$$\sigma_x = \frac{M_x}{W_x} \quad \text{(B.23)}$$

B-2.3.2 *Buckling*

$$F_v = M_g \times g_n + F_p \quad \text{(B.24)}$$

$$\sigma_k = \frac{F_v + k_3 \times M_{aux}}{A} \quad \text{(B.25)}$$

B-2.3.3 *Combined Stress*[8)]

$$\sigma = \sigma_m = \sigma_x + \sigma_y \leq \sigma_{perm} \quad \text{(B.26)}$$

$$\sigma = \sigma_m + \frac{F_v + k_3 \times M_{aux}}{A} \leq \sigma_{perm} \quad \text{(B.27)}$$

Key:

8) - If $\sigma_{perm} < \sigma_m$, the figures for **5.10.2.2** can be used in the interest of minimum guide rail dimensions.

B-2.3.4 *Flange Bending*

$$\sigma_F = \frac{1.85 \times F_x}{c^2} \leq \sigma_{perm}, \text{ or} \quad \text{(B.28)}$$

$$\sigma_F = \frac{6 \times F_x \times (h_1 - b - f)}{c^2 \times [l + 2 \times (h_1 - f)]} \leq \sigma_{perm} \quad \text{(B.29)}$$

B-2.3.5 *Deflections*

$$\delta_x = 0.7 \times \frac{F_x \times l^3}{48 \times E \times I_y} \leq \delta_{perm},$$

$$\delta_y = 0.7 \times \frac{F_y \times l^3}{48 \times E \times I_x} \leq \delta_{perm} \quad \text{(B.30)}$$

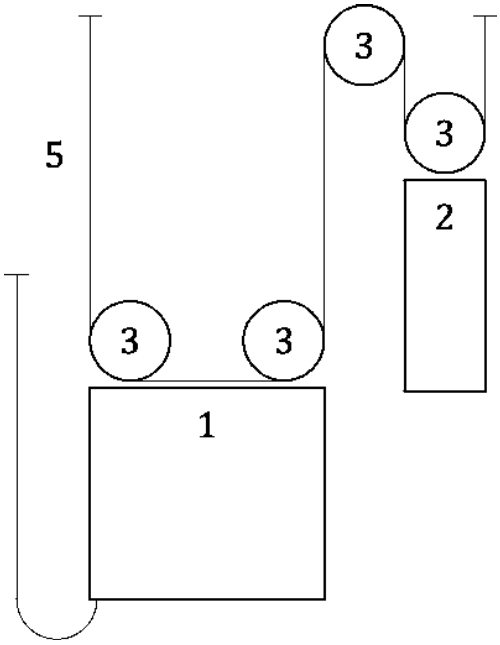
ANNEX C

(*Informative*)

(*Clause* 5.11.3)

CALCULATION OF TRACTION — EXAMPLE

For the example according to Fig. C-1, Formulae (C.1) to (C.8) apply.



Key

1 car
2 counterweight
3 pulley
4 travelling cable
5 suspension means

FIG. C-1 EXAMPLE 2:1, NO COMPENSATION MEANS

Car loading condition

Car loaded with 125 percent rated load at lowest landing, no friction considered.

$$T_1 = \frac{(P + 1.25 \times Q)}{2} \times g_n + M_{SRcar} \times g_n \quad \text{(C.1)}$$

$$T_2 = \frac{M_{cwt}}{2} \times g_n \quad \text{(C.2)}$$

Emergency braking condition

Minimum friction due to pulleys and guiding force assumed

a) Car loaded with rated load at lowest landing

$$T_1 = \frac{(P+Q)}{2} \times (g_n + a) + M_{SRcar} \times (g_n + 2 \times a) + \frac{m_{Pcar} \times 2 \times a}{2} - \frac{FR_{car}}{2} \quad \text{(C.3)}$$

$$T_2 = \frac{M_{cwt}}{2} \times (g_n - a) - \frac{m_{Pcwt} \times 1 \times a}{2} + \frac{FR_{cwt}}{2} \quad \text{(C.4)}$$

b) Empty car at highest landing

$$T_1 = \frac{M_{c\omega t}}{2} \times (g_n + a) + M_{SRcwt}\,(g_n + 2 \times a) + \frac{m_{Pc\omega t} \times 1 \times a}{2} - \frac{FR_{cwt}}{2} \quad \text{(C.5)}$$

$$T_2 = \frac{(P + M_{Trav})}{2} \times (g_n - a) - \frac{m_{Pcar} \times 2 \times a}{2} + \frac{FR_{car}}{2} \quad \text{(C.6)}$$

Counterweight stalled condition

Empty car at highest position, no friction considered.

$$T_1 = \frac{(P + M_{Trav})}{2} \times g_n \quad \text{(C.7)}$$

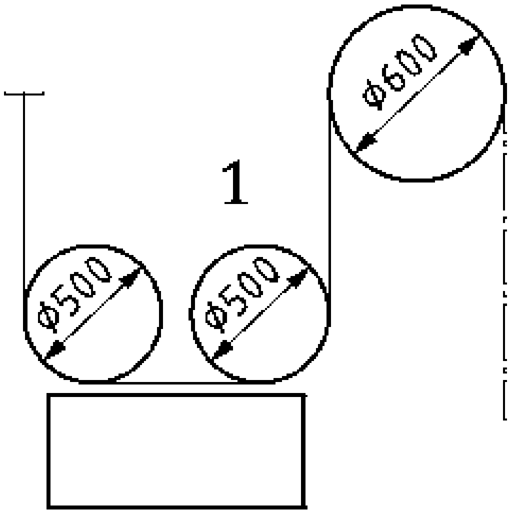
$$T_2 = M_{SRcwt} \times g_n \quad \text{(C.8)}$$

ANNEX D

(*Informative*)

(*Clause* 5.12.2.3)

EQUIVALENT NUMBER OF PULLEYS, N_{equiv} — EXAMPLES



Key

1 car side

FIG. D-1 2 TO 1 ROPING — V GROOVES

γ	=	40°
$N_{equiv\ (t)}$	=	10 (according to Table 2)
K_p	=	$(600 / 500)^4 = 2.07$
$N_{equiv\ (p)}$	=	$2.07 \times (2 + 0) = 4.14$
N_{equ}	=	$10 + 4.14 = 14.14$

NOTE — No reversed bend because of moving pulley.

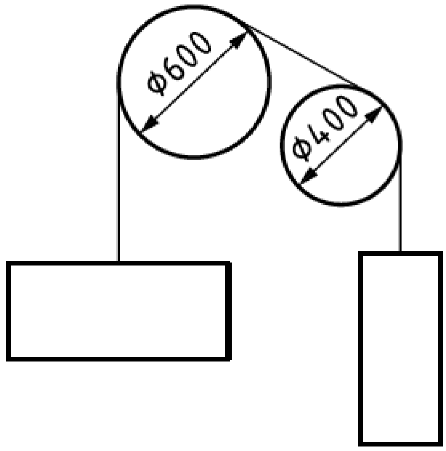


FIG. D-2 1 TO 1 ROPING — UNDERCUT U GROOVES

β	=	90°
$N_{equiv\ (t)}$	=	5 (according to Table 2)
K_p	=	$(600/400)^4 = 5.06$
$N_{equiv(p)}$	=	$5.06 \times (1 + 0) = 5.06$
N_{equiv}	=	$5 + 5.06 = 10.06$

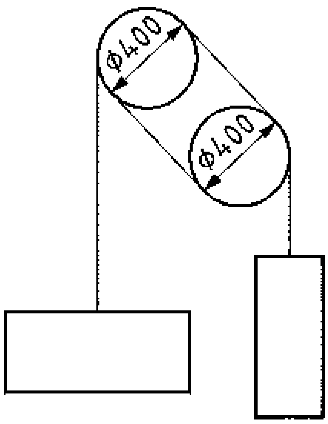


FIG. D-3 1 TO 1 ROPING (DOUBLE WRAP) — U GROOVES

$N_{equiv\ (t)}$	=	1 +1
K_p	=	1
$N_{equiv\ (p)}$	=	$1 \times (1 + 1) = 2$
N_{equiv}	=	$2 + 2 = 4$

NOTE — The rope passes traction sheave and secondary sheave 2 times.

ANNEX E

(*Informative*)

RELATIONSHIP BETWEEN ISO 22559-1 AND THIS STANDARD

The requirements of this standard are not intended to prevent the use of systems, methods, devices or components of equivalent or superior safety, strength, effectiveness, durability, etc. to those prescribed by this standard, provided that the equivalency of the system, method, device, or component can be verified. ISO 22559-1 and national implementations should be consulted for further information.

ANNEX F

(*Foreword*)

COMMITTEE COMPOSITION

Lifts, Escalators and Moving Walks Sectional Committee, ETD 25

Organization	*Representative (s)*
Central Public Works Department (CPWD)	Shri C. K. Varma (***Chairman***)
Airport Authority of India, New Delhi	Shri O. P. Chugh Shri Thomas Mathew T. (*Alternate*)
Central Electricity Authority, New Delhi	Shri Ashok Kumar Rajput
Central Public Works Department (CPWD), New Delhi	Shri Vimal Kumar Shri Rajiv Gupta (*Alternate*)
Delhi, Land and Finance Limited, Delhi	Shri Virender Kumar Sharma
Department of Delhi Fire Services, Govt of NCT of Delhi	Shri A. K. Sharma Dr G. C. Misra (*Alternate*)
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Elevator and Escalator Component Manufacturers' Association of India, Chennai	Shri Suraj Thodimarath Shri Vikas Patil (*Alternate*)
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