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TECHNICAL
REPORT

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11071-2

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Comparison of worldwide lift safety standards —

Part 2:
Hydraulic lifts (elevators)

Comparaison des normes mondiales de sécurité des ascenseurs —

Partie 2: Ascenseurs hydrauliques

Reference number
ISO/TR 11071-2:1996(E)

Foreword

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

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 11071-2, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 178, *Lifts, escalators, passenger conveyors.*

ISO/TR 11071 consists of the following parts, under the general title *Comparison of worldwide lift safety standards:*

- *Part 1: Electric lifts (elevators)*
- *Part 2: Hydraulic lifts (elevators)*

Annexes A to C form an integral part of this part of ISO/TR 11071.

Introduction

At the 1981 plenary meeting of ISO/TC 178, work was started on a comparison of CEN standard EN 81/1 with the American, Canadian, and USSR lift safety codes. In 1983, Working Group 4 was officially formed to carry out the task of preparing a cross reference between the relevant sections of these standards and to analyze the differences on selected subjects. The goal at that time was to prepare a technical report which would provide reference information to assist national committees when reviewing and revising individual standards which may initiate a gradual convergence of the technical requirements. In 1984, the study was expanded to include the CMEA safety standard. That report, ISO/TR 11071-1, *Comparison of worldwide lift safety standards: Part I Electric lifts (elevators), was published 1990-12-01.*

In 1989, the charge to WG 4 was expanded to include hydraulic lifts. Since there was no standard for hydraulic lifts in the Russian Federation, and the Council for Mutual Economics Assistance (CMEA) standard was being phased out of use, this Part 2 of the comparison is generally limited to the ASME, CEN, and CSA standards. The Japan Elevator Association was invited to add their standards to this comparison, however, no response to this request was received.

This report is intended to aid standards writers in developing their safety requirements, and to help standard users understand the basis for the requirements as they are applied throughout the world.

This report is not intended to replace existing safety standards. Conclusions are arrived at in some cases, but only where there is unanimity amongst the various experts. In other cases, the reasons for the divergent views are expressed.

This report must be read in conjunction with the various safety standards, as it was often necessary to summarize the requirements for the sake of clarifying the comparisons. Further, the information contained in this report does not necessarily represent the opinions of the standards writing organizations responsible for the development of the safety standards which are being compared, and they should be consulted regarding interpretations of their requirements (see Annex B).

Comparison of worldwide lift safety standards —

Part 2:
Hydraulic lifts (elevators)

1 Scope and field of application

This Technical Report consists of a comparison of the requirements of selected topics as covered by the following worldwide safety standards (excluding regional or national deviations):

a) CEN -- European Standard EN81: Part 2, Lifts and Service Lifts [Edition 1987 - as presented in BS5655:Part 2:1988 (excluding national Appendix)]

b) ASME -- ASME A17.1 Safety Code for Elevators and Escalators (Edition 1993)

c) CSA -- CSA Standard CAN-B44 Safety Code for Elevators (Edition 1994)

This Technical Report applies to hydraulic lifts only, both of the direct and indirect acting type.

It should be noted that in addition to the above listed standards, lifts must conform to the requirements of other standards (for example, standards covering mechanical, structural, and electrical equipment; building codes, and environmental regulations). Some of the standards will be referred to in this Technical Report.

2 Terminology

2.1 Lifts and elevators

2.1.1

The CEN term *lift* corresponds to the ASME and CSA term *elevator*. These terms are used interchangeably in this report.

2.1.2

For the purposes of this report, unless otherwise specified, the term *passenger lift* and *freight lift* correspond to the following terms used in other standards:

Term used in this report	**Correspond to terms used in the following standards***	
	CEN	**ASME & CSA**
Passenger lift	Lift, except non-commercial vehicle lift	Passenger elevator & freight elevator permitted to carry passengers
Freight lift	Non-commercial vehicle lift with instructed users**	Freight elevator

**See the definitions in the applicable Standards.*
***This term is used only to enable comparisons to be made later in this report. It does not indicate recognition of the term "freight lift" by CEN.*

2.2 Hydraulic terminology

2.2.1 Difference

There are some notable differences in the standards respecting hydraulic lift terminology as shown in the Table 2.2, Column A and B.

2.2.2 Agreed-upon points, re: hydraulic terminology

The differences should be eliminated or minimized through recently proposed changes to ASME and CSA Standards, as shown in Table 2.2, Column D.

If approved by ASME and CSA Committees, the proposed changes would eliminate major differences between CEN and North American Standards.

Column C gives the description of the equipment that a term (listed in Column A, B, or D) embraces.

In addition to "hydraulic machine", ASME and CSA propose to introduce the term "hydraulic driving machines" which may be "direct or roped hydraulic driving machines". The terms are needed to differentiate between "electric" and "hydraulic" driving machines all covered in one ASME and one CSA Standard. This is not necessarily applicable to CEN, as the electric and hydraulic lifts are covered by two separate standards.

2.2.3 Terminology in this report

In this report, the CEN terminology will be used, with the ASME and CSA terms in brackets if different.

Table 2.2
Hydraulic Terminology

Column A	**Column B**	**Column C**	**Column D**
CEN	**ASME & CSA Current**	**Description**	**Agreed upon points: ASME & CSA proposed changes**
Direct acting lift	Direct plunger hydraulic elevator	—	Direct acting hydraulic elevator
Indirect acting lift	Roped hydraulic Elevator	—	No change
Machine	—	Pump, motor, valves	Hydraulic machine
Jack	Driving machine	Cylinder and ram	Hydraulic jack
Ram	Plunger or piston	—	Plunger(ram) or piston
Base	Head/bottom (includes plunger end cap as well)	Cylinder end cap	No change
Valves:			
Non-return	Check	—	No change
Pressure relief	Pump relief	—	No change
Direction	Control	—	No change
Rupture	ASME-Safety CSA-Rupture	—	No change

2.3 Working pressure vs full load pressure

ASME uses *working pressure* (WP), which is defined as the pressure at the cylinder when lifting the car and its rated load at rated speed, or with class C2 loading, when levelling up with maximum speed.

CEN defines *full load pressure* (FLP) as the static pressure exerted at the piping directly connected to the jack, the car with the rated load being at rest at the highest landing level.

CEN clause 12, Note 1, recognizes that friction losses as a result of fluid flow are on the order of

15%; thus a factor of 1,15 is included in their factor of safety determination.

Thus, ASME WP = 1,15 x (CEN FLP)

The CSA definition of working pressure (WP) corresponds to that in ASME.

2.4 Other terms

Additional terminology, where there is a difference between the CEN and the ASME and CSA standards, is shown in Table 2.4:

Table 2.4

CEN	ASME & CSA
Docking operation	Truck zone operation
Electric safety device	Electrical protective device
Fixings	Fastenings
Landing door	Hoistway door (ASME) Landing door (CSA)
Mains	Main power supply
Reeving ratio	Roping ratio
Instantaneous safety gear	Type A safeties (instantaneous safeties)
Progressive safety gear	Type B safeties (progressive safeties)
Pulley	Sheave
Safety gear	Safeties
Well	Hoistway

2.5 Abbreviations

The following abbreviations are used in this report:

FOS = Factor of safety or safety factor
YP = Yield point
WP = Working pressure
UTS = Ultimate tensile strength
FLP = Full load pressure

Note: See also list of abbreviations in items 4.1.2.

3 Basis for lift safety standards development (basic assumptions)

3.1 Historical background

3.1.1 All lift safety standards assume certain things as being true, without proving them as such, and stipulate safety rules that are based on these assumptions.

3.1.2 No standard, however, clearly spells out the assumptions used. The CEN committee analyzed its standard and summarized in the document CEN/TC10/WG1 N99 (see Annex C) the assumptions that, in the opinion of the committee, were used in the CEN standard.

3.1.3 The CEN assumptions were compared with assumptions implicitly built into other safety standards. It has been indicated that:

a) Some assumptions apparently used in the CEN standard were not listed in the document referred to in CEN/TC10/WG1 N99;

b) Some assumptions used in other standards differ from those in CEN/TC10/WG1 N99.

3.1.4 Using CEN/TC10/WG1 N99 as a model, the following list of assumptions (see 3.3 through 3.9 in this report) has been developed, which could be used as a basis for future work on safety standards.

The CEN assumptions 5 (related to car speed) and 7 (related to restrictors) as listed in Annex C have not been considered for adoption in this report, since they are deemed to be design parameters.

Further, CEN assumption 2 is adopted in this report as assumption 1 and CEN assumption 6 as assumption 3(c) in order to be consistent with Part 1 of this report.

In summary, CEN assumptions 1, 3, 4, 8, 9, and 10 correspond to assumptions 1, 2, 3, 4, 5, and 6 in this report. Assumption 7 is not covered in the CEN document.

3.2 General

3.2.1 Listed in 3.3 through 3.9 (except as noted) are those things specific to lifts that are assumed as true, although not yet proven or demonstrated as such, including:

a) Functioning and reliability of lift components;

b) Human behaviour and endurance; and

c) Acceptable level of safety and safety margins.

3.2.2 Where the probability of an occurrence is considered highly unlikely, it is considered as not happening.

3.2.3 Where an occurrence proves that an assumption is false, it does not necessarily prove that all other assumptions are false.

3.2.4 The assumptions should be subject to periodic review by standards writing organizations to ensure their continuing validity -- considering accident statistics, as well as such things as changes in technologies, public expectations (e.g. product liability), and human behaviour.

3.3 Assumption 1—safe operation assured to 125% of rated load

Safe operation of lifts is assured for loads ranging from 0 to 100% of the rated load. In addition, in the case of *passenger lifts* (see 2.1.2), safe operation is also assured for an overload of 25%; however, it is not necessary to be able to raise this overload nor to achieve normal operation (rated load performance).

3.3.1 Rationale for Assumption 1

3.3.1.1 All safety standards limit the car area in relation to its rated capacity (load and/or number of persons) in order to minimize the probability of inadvertent overloading. However, it is recognized that the possibility of an overloading of up to 25% still exists on *passenger lifts*. To eliminate any hazard for passengers, safe operation must be assured, but not necessarily normal operation.

3.3.1.2 In the case of *freight lifts*, no overloading is anticipated. It is assumed that designated attendants and freight handlers will adhere to instructions posted in cars and will not overload them.

3.3.2 Assumption 1 as applied in current standards

3.3.2.1 Currently CEN does not specifically require a 25% overload safety margin; however, the design requirements provide for that level of safety.

ASME (Rules 301.10 and 207.8) and CSA (Clauses 4.17.1 and 3.9.8) specifically require that safety be assured on *passenger lifts* in the case of 25% overload.

3.3.2.2 With exceptions given in 3.3.2.5, the ratio of the rated load to the car platform area for passenger lifts is equal (±5%) in all standards for the range of 320 to 4000 kg, and in that respect, universality of the assumption #1 is achieved.

However, the assumed average weight of a passenger differs: 75kg (CEN), 72,5kg (CSA), while in ASME it is not specified (prior to A17.1a-1985, the assumed weight for purposes of computing the maximum number of passengers which could be safely transported in an emergency was 68 kg).

3.3.2.3 Furthermore, the rated load to car platform area ratio is different for *freight lifts*.

CEN (non-commercial vehicle with instructed users)	200kg/m^2
ASME/CSA (general freight Class A)	244/240 kg/m^2
(motor vehicle Class B)	146/145 kg/m^2
(industrial truck Class C)	244/240 kg/m^2

3.3.2.4 The CEN standard contains two tables showing the ratio between the rated load and the maximum available car area (for *passenger lifts*). The CEN table "1.1" corresponding to the requirements for electric lifts is based on the rationale explained in 3.3.1.1 and was taken into consideration when formulating the statement in 3.3.2.2.

3.3.2.5 The CEN table "1.1A" is based on the rationale that where there is a low probability of the car being overloaded with persons, the available area of a hydraulic lift may be increased up to therein specified maximum, provided that additional safety measures are taken to ensure the safe interruption in the lift operation. Such measures include:

a) A pressure switch to prevent a start for a normal journey when the pressure exceeds the full load pressure by more than 20%;

b) The design of the car, car sling, car-ram connection, suspension means, car safety gear, rupture valve, clamping or pawl device, guide rails, and buffers must be based on a load resulting from table "1.1";

c) The design pressure of the jack and the piping shall not be exceeded by more than 1,4.

Starting point for CEN's Table "1.1A" was the comparison of safety factors of driving systems on electric traction lifts versus hydraulic lifts. On hydraulic lifts the safety factor for the car suspension means and supporting structure is at least 3 times higher than that of the traction driving systems, when friction between the suspension ropes and the grooves of the drive sheave is taken into account. Consequently, the safety risk of unintended car movement downwards due to the overloading on hydraulic lifts is significantly lower than on electric traction lifts.

Furthermore, assuming that the car weight is equal to the rated load, in that case an overload of x% on the electric traction lift would correspond to only x/2% overload for the hydraulic system.

For car areas up to 5 m^2, the required rated load in table "1.1A" for a hydraulic lift may be 1,6 times less than the rated load of an electric lift. Note that 1.6 is an ISO-standard number R5. This is important in view of the rated loads according to ISO 4190-1, e.g. a bed lift with 5 m^2 available car area requires 2500 kg rated load in the case of an electric lift, and 1600 kg in the case of a hydraulic lift. For car areas bigger than 5 m^2 there is no mathematical background.

See Table 3.3.2.5 for an abbreviated comparison of the CEN Tables.

TABLE 3.3.2.5

Rated Load	Maximum Car Area		Increase in Car Area
	CEN Table 1.1	CEN Table 1.1A	"1.1A" over "1.1"
kg	m^2	m^2	%
400	1,17	1,68	44
800	2,00	2,96	48
1200	2,80	4,08	46
1600	3,56	5,04	42
over 1600, add	N/A	0,40/100 kg	N/A
2000	4,20	6,64	58
2500	5,00	8,84	73
over 2500, add	0,16/100 kg	0,4/100 kg	250

3.3.2.6 Lift components that are normally designed to withstand, without permanent damage, overloads greater than 25% (such as ropes, guides, sheaves, buffers, disconnect switches) are not considered in this comparison.

Note: *CEN Assumption 2 (see Annex C) is not a new assumption, but rather one of the methods as to how Assumption 1 is applied in the CEN standard.*

3.4 Assumption 2 — failure of electric safety devices

The possibility of a failure of an electric safety device complying with the requirement(s) of a lift safety standard is not taken into consideration.

Since national safety rules for lifts may be based on different assumptions (some are listed below), universality of Assumption 2 may be questioned.

3.4.1 Rationale for Assumption 2

Reliability and safety performance of lift components designated as electric safety devices is assured if designed in accordance with rules contained in a given lift safety standard. However, the design rules may be based on different assumptions.

3.4.2 Assumption 2 as applied in current standards

Most methods of assuring performance reliability of electric safety devices are similar in present standards. There are, however, differences and inconsistencies, as detailed in section 11. Section 11.1.3 deals in particular with discrepancies in assumptions implied in requirements for design of electric safety devices.

3.5 Assumption 3 — failure of mechanical devices

a) With the exception of items listed below, a mechanical device built and maintained according to good practice and the requirements of a standard comprising safety rules for lifts is assumed not to deteriorate to the point of creating hazards before the failure is detected. (**Note:** *National practices and safety rules may be different, such as safety factors. See sections 4.1.3 and 4.2.1 of this report.*)

b) The possibility of the following mechanical failures shall be taken into consideration:

    1) rupture of car suspension means.

    2) rupture and slackening of any connecting means such as safety related auxiliary ropes, chains and belts where the safety of normal lift operation or the operation of a safety related standby component is dependent on such connections.

    3) small leakage in the hydraulic system (jack included)

c) The possibility of a car or counterweight striking a buffer at a speed higher than the buffer's rating is not taken into consideration.

d) The possibility of a simultaneous failure of a mechanical device listed above and another mechanical device provided to ensure safe operation of a lift, should the first failure occur, is not taken into consideration.

NOTES:

1) *The Working Group could not agree upon adopting the CEN Assumption 4.3 (see Annex C) requiring that "the possibility of rupture in the hydraulic system (jack excluded) shall be taken into consideration."*

2) *Presently, this assumption is implemented only in CEN by requiring a rupture valve or similar devices, while CSA assumes the rupture of flexible hoses only and, in that case only, the rupture valve is required. In ASME, the rupture valve (safety valve) is only required in seismic risk zones 2 or greater.*

3) *The CEN rupture valve protects only in the case of rupture of piping, not the cylinder. The USA's experience indicates that most problems arise from the rupture of cylinders rather than piping.*

4) *Refer to section 10 and table 10.1.2 in this Report for detailed comparison of requirements for free fall and excessive speed protection.*

3.5.1 Rationale for Assumption 3

3.5.1.1 Although recent accident records do not support the assumption in 3.5(b)(1), most safety standards (including those studied in the preparation of this report) still assume that the risk of suspension means failure, in particular wire ropes and chains, exists.

3.5.1.2 With the assumption in 3.5 (b)(2) it is recognized that the listed components could deteriorate to the point of creating a direct or potential hazard (by making a safety related standby component inoperative) before the deterioration is detected.

3.5.2 Assumption 3 as applied in current standards

3.5.2.1 CEN (9.5.1) clearly assumes failure of suspension means, while ASME (301.8) and CSA (4.16.1) rules imply that safety gear must be able to stop, or at least slow down, a free falling car.

3.5.2.2 Standards differ significantly in regard to the rupture or slackening of connecting means. Only CEN seems to be consistent in adopting this assumption. Some standards are inconsistent, e.g. ASME [209.2d(2)] and CSA (3.11.2.4c) anticipate failure of tapes, chains or ropes operating normal terminal stopping devices, but they do not anticipate failure of an overspeed governor rope. Only CEN (9.10.2.10.3) assumes the possibility of governor rope failure.

3.5.2.3 All standards have adopted the assumption that the possibility of a car or counterweight striking buffers at a speed higher than the buffer's rating is not taken into consideration.

3.5.2.4 All standards have adopted the assumption that the possibility of a simultaneous failure of a mechanical device mentioned in Assumption 3 and another mechanical device provided to ensure safe operation of a lift, should the first failure occur, is not taken into consideration.

3.5.2.5 All standards require an anti-creep system based on assumption 3.5(b)(3).

3.6 Assumption 4 - imprudent act by users

A user may in certain cases make one imprudent act, intentionally made to circumvent the safety function of a lift component without using special tools. However, it is assumed that:

a) two imprudent acts by users will not take place simultaneously; and

b) an imprudent user's act and the failure of the backup component designed to prevent the safety hazard resulting from such imprudent acts will not take place simultaneously (e.g. a user manipulating an interlock and a safety circuit failure).

3.6.1 Assumption 4 as applied in current standards

All three standards are based on this assumption.

3.7 Assumption 5 - neutralization of safety devices during servicing

If a safety device, inaccessible to users, is deliberately neutralized in the course of servicing work, the safe operation of the lift is no longer assured.

3.7.1 Rationale for Assumption 5

If a mechanic, while servicing a lift, neutralizes or circumvents a safety device (e.g. bypassing door interlocks using a jumper cable or readjusting overspeed governor) safe lift operation cannot be assured.

While it is assumed that lifts will be designed to facilitate ease of servicing work and that service mechanics will be equipped with adequate instructions, tools and expertise to safely service lifts, it is recognized that "fail-safe" service work can never be assured solely by the design of a lift.

3.7.2 Assumption 5 as applied in existing standards

3.7.2.1 All three standards are based on this assumption.

3.7.2.2 The standards, however, differ in requirements for the "tools" that must be provided by the design of a lift in order to facilitate ease and safety of servicing work. All standards require stop switches on the car roof, in the hoistway pit and pulley room, and also means for inspection operation from the car top. The standards differ in the following:

a) CEN(7.7.3.2) requires "emergency unlocking device "to be provided for every landing door, while ASME (111.9 & 111.10) and CSA (2.12.9 & 2.12.10) require such a device only on two landings and permit it on all other landings.

b) Only CSA (3.12.1.4) requires "bypass switches" to be provided in the machine room, which would bypass interlocks or car-door-contact, disconnect normal operation and enable car-top-inspection operation, in order to facilitate the mechanic's servicing of faulty interlocks or car-door contacts.

c) Only CEN (5.9) requires lighting of the hoistway.

3.8 Assumption 6 - horizontal forces exerted by a person

One person can exert either of the following horizontal forces at a surface perpendicular to the plane at which the person stands:

a) static force - 300 N

b) force resulting from impact - 1000 N

Static forces of short time duration may be exerted by the simultaneous deliberate acts of several people located immediately adjacent to each other at every 300 mm interval along the width of a surface.

3.8.1 Rationale for Assumption 6

It is assumed that a person leaning against a vertical surface will exert these forces at that surface. It is further assumed that more than one person can exert this force on a surface simultaneously. Only by relating a force to the width of a surface on which it can be exerted, can a realistic design requirement be obtained.

3.8.2 Assumption 6 as applied in current standards

From Table 3.8.2 it is obvious that forces assumed in the standards are different.

3.9 Assumption 7 - retardation

A person is capable of withstanding an average vertical retardation of 1g (9,81 m/s^2) and higher transient retardations.

3.9.1 Rationale for assumption 7

The retardation which can be withstood without injury varies from person to person. Historically, the values used in the standards (see table 3.9.2) have not been shown to be unsafe for a vast majority of people.

Note: *See 3.9.3 regarding retardation limits on emergency car stops.*

3.9.2 Assumption 7 as applied in current standards

Table 3.9.2 gives a comparison of requirements based on the assumed safe retardation rates. Major differences are noted in relation to rupture valves, plunger stops, and emergency speed limits.

No standard limits retardation in the case of car stops initiated by an electrical safety device.

3.9.3 Agreed-upon points

All Standards should consider retardation limits on emergency stops initiated by an electrical safety device, albeit based on bio-mechanical studies.

TABLE 3.8.2
ASSUMPTION 6 AS APPLIED IN CURRENT STANDARDS

Assumptions	**CEN**	**ASME**	**CSA**
1.0 **Static force**			
1.1 Landing doors	300 N (7.2.3)	5004 N [110.11e(7)]	2500 N (2.11.10.4.7)
1.2 Car enclosure	300 N (8.3.2.1)	334 N (204.1c)	330 N (3.6.1.3)
2.0 **Impact**	No spec.	5004 N (110.11h)	5000 N (2.11.10.5)
3.0 **Force distribution**	No spec.	No spec.	No spec.

TABLE 3.9.2
ASSUMPTION 7 AS APPLIED IN CURRENT STANDARDS

Assumption	CEN	ASME	CSA
Maximum Average Retardation*			
•Progressive Safety Gear	1 g (9.8.4)	1 g (205.8b)	1 g (3.7.9.2)
•Progressive Clamping Device	1 g (9.9.4)	N/A	N/A
•Oil Buffers	1 g (10.4.3.2)	1 g (3.3.5.2)	1 g (3.3.5.2)
•Rupture valve	1 g (12.5.5.1)	No spec.	No spec.
•Plunger stops	1 g (12.2.3)	No spec.	No spec.
•Emergency speed limit	No spec.	1 g [305.2b(2)]	1 g (4.21.2.2.b)
•Emergency car stops	No spec.	No spec.	No spec.
Maximum retardation			
•Safety gear	No spec.	No spec.	No spec.
•Buffers *(if t = Duration)*	> 2,5 g (10.4.3.2) t ≤ 0,04 s	> 2,5 g (201.4b) t ≤ 0,04 s	> 2,5 g (3.3.5.2) t ≤ 0,04 s

**Maximum average retardation levels exceeding 1 g can occur with a lightly loaded lift during safety or buffer application.*

Note: 1 g = 9,81 m/s^2

4 Approach to design safety for hydraulic components

4.1 Historical Background

4.1.1 Philosophical differences

This section concentrates on differences between the CEN and ASME requirements for the design of hydraulic components. Reference to the CSA standard is made where it differs from ASME.

a) Differences in both design philosophy and design formulae lead to different cylinders and rams, valves, pipes, and fittings when designed to CEN and ASME standards. Philosophical differences are as follows:
   1) ASME uses the ultimate tensile strength subject to a minimum percentage elongation of the material as a design criterion.
   2) CEN uses the 0,2% proof stress yield point as the design criterion. Percentage elongation is not considered.
   3) The working pressure is differently defined in ASME and CEN.
   4) The factors of safety used are also different.

b) The differences are demonstrated by examples as illustrated by the following comparisons:
   1) Thickness of cylinder walls of single stage jacks (4.1.4);
   2) Thickness of flat cylinder base/head (4.1.5);
   3) Thickness of semi-elliptical cylinder head/cambered base (4.1.6);
   4) Thickness of ram wall for buckling (4.1.7).

4.1.2 Nomenclature

The following nomenclature is used in the two different standards:

Item	Units*	CEN	ASME
Working pressure	kPa	—	p
Full load pressure	MPa	p	—
Inside diameter of cylinder	mm	D_i	d
Diameter of flat head	mm	—	d
Inside diameter of skirt	mm	D_i	D
Outside dia. of cylinder, pipe	mm	D	D
Wall thickness, cylinder	mm	e_{cyl}	t
Wall thickness, flat bottom	mm	e_1	t
Wall thickness, semi-elliptical	mm	e_2	t
Additional wall thickness	mm	e_0	C
Design or allowable stress	kPa	—	S
0.2% proof stress	N/mm²/kPa	$Rp_{0.2}$	Y.P.
Tensile strength	N/mm²	R_m	—
Modulus of elasticity	N/mm²	E	—
Cross-sectional area of plunger	mm²/m²	An	A
Slenderness ratio	(dimensionless)	λ	—
Maximum unsupported ram length	mm	l	L
Radius of gyration	mm	—	R
Acceleration of gravity	m/s²	g_n	—
Reeving (roping) ratio	(dimensionless)	Cm	—
Mass of empty car	kg	P_3	—
Rated load in car	kg	Q	—
Mass of ram	kg	Pr	—
Mass of ram head equipment	kg	Prh	—
Design load on ram	N	F_5	—
Actual load on ram	N	F	—
Second moment of ram area	mm⁴	J_n	—

**If two entries, then the first applies to CEN, the second to ASME.*

4.1.3 Factor of Safety Comparison

CSA Clause 4.19.1.1.1, and ASME Rules 302.2a and 303.3a require that:

1) For tensile, compressive bending and torsional loading, the plunger, cylinder and connecting couplings shall have a factor of safety not less than 5 based on ultimate tensile strength (UTS).

2) For pressure calculations of the components that are subject to fluid pressure, including the plunger, connecting coupling, control valves, cylinder, and rigid piping shall have a factor of safety (FOS) not less than that calculated from:

$$F = \frac{5{,}04}{E - 2{,}8} + 2{,}7 \qquad (A)$$

where

F = Minimum FOS based on 0,2% proof stress yield point. The minimum allowable F shall be 3.

E = Percentage Elongation in 50 mm gauge length as per ASTM Standard E8, expressed as a whole number (eg, 20% = 20 and 5% = 5). The minimum allowable E shall be 5.

The allowable stress to be used for pressure calculations, according to ASME (130.2.5b), shall be determined as follows:

$$S = \frac{Y.P.}{F} \qquad (B)$$

where

S = Allowable stress (kPa).

Y.P. = Yield point based on 0,2% proof yield stress point.

F = FOS per formula (A).

CEN (12.2.1.1.1) requires that rams and cylinders be designed with a FOS of 3,91 (2,3 x 1,7), based on the 0,2% proof stress (YP) and the *full load pressure* (FLP).

For calculations of tensile, compressive, bending and torsional loads the following relationship between ASME and CEN requirements can be established:

$R_{p0.2}$=0,2% proof stress

ASME WP = 1,15 (CEN FLP)
ASME FOS = 5 (ASME Working Stress)
CEN FOS = 3,91 (CEN working stress at FLP)
or
= 3,4(ASME working stress at WP)

Therefore:

UTS ≥ 5 ASME working stress
YP ≥ 3,4 ASME working stress
(0,2% proof stress = YP)

Nominal equality of ASME and CEN requirements would occur if:

$$\frac{UTS}{YP} = \frac{5}{3{,}4} = 1{,}47$$

However, the formulae employed are different in the two codes, so the comparison is more complex.

For comparisons of stresses due to pressure it is necessary to determine the FOS from the formula (A) and the allowable stress from formula (B).
Examples of the differences between CEN and ASME/CSA are presented in the following sections 4.1.4 through 4.1.7

Note: *For further observations and suggestions regarding the factor of safety, refer to Section 4.2.1 and 4.2.4.*

4.1.4 Cylinder wall thickness of single stage jacks

According to ASME (1302.2), the cylinder wall thickness of a single stage jack is calculated with the following formula:

$$t = \frac{pd}{2S} \tag{1}$$

where
d = inside diameter
p = working pressure
S = working (or allowable) stress
t = minimum wall thickness

From CEN Clause 12 Note 1.1:

$$e_{cyl} \geq \frac{2{,}3 \cdot 1{,}7}{R_{p0.2}} \, p \cdot \frac{D}{2} + e_0 \tag{2}$$

where
e_{cyl} = wall thickness
p = full load pressure
D = outside diameter

e_0=1,0 mm

It was noted that e_0 may be 0,5 in some cases; however it was agreed to leave it at 1,0 for the sake of simplicity.

For a valid comparison, the two formulae should be written as close, as possible in the same form, using common parameters.

As the full load pressure (p) in Equation (2) is in fact the static pressure of the system (P_s), and, based on Section 2.3 in this report, the working pressure (p) in Equation (1) may be written as p = 1,15(P_s), consequently Equation (1) may be rewritten as follows:

$$t = \frac{1{,}15}{2} \cdot \frac{P_s \cdot d}{S}$$

$$t = 0{,}575 \cdot \frac{P_s \cdot d}{S} \tag{1a}$$

Recognizing that D = d + 2e_{cyl}, Equation (2) may be rearranged in terms of the inside diameter as follows:

$$e_{cyl} \geq \frac{1{,}96 P_s \cdot d + e_0 R_{p0.2}}{R_{p0.2} - 3{,}91 P_s} \tag{2a}$$

In order to establish difference in the cylinder wall thickness when calculated per ASME versus CEN formula, the following is assumed:

a) the cylinder is made of material having Y.P. = $R_{p0.2}$ = 187,5 MPa, and

E = 14,8

b) the static pressure of the system is P_s = 3 MPa

From formula (A) F = 3,125, and from formula (B) S = 60 MPa.

The wall thickness is calculated in formulae (1a) and (2a) and plotted against cylinder inner diameter in Figure 4.1.4.

The graphs show that for a practical range of cylinder diameters the wall thickness required by CEN is always greater than that by ASME.

4.1.5 Thickness of flat cylinder base/head

ASME Rule 1302.3a requires that the wall thickness of a flat unreinforced head be designed according to the formula: