



BSI Standards Publication

Entertainment technology — Machinery for stages and other production areas — Safety requirements and inspections

National foreword

This British Standard is the UK implementation of EN 17206:2020 incorporating corrigendum October 2021. It supersedes BS 7905-1:2001 and BS 7906-1:2005, which are withdrawn.

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Veranstaltungstechnik - Maschinen für Bühnen und andere Produktionsbereiche - Sicherheitstechnische Anforderungen und Prüfungen

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Contents

Page

European foreword.....	7
Introduction	8
1 Scope	10
2 Normative references	10
3 Terms and definitions	12
3.1 General terms	12
3.2 Loads, forces and pressures	16
3.3 Electrical equipment and control systems.....	18
3.4 Tolerances relating to movement.....	21
4 Hazards	21
4.1 General.....	21
4.2 List of Significant Hazards.....	22
5 Design requirements	26
5.1 General.....	26
5.2 Examples of machine installations showing the groups	27
5.3 Load assumptions for stage elevators	29
5.4 Load bearing equipment	30
5.4.1 General.....	30
5.4.2 Load bearing lines.....	30
5.4.3 Load bearing lines terminations	30
5.5 Winding devices and diverter pulleys.....	33
5.5.1 Winding devices for wire ropes	33
5.5.2 Diverter pulleys for round wire ropes	33
5.5.3 Drive and idler sprockets for steel chains	33
5.6 Drive systems	34
5.6.1 General.....	34
5.6.2 Screw jack systems (spindle drives).....	35
5.6.3 Hydraulic systems.....	35
5.6.4 Auxiliary drive systems	36
5.6.5 Manual systems.....	36
5.7 Load carrying devices.....	36
6 Safeguarding hazardous areas	37
6.1 Protective spaces for inspection and maintenance	37
6.2 Accessibility of maintenance areas.....	37
6.3 Safeguarding at crushing, shearing and trapping points, and fall protection.....	38
6.4 Elevator shaft walls, openings and landing doors.....	38
6.4.1 General.....	38
6.4.2 Interlocking of doors	38
6.5 Counterweights.....	38
7 Electrical equipment and control systems.....	39
7.1 General requirements	39
7.1.1 General.....	39
7.1.2 Selection of equipment.....	40

7.1.3	Physical environment and operation conditions.....	40
7.2	Incoming supply conductor terminations and devices for disconnecting and switching off	41
7.2.1	Electric motors and associated equipment.....	41
7.2.2	Protection against electric shock.....	41
7.2.3	Protection of equipment	41
7.2.4	Control circuits and control functions	42
7.2.5	Travel of groups of machines	43
7.3	Safety functions and control functions in the event of failure	43
7.3.1	General	43
7.3.2	Providing redundancy	44
7.3.3	Hazardous operating conditions.....	44
7.3.4	Safety devices and safety functions.....	45
7.3.5	Means for testing safety devices and safety functions	48
7.4	Emergency stop functions	49
7.4.1	Emergency stop	49
7.4.2	Actuators for and design of emergency stop functions.....	49
7.5	Complementary Protective Measures.....	49
7.5.1	General	49
7.5.2	Limitation of number of simultaneous moving machines.....	50
7.5.3	Protection against unplanned load deviations (load profile monitoring)	50
7.6	Electronic and programmable electronic systems (E/PES)	50
7.6.1	General	50
7.6.2	Programmable controllers.....	50
7.6.3	Use of programmable electronic systems (E/E/PES) to implement safety functions.....	50
7.7	Use of electronic and programmable electronic systems (E/PES) without safety functions	50
7.8	Operator interfaces, control devices and contactors	50
7.8.1	General	50
7.8.2	Requirements for contactors	50
7.9	Marking, warning signs and reference designations.....	51
7.10	Testing and validation of electrical systems.....	51
7.10.1	General	51
7.10.2	Scope of routine testing.....	51
7.11	Validation and verification of functional safety systems.....	51
8	Documentation	52
8.1	General	52
8.2	Technical data to be included	52
8.2.1	General	52
8.2.2	User information for safety functions	52
8.3	Marking	53
8.3.1	General	53
8.3.2	Entertainment load limit	53
8.3.3	Supplementary loading information.....	54
8.3.4	Machinery.....	54
8.3.5	Remote operation.....	55
8.4	Documentation and information	55
8.4.1	General	55
8.4.2	Operating manual.....	55
8.4.3	Installation Instructions	57
8.4.4	Repair and maintenance instructions.....	57
8.4.5	Inspection and examination	58

8.4.6	Dismantling instructions.....	58
8.4.7	Appendix to instructions (for additional necessary documents).....	58
9	Testing prior to first use and after substantial changes	59
9.1	General.....	59
9.2	Test log.....	59
9.3	Testing prior to first use.....	59
9.3.1	Type, extent and performance of tests.....	59
9.3.2	Acceptance test	60
9.4	Test after changes and modifications.....	62
9.4.1	Substantial Changes	62
9.4.2	Any other changes.....	62
	Annex A (normative) Examples of hazards and risk origin	63
	Annex B (normative) Use case definitions	72
B.1	General.....	72
B.2	Upper machinery.....	72
B.3	Lower stage machinery – lifting.....	73
B.4	Lower stage machinery – horizontal movement	74
	Annex C (informative) Recommended safety functions and measures	75
C.1	General.....	75
C.2	Upper machinery.....	75
C.3	Lower machinery – lifting	76
C.4	Lower machinery – horizontal movement.....	77
	Annex D (normative) End user information table to be supplied by the manufacturer	78
	Annex E (informative) Designing safeguards on the basis of risk assessment	81
E.1	General.....	81
E.2	Risk assessment as in EN 62061	81
E.2.1	General.....	81
E.2.2	Guidance for selecting parameters Se, Fr and Pr for the risk estimation.....	82
E.2.2.1	Severity of injury (Se).....	82
E.2.2.2	Probability of occurrence of harm	83
E.2.2.3	Frequency and duration of exposure (Fr)	83
E.2.2.4	Probability of occurrence of a hazardous event	83
E.2.2.5	Probability of avoiding or limiting harm (Av)	85
E.2.2.6	SIL assignment	85
E.3	Risk assessment as in EN ISO 13849-1	88
E.3.1	General.....	88
E.3.2	Guidance for selecting parameters S, F and P for the risk estimation	88
E.3.2.1	Severity of injury S1 and S2	88
E.3.2.2	Frequency and/or exposure times to hazard, F1 and F2	88

E.3.2.3 Possibility of avoiding the hazard P1 and P2	88
Annex F (informative) Examples of using the risk graphs	91
F.1 Guidance for risk evaluation values for control system functions	91
F.2 Severity.....	91
F.3 Possibility of avoiding the hazardous event.....	92
F.4 Possibility frequency and duration of exposure	92
F.5 Probability of occurrence of a hazardous event.....	93
Annex G (informative) Application examples	94
G.1 General	94
G.2 Chain hoist for a speaker cluster – Stop on “deadman release”.....	94
G.2.2 Use Case identification – Annex B.....	95
G.2.3 Hazard definition – Annex A	95
G.2.4 Safety function allocation – Annex C.....	95
G.2.5 Initial risk estimation – Annex F	96
G.2.6 Safety function estimation – Annex E	96
G.3 Broadcast studio lighting hoist – Protection against overload	96
G.3.2 Use Case identification – Annex B.....	97
G.3.3 Hazard definition – Annex A	97
G.3.4 Safety function allocation – Annex C.....	97
G.3.5 Initial risk estimation – Annex F	98
G.3.6 Safety function estimation – Annex E	98
G.4 Group of winches lifting a common load – protection against loss of group synchronisation.....	98
G.4.2 Use Case identification – Annex B.....	99
G.4.3 Hazard definition – Annex A	99
G.4.4 Safety function allocation – Annex C.....	99
G.4.5 Initial risk estimation – Annex F	99
G.4.6 Safety function estimation – Annex E	100
G.5 Chain hoist to fly a performer – protection against over-speed	100
G.5.2 Use Case identification – Annex B.....	101
G.5.3 Hazard definition – Annex A	101
G.5.4 Safety function allocation – Annex C.....	101
G.5.5 Initial risk estimation – Annex F	101
G.5.6 Safety function estimation – Annex E	102
G.6 Two winches to fly a performer – Protection against position deviation	102
G.6.2 Use Case identification – Annex B.....	102
G.6.3 Hazard definition – Annex A	103

G.6.4	Safety function allocation – Annex C	103
G.6.5	Initial risk estimation – Annex F	103
G.6.6	Safety function estimation – Annex E.....	103
G.7	Orchestra pit elevator – Protection against crushing/shearing	104
G.7.2	Use Case identification – Annex B	104
G.7.3	Hazard definition – Annex A.....	104
G.7.4	Safety function allocation – Annex C	104
G.7.5	Initial risk estimation – Annex F.....	105
G.7.6	Safety function estimation – Annex E.....	105
G.8	Stage elevator platform – Protection against overload.....	105
G.8.2	Use Case identification – Annex B	106
G.8.3	Hazard definition – Annex A.....	106
G.8.4	Safety function allocation – Annex C	106
G.8.5	Initial risk estimation – Annex F.....	106
G.8.6	Safety function estimation – Annex E.....	107
	Bibliography	108

European foreword

This document (EN 17206:2020+AC:2021) has been prepared by Technical Committee CEN/TC 433 “Entertainment Technology – Machinery, equipment and installations”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2020, and conflicting national standards shall be withdrawn at the latest by November 2020.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes CWA 15902-1:2008.

This document differs from CWA 15902-1:2008 mainly as follows:

- a) evaluated and revised according to new European standards, Directives and Regulations;
- b) terms and definitions have been revised;
- c) updated examples and informative annexes;
- d) standard revised editorially.

This document includes the corrigendum EN 17206:2020/AC:2021 issued by CEN on 13 October 2021, which adds a note in 3.2.11 and corrects text in 5.6.1.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags AC AC.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The purpose of this document is to produce European specifications for the design, manufacture and installation of lifting and load bearing equipment within the entertainment industry. Apart from the Machinery Directive, the Council Directive 2009/104/EC of 16 September 2009 concerning the minimum safety and health requirements for the use of work equipment by workers at work states in Annex II:

“3.1.3.

Measures must be taken to ensure that workers are not present under suspended loads, unless such presence is required for the effective operation of the work

Loads may not be moved above unprotected workplaces usually occupied by workers.

Where that is the case, if work cannot be carried out properly any other way, appropriate procedures must be laid down and applied.”

This document considers situations that give rise to danger, such as moving or holding scenery or equipment:

- a) over persons and/or unprotected areas;
- b) in areas with low light conditions, limited visibility, for example while using stage fog and other masking effects.

These situations apply not only during performances, but also during rehearsals, technical set-up, preparations, installations and other situations. This document covers these hazards and suggests appropriate procedures to maintain safety.

Machinery installations are all technical installations and equipment used for operations in stage and production facilities in the entertainment industry. Such installations are used to lift, lower, suspend and carry loads (e.g. scenery, traverse systems, or lighting, film/video and sound equipment). They can also be used to move persons, and persons can stand under such equipment while the loads are at rest or in motion.

“Stages” are, for example, staging facilities and production areas in theatres, multipurpose halls, studios, production facilities for film, television or radio, concert halls, congress centres, schools, exhibition centres, trade-fair centres, museums, discotheques, amusement parks, sports facilities and open-air-theatres.

“Events” are, for example, concerts, shows, congresses, exhibitions, presentations, demonstrations, film or television recordings, etc.

This document considers permanently and temporarily installed lifting and movement equipment for stages and production areas within the entertainment industry.

This document does not consider the design or control of fire curtains.

Typical applications of this document include but are not limited to the following:

- acoustic doors;
- auditorium elevators;
- compensating elevators;
- cycloramas;
- fly bar systems (manual and motor driven);

- lighting bars;
- movable lighting towers;
- movable proscenium arches;
- orchestra elevators;
- performer flying systems;
- point hoists;
- revolving stages and turntables;
- scenery storage elevators;
- side stage and rear stage shutters;
- stage elevators;
- stage wagons;
- tiltable stage floors;
- trap elevators.

1 Scope

This document applies to machinery, machinery installations and machinery control systems used in places of assembly and in staging and production facilities for events and theatrical productions (stage machinery, for short). Such facilities include: theatres, multi-purpose halls, exhibition halls; film, television and radio studios; concert halls, schools, bars, discotheques, open-air stages and other rooms for shows and events.

The document applies to machinery installations with guided or unguided loads.

This document covers machinery used in the entertainment industry including machinery that is excluded from the Machinery Directive (2006/42/EC) specifically Article 1, 2(j) which excludes “*machinery intended to move performers during artistic performances*”.

This machinery includes controls, electrical and electronic control systems, electrical and electronic equipment, hydraulic and pneumatic power supplies.

The principles in this document also apply to machinery installations based on new technologies or specially designed installations which are not expressly mentioned here but which nevertheless operate in a similar manner or are meant for similar purposes to the equipment listed above.

2 Normative references

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

EN 818-1, *Short link chain for lifting purposes — Safety — Part 1: General conditions of acceptance*

EN 818-7, *Short link chain for lifting purposes — Safety — Part 7: Fine tolerance hoist chain, Grade T (Types T, DAT and DT)*

EN 1090-2, *Execution of steel structures and aluminium structures — Part 2: Technical requirements for steel structures*

EN 1090-3, *Execution of steel structures and aluminium structures — Part 3: Technical requirements for aluminium structures*

EN 1993-1-10, *Eurocode 3: Design of steel structures — Part 1-10: Material toughness and through-thickness properties*

EN 1999-1-1, *Eurocode 9: Design of aluminium structures — Part 1-1: General structural rules*

EN 10204, *Metallic products — Types of inspection documents*

EN 12385-1, *Steel wire ropes — Safety — Part 1: General requirements*

EN 12385-2, *Steel wire ropes — Safety — Part 2: Definitions, designation and classification*

EN 12385-4, *Steel wire ropes — Safety — Part 4: Stranded ropes for general lifting applications*

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

EN 13411 (all parts), *Terminations for steel wire ropes — Safety*

EN 13480-3, *Metallic industrial piping — Part 3: Design and calculation*

- EN 14492-1, *Cranes — Power driven winches and hoists — Part 1: Power driven winches*
- EN 14492-2:2019, *Cranes — Power driven winches and hoists — Part 2: Power driven hoists*
- EN 60034-1, *Rotating electrical machines — Part 1: Rating and performance (IEC 60034-1)*
- EN 60204-1:2018, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements (IEC 60204-1:2016)*
- EN 60204-32:2008, *Safety of machinery — Electrical equipment of machines — Part 32: Requirements for hoisting machines (IEC 60204-32:2008)*
- EN 60947-4-1, *Low-voltage switchgear and controlgear — Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters (IEC 60947-4-1)*
- EN 60947-5-1, *Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices (IEC 60947-5-1)*
- EN 61000-6-2, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments (IEC 61000-6-2)*
- EN 61000-6-4, *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments (IEC 61000-6-4)*
- EN 61326-3-1, *Electrical equipment for measurement, control and laboratory use — EMC requirements — Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) — General industrial applications*
- EN 61439-1, *Low-voltage switchgear and controlgear assemblies — Part 1: General rules (IEC 61439-1)*
- EN 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems (IEC 61508)*
- EN 62061:2005, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems (IEC 62061:2005)*
- EN 81346-1, *Industrial systems, installations and equipment and industrial products — Structuring principles and reference designations — Part 1: Basic rules (IEC 81346-1)*
- EN 82079-1, *Preparation of instructions for use — Structuring, content and presentation — Part 1: General principles and detailed requirements (IEC/IEEE 82079-1)*
- EN ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction (ISO 12100:2010)*
- EN ISO 13849-1:2015, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design (ISO 13849-1:2015)*
- EN ISO 13849-2, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation (ISO 13849-2)*
- EN ISO 13850, *Safety of machinery — Emergency stop function — Principles for design (ISO 13850)*

EN ISO 13854, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body (ISO 13854)*

EN ISO 13857, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs (ISO 13857)*

3 Terms and definitions

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

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp/ui>

3.1 General terms

3.1.1

competent person

person with sufficient practical and theoretical knowledge and experience to carry out the person's duties, and who is aware of the limits of the person's competency, expertise and knowledge

3.1.2

drive system

part of a load bearing machine that executes movement and holding of the load and which converts energy into movement

Note 1 to entry: See Figure 2 c), Figure 3 c) and Figure 4 c).

3.1.3

emergency stop

emergency stop function

E-stop

function which is intended to

- avert arising or reduce existing hazards to persons, damage to machinery or to work in progress, and
- be initiated by a single human action

Note 1 to entry: ISO 13850 gives detailed provisions.

[SOURCE: EN ISO 12100:2010, 3.40 – modified: Term “E-Stop” added]

3.1.4

failure

termination of the ability of an item to perform a required function

Note 1 to entry: After failure the item has a fault.

Note 2 to entry: “Failure” is an event, as distinguished from “fault”, which is a state.

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

Note 4 to entry: In practice the terms “failure” and “fault” are often used synonymously.

[SOURCE: IEV 192-03-01]

3.1.5

fault

state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

Note 1 to entry: A fault is often the result of a failure of the item itself, but can exist without prior failure.

Note 2 to entry: In the field of machinery, the English term “fault” is commonly used in accordance with the definition in IEV 192-04-01, whereas the French term “défaut” and the German term “Fehler” are used rather than the terms “Panne” and “Fehlzustand” that appear in the IEV with this definition.

Note 3 to entry: In practice, the terms “fault” and “failure” are often used synonymously.

[SOURCE: EN ISO 12100:2010, 3.33]

3.1.6

fly bar

fly bar (e.g. bar or truss) having several load bearing lines for lifting, lowering, and suspending loads, with the load being either uniformly distributed or concentrated (point load)

Note 1 to entry: A distinction is made between manually operated flying systems (e.g. manual counterweight systems) and motor-driven systems (e.g. with electric or hydraulic drive).

3.1.7

hazard

potential source of harm

Note 1 to entry: The term “hazard” can be qualified in order to define its origin (for example, mechanical hazard, electrical hazard) or the nature of the potential harm (for example, electric shock hazard, cutting hazard, toxic hazard, fire hazard).

Note 2 to entry: The hazard envisaged by this definition either

- is permanently present during the intended use of the machine (for example, motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature), or
- can appear unexpectedly (for example, explosion, crushing hazard as a consequence of an unintended/unexpected start-up, ejection as a consequence of a breakage, fall as a consequence of acceleration/deceleration).

Note 3 to entry: The French term “*phénomène dangereux*” should not be confused with the term “*risque*”, which was sometimes used instead in the past.

[SOURCE: EN ISO 12100:2010, 3.6]

3.1.8

hazard zone

danger zone

space within and/or around machinery in which a person can be exposed to a hazard

3.1.9

lifting accessory

component or equipment, allowing the load to be held, which is placed between the lifting machinery and the load or on the load itself, or which is intended to constitute an integral part of the load and which is independently placed on the market

3.1.10

load bearing element

parts of a machine between the load and the machinery anchor point

3.1.11

load bearing equipment

assembly of load bearing elements, including the drive mechanism

Note 1 to entry: See Figure 2 b), Figure 3 b) and Figure 4 b).

3.1.12

load carrying device

part of stage machinery which directly carries the intended load

EXAMPLE Fly bar of a bar hoist, platform of an elevator, truss, hook of a point hoist

Note 1 to entry: For trusses refer to EN 17115.

Note 2 to entry: See Figure 2 d), Figure 3 d) and Figure 4 d).

3.1.13

load securing device

mechanical device that can bring a load to a defined stop and prevents unintentional movement

EXAMPLE A brake, self-braking worm gear, shut-off valve.

3.1.14

load holding device

device that prevents unintentional movement of an already stationary load

EXAMPLE Rope lock, locking pin.

3.1.15

machinery installation

all elements between the load and the machinery anchor point

Note 1 to entry: See Figure 2 a); Figure 3 a); Figure 4 a).

3.1.16

manual counterweight system

manually operated fly bar moved by means of an operating rope, where the load is fully or partially balanced by counterweights carried in a guided frame connected to the flying bar

3.1.17

rated speed

maximum speed at which the machine is designed to operate

3.1.18

point hoist

lifting equipment having one load bearing line for lifting, lowering, and suspending loads

3.1.19

protective measure

measure intended to achieve risk reduction

3.1.20

risk

combination of the probability of occurrence of harm and the severity of that harm

3.1.21

safeguard

guard or protective device

[SOURCE: EN ISO 12100:2010, 3.26]

3.1.22

stage elevator

part of a horizontal or inclined (tilted) stage, performance area, studio or auditorium floor which can be moved vertically up and/or down, including all necessary drive elements

EXAMPLE 1 Elevator which is a permanent part of the stage, performance area, studio or auditorium floor (e.g. orchestra elevator, single- or double-deck stage elevator, stage compensating elevator, scenery storage elevator or auditorium elevator).

EXAMPLE 2 Elevator which is not a permanent part of the stage, performance area, studio or auditorium floor, which is used primarily for scenic purposes and which normally rests below stage (e.g. stage trap elevator).

Note 1 to entry: A stage elevator at rest can be part of the stage.

3.1.23

stage elevator platform

part of a stage elevator which supports the load

3.2 Loads, forces and pressures

Table 1 — Loads and forces

Loads and forces in normal operation	
	ENTERTAINMENT LOAD LIMIT (ELL)
+	WEIGHT OF LOAD CARRYING DEVICE
=	SYSTEM LOAD
+	DYNAMIC FORCES
=	CHARACTERISTIC LOAD
x 2	= DESIGN LOAD

Loads and forces occurring at failure	
	ENTERTAINMENT LOAD LIMIT (ELL)
+	WEIGHT OF LOAD CARRYING DEVICE
=	SYSTEM LOAD
+	DYNAMIC FORCES AT FAILURE
=	LOAD AT FAILURE
x 1	= DESIGN LOAD

3.2.1

characteristic load

characteristic load is the sum of the system load and the dynamic forces occurring during normal operation

Note 1 to entry: Normal operation also includes holding of loads at rest.

3.2.2

characteristic load pressure

in a hydraulic system, the pressure generated by the characteristic load

3.2.3**design load**

load to be used for calculation/validation of a specific component according to the standards and the technical literature applicable for the specific component

Note 1 to entry: Design load is obtained by multiplying the characteristic load (or the load at failure, depending on the specific condition being considered) of the component by the design risk coefficient (specific to the same component). See 5.3.

3.2.4**entertainment load limit****ELL**

maximum load that an item of lifting equipment is designed to raise, lower or sustain

3.2.5**entertainment load limit at rest****ELL/R**

maximum load that an item of lifting equipment is designed to sustain at rest

Note 1 to entry: Due to additional measures (such as locking pins in elevators), the Entertainment Load Limit at Rest could be higher than the entertainment load limit that the machine is capable of moving.

3.2.6**load at failure**

sum of the system load and the dynamic forces occurring due to uncontrolled stops in case of failure

Note 1 to entry: Uncontrolled stops may occur e.g. due to:

- a) failure in electric power supply;
- b) pressure failure in hydraulic system;
- c) activation of a safety device;
- d) stalling of the motor due to snagging of the load/load carrying device;
- e) sudden lifting of a load started with no tension on the ropes.

3.2.7**nominal pressure**

pressure stated by the manufacturer of the component

3.2.8**operating pressure**

pressure generated by the system

3.2.9**system load**

sum of entertainment load limit and the weight of the load carrying device

3.2.10**system pressure**

operating pressure limited by a pressure device

3.2.11

test load

load used when testing a lifting device, load bearing equipment, or load carrying or securing devices

ⓘ Note 1 to entry: See 9.3.2.3 for further details. ⓘ

3.3 Electrical equipment and control systems

3.3.1

control circuit

circuit used for the operational control of stage machinery and for protection of the power circuits

3.3.2

control device

device for the activation of a movement, e.g. lever, push button, wheel

3.3.3

controlled stop

stopping of machine motion with power to the machine actuators maintained during the stopping process

[SOURCE: EN 60204-1:2018, 3.1.14]

3.3.4

electrical/electronic/programmable electronic system

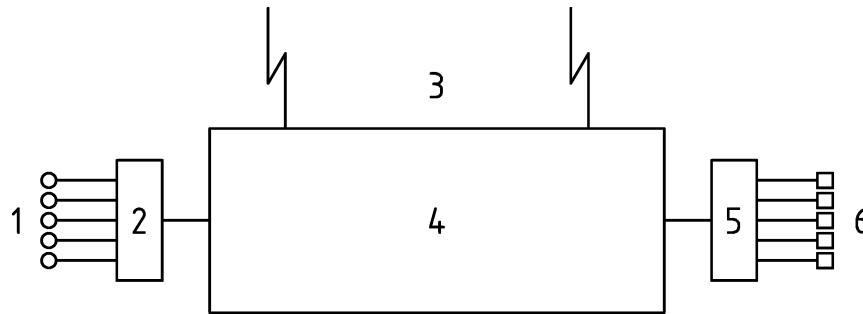
E/E/PE system

system for control, protection or monitoring based on one or more electrical/electronic programmable electronic (E/E/PE) devices, including all elements of the system such as power supplies, sensors and other input devices, data highways and other communication paths, and actuators and other output devices

Note 1 to entry: For structure and terminology see Figure 1.

EXAMPLE Electrical/electronic/programmable electronic devices include:

- a) electro-mechanical devices (electrical);
- b) solid-state non-programmable electronic devices (electronic); and
- c) electronic devices based on computer technology (programmable electronic).

**Key**

1 input devices (e.g. sensors, switches)

2 input interfaces A-D-converters

3 communications

4 E/E/PE device

5 output interfaces D-A-converters

6 output devices, final elements (e.g. actuators)

NOTE The E/E/PE device is shown centrally located but such device(s) could exist at several places in the E/E/PE system.

Figure 1 — Electrical/electronic programmable electronic system (E/E/PE system) – Structure and terminology

3.3.5**equipotential bonding**

provision of electric connections between conductive parts, intended to achieve equipotentiality

[SOURCE: IEC 195-1-10]

3.3.6**load profile monitoring**

programming of a specific axis load condition followed by monitoring of the load with an automatic stop of the axis once the measured load deviates from the programmed load

3.3.7**muting**

temporary suspension of a safety function by the SRP/CS

3.3.8**overload condition**

condition in which the load has gone above a preset value

3.3.9**performance level****PL**

discrete level used to specify the ability of safety related parts of control systems to perform a safety function under foreseeable conditions

[SOURCE: EN ISO 13849-1:2015, 3.1.23 – modified: Note 1 removed]

3.3.10**power source failure**

change in the electrical or fluid (liquid or gas) power supply that could adversely affect the performance of a machine

Note 1 to entry: This might include under-voltage, over-voltage, phase loss, incorrect phase sequence and fluid over-pressure or fluid under-pressure.

3.3.11

protective bonding circuit

protective conductors and conductive parts connected together to provide protection against electric shock in the event of an insulation failure

[SOURCE: EN 60204-1:2018, 3.1.50]

3.3.12

protective conductor

PE

conductor required by some measures for protection against electric shock for electrically connecting any of the following parts:

- a) exposed conductive parts;
- b) extraneous conductive parts;
- c) main earthing terminal;
- d) earth electrode; and
- e) earthed point of the source or artificial neutral

[SOURCE: EN 61984:2009, 3.35]

3.3.13

redundancy

application of more than one device or system, or part of a device or system, with the objective of ensuring that in the event of one failing to perform its function another is available to perform that function

[SOURCE: EN 60204-32:2008, 3.57]

3.3.14

safety function

function that is intended to achieve or maintain a safe state for the machine in respect of a specific hazardous event

3.3.15

safety integrity level

SIL

discrete level (one out of a possible three) for specifying the safety integrity requirements of the safety-related control functions to be allocated to the SRECS, where safety integrity level three has the highest level of safety integrity and safety integrity level one has the lowest

Note 1 to entry: See EN 61508-4:2010, 3.5.8.

Note 2 to entry: SIL 4 is not considered in this document, as it is not relevant to the risk reduction requirements normally associated with machinery. For requirements applicable to SIL 4, see EN 61508-1 and EN 61508-2.

3.3.16**slack condition**

condition in which a wire or load bearing device is no longer supporting its attached load

Note 1 to entry: Commonly referred to as a slack wire condition.

3.3.17**safety-related part of a control system****SRP/CS**

part of a control system that responds to safety-related input signals and generates safety-related output signals

Note 1 to entry: The combined safety-related parts of a control system start at the point where the safety-related input signals are initiated (including, for example, the actuating cam and the roller of the position switch) and end at the output of the power control elements (including, for example, the main contacts of a contactor).

Note 2 to entry: If monitoring systems are used for diagnostics, they are also considered as SRP/CS.

[SOURCE: EN ISO 13849-1:2015, 3.1.1]

3.3.18**uncontrolled stop**

stopping of machine movement by loss of or removal of power to the machine

3.3.19**underload condition**

condition in which the load has gone below a preset value

3.4 Tolerances relating to movement**3.4.1****group synchronisation tolerance**

permissible deviation in the position in relation to another machine within a group

3.4.2**group synchronisation tolerance in the event of failure**

permissible deviation in the position in relation to another of the machine within a group during (moving) and after (stationary) an event of failure.

4 Hazards**4.1 General**

When designing and using lifting and load bearing equipment as in this document, all foreseeable hazards shall be identified.

Only competent persons shall be responsible for:

- a) describing the intended use;
- b) risk assessment.

After risk assessment has been carried out, the appropriate measures to be taken shall be established for specific hazards. The risk assessment can be carried out on the basis of EN ISO 12100 or according

to the example hazards listed in Annex A. Suitable facilities and provisions to enable the recovery of performers and other persons shall be provided in the event of any of the identified hazards occurring.

The following steps shall be taken when selecting protective measures:

- a) specify the limits of the machinery (intended use, reasonably foreseeable misuse, space limits, the foreseeable life limit, and wear factors);
- b) identify hazards and estimate risks;
- c) avoid hazards by means of inherently safe design measures and reduce risks as much as possible;
- d) inform users of any residual risks (information for use).

4.2 List of Significant Hazards

Table 2 shows a list of significant hazards, hazardous situations and hazardous events that could result in risks to persons during normal use and foreseeable misuse. It also contains the relevant clauses in this document that are necessary to reduce or eliminate the risks associated with those hazards.

Table 2 — List of Significant Hazards

	Hazards	Relevant clause(s) in this document
	<i>The significant hazards below are based upon EN 12100:2010</i>	
1	Mechanical hazards due to:	
1.1	Acceleration, deceleration	5.1; 5.3; 6.3; 6.4; 6.5
1.2	Angular parts	5.1; 6.3
1.3	Approach of moving element to a fixed part	5.1; 6.3
1.5	Elastic elements	5.1; 6.3
1.6	Falling objects	5.1; 5.3; 5.4
1.7	Gravity	5.1; 5.3
1.8	Height from the ground	5.1; 5.3;
1.9	High pressure	5.6.3
1.10	Instability	5.1; 5.3
1.11	Kinetic energy	5.1; 5.3; 6.3
1.12	Machinery mobility	5.1; 6.3; 7.3.4.14; 7.3.4.15
1.13	Rotating elements	5.1; 6.3
1.14	Rough, slippery surface	—
1.15	Sharp edges	5.1; 6.3
1.16	Stored energy	5.6.3
2	Electrical hazards due to:	
2.1	Electromagnetic phenomena	7.1; 7.1.3.1
2.2	Electrostatic phenomena	7.1; 7.2.1; 7.2.3

	Hazards	Relevant clause(s) in this document
2.3	Live parts	7.1; 7.2.2; 7.2.3
2.4	Overload	7.1; 7.2.2; 7.2.3
2.5	Part which have become live under fault conditions	7.1; 7.2.2; 7.2.3
2.6	Short-circuit	7.1; 7.2.2; 7.2.3
2.7	Thermal radiation	7.1; 7.2.2; 7.2.3
3	Thermal hazards due to:	
3.1	Explosion	—
3.2	Flame	—
3.3	Objects or materials with high or low temperature	5.6
3.4	Radiation from heat sources	—
4	Noise hazards due to:	
4.1	Cavitation phenomena	—
4.2	Exhausting system	—
4.3	Gas leaking at high speed	5.6.3
4.4	Manufacturing process (stamping, cutting, etc.)	—
4.5	Moving parts	5.6
4.6	Scraping surfaces	—
4.7	Unbalanced rotating parts	5.6
4.8	Whistling pneumatics	—
4.9	Worn parts	—
5	Vibration hazards due to:	
5.1	Cavitation phenomena	—
5.2	Misalignment of moving parts	5.4.1
5.3	Mobile equipment	6.3
5.4	Scraping surfaces	—
5.5	Unbalanced rotating parts	5.6
5.6	Vibrating equipment	5.4.1; 5.6
5.7	Worn parts	—
6	Radiation hazards	
6.1	Low frequency, radio frequency radiation	7.1.3.1; 7.2.4.4
6.2	Infrared, visible and ultraviolet lights	7.2.4.4
6.3	Lasers	7.3.1; 7.3.4.2; 7.3.4.14; 7.3.4.16; 7.5.1

	Hazards	Relevant clause(s) in this document
7	Material and substances hazards	
7.1	Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes and dust	5.6.3; 7.3.4.10
7.2	Fire or explosion hazards	5.6.3
8	Ergonomic hazards	
8.1	Access	6.1; 6.2; 6.3; 6.4; 6.5; 7.5.1
8.2	Design or Location of indicators and visual display units	7.2.4.2; 7.8.1;
8.3	Design, location or identification of control devices	7.2.4.2; 7.8.1
8.4	Effort	5.6.5; 6.5; 7.8
8.5	Human error, human behaviour	7.2.4.2
8.6	Local lighting	7.8.1
8.7	Mental overload/underload	—
8.8	Posture	6.1; 6.2; 6.3; 6.4; 6.5
8.9	Repetitive activity	6.1; 6.2; 6.3; 6.4; 6.5
8.10	Visibility	6.1
9	Hazards associated with the environment in which the machine is used	
9.1	Dust and fog	—
9.2	Electromagnetic disturbance	7.1.3.1; 7.2.3.1
9.3	Lightning	7.2.3.1
9.4	Moisture	7.1.3.2
9.5	Pollution	—
9.6	Snow	—
9.7	Temperature	7.1.3.2; 7.2.3.1
9.8	Water	7.1.3.2
9.9	Wind	—
9.10	Lack of oxygen	5.6.3
10	Combination of hazards	
	<i>Additional hazards and hazardous events due to lifting procedures, load or machinery collisions due to:</i>	
11	Unintentional movements hazards	
11.1	Failure/malfunctioning of the control system	7.3.4; 7.4
11.2	Software errors	7.6; 7.7; 7.8

	Hazards	Relevant clause(s) in this document
11.3	Uncontrolled movements	5.6
11.4	Unintentional movement due to mechanical failure	5.1; 5.3; 5.4; 5.5; 5.6
12	Improper use hazards	
12.1	Unauthorised start-up	7.1.1; 7.2.4.2; 7.3.1
12.2	Unauthorised use	7.1.1; 7.2.4.2
12.3	Improper operation	8
12.4	Insufficient instructions for the operator	8
	<i>Additional hazards, hazardous situations and hazardous events due to lifting</i>	
13	Mechanical hazards and hazardous events	
13.1	Lack of stability	5.1; 5.3; 5.4; 5.5; 5.6
13.2	Uncontrolled loading – overloading – overturning moments exceeded	7.3.4.3; 7.3.4.4; 7.3.4.11
13.3	Unexpected/unintended movement of loads	5.6.1
13.4	Inadequate holding devices/accessories	5.4
13.5	Collision of more than one machine	7.3.4.14
13.6	From insufficient mechanical strength of parts	5.1; 5.3; 5.4; 5.5; 5.6
13.7	From inadequate design of pulleys, drums	5.5
13.8	From unsuitable selection of chains, ropes, lifting and accessories and their inadequate integration into the machine	5.4
13.9	From abnormal conditions of assembly/testing/use/maintenance	8
13.10	From the effect of load on persons (impact by load or counterweight)	6.1; 6.2; 6.3; 6.4; 6.5
13.11	Incorrect arrangement of machinery parts	5.1; 5.6
13.12	Incorrect installation, testing, use and maintenance	5.6; 8
	<i>Additional hazards, hazardous situations and hazardous events due to the lifting or moving of persons</i>	
14	Mechanical and unintentional movement hazards	
14.1	Inadequate mechanical strength – inadequate working coefficients	5.1; 5.6
14.2	Failure/malfunctioning of the control system	7.3.1; 7.3.2; 7.3.3; 7.3.4
14.3	Software errors	7.6
14.4	Uncontrolled movements	5.1; 5.6

5 Design requirements

5.1 General

Stage machinery can be grouped into four parts:

- a) load bearing equipment;
- b) control systems;
- c) drive system;
- d) load carrying device.

The basic safety concept laid down in this document is based on the principles of intrinsic safety or single fault safety design. This is achieved either through doubling the working coefficient in calculations (designing for twice the characteristic load) or through redundancy.

Load bearing elements of stage machinery shall be designed such that the design load is twice the characteristic load.

To account for failure conditions (e.g. due to a power failure, failure of the drive control system, or bursting of pipes), elements shall be designed such that the design load is 1 times the load at failure.

If the failure of load bearing elements does not lead to the load carrying device and its load failing, then it is acceptable that the design load is equal to the characteristic load. If the failure of a single load bearing element will not lead to catastrophic failure of the machinery then the design load is equal to the characteristic load.

Load bearing elements shall be designed according to appropriate standards, for example EN 1993-1-10 (Eurocode 3) for steel constructions and EN 1999-1-1 (Eurocode 9) for aluminium constructions.

All welding of fabrications shall be constructed and manufactured according to EN 1090-2 and EN 1090-3.

Natural frequency and lateral torsional buckling and lateral buckling of the structures shall be considered.

Inflammable elements are permitted only where design measures ensure that their destruction does not lead to the load carrying device and its load falling.

5.2 Examples of machine installations showing the groups

Examples of machine installations are given in Figure 2 to Figure 4.

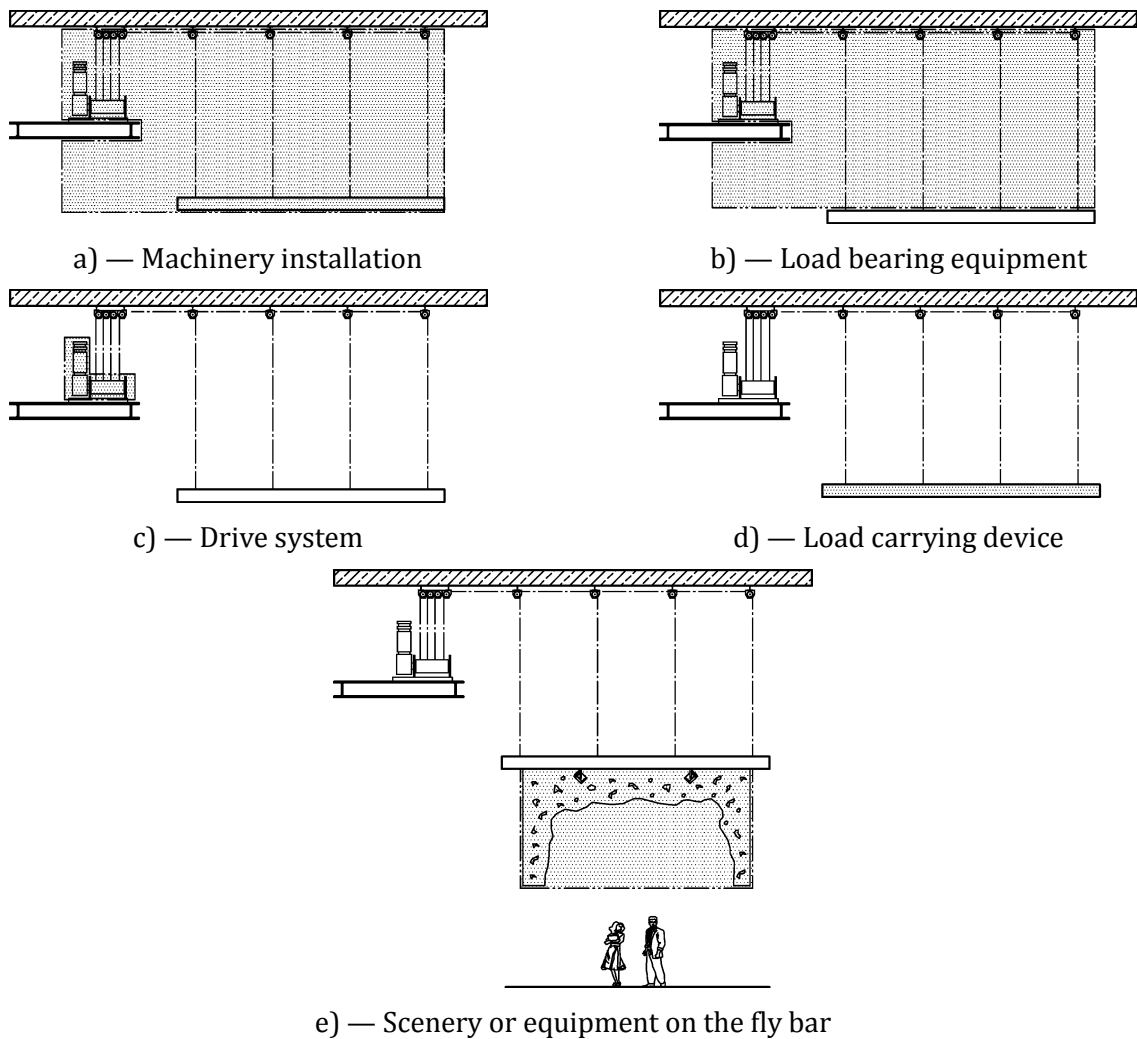


Figure 2 — Schematic representation of a bar hoist winch system

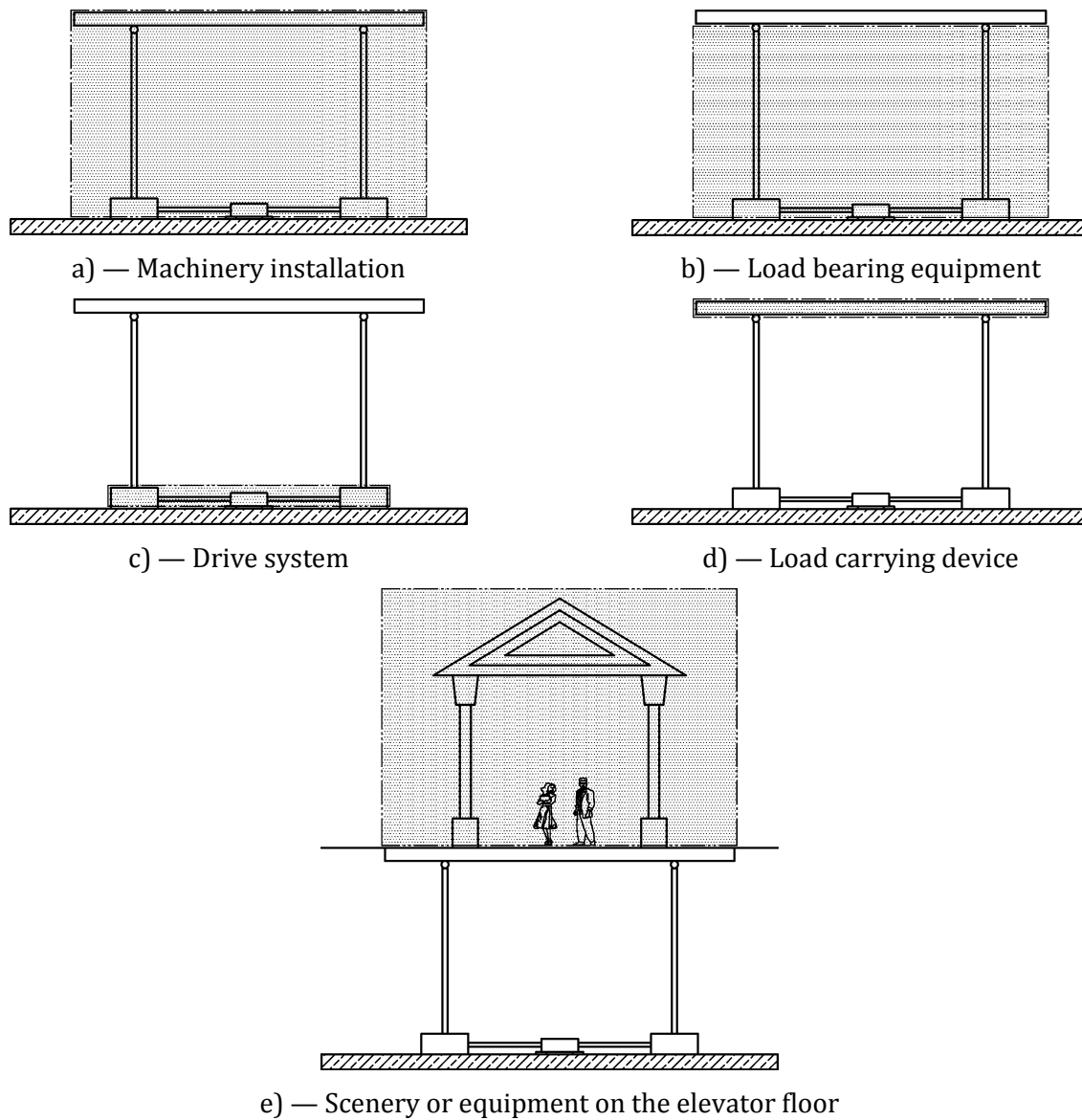


Figure 3 — Schematic representation of a stage elevator

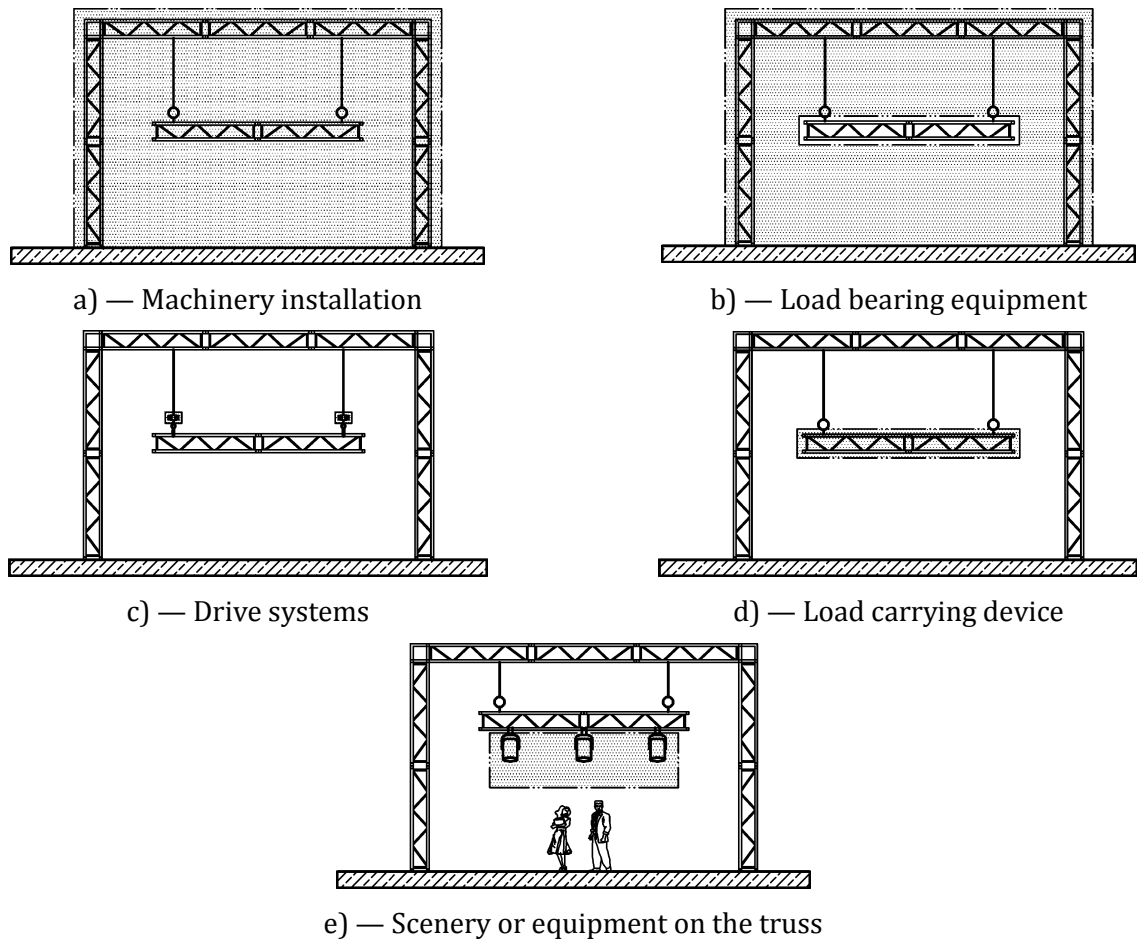


Figure 4 — Schematic representation of a system using multiple hoists

5.3 Load assumptions for stage elevators

The following minimum loads shall be assumed when making calculations:

- a) distributed load with elevator at rest as part of the stage floor shall be at least the same as the surrounding stage floor;
- b) point loads shall be defined;
- c) ELL shall be specified.

An exception to item a) are stage elevators used solely for artistic purposes and which are not a permanent part of the stage floor construction.

To obtain sufficient longitudinal and lateral rigidity the elevator should be capable of withstanding a horizontal force of at least 5 % of the ELL when in motion, and 5 % of the ELL/R when at rest.

5.4 Load bearing equipment

5.4.1 General

It is possible to use a single load bearing line.

All elements shall be secured against unintentional loosening.

EXAMPLE When quick links are used the direction of the link shall be with the nut screwing downwards when the link is closed.

All structural elements of load bearing equipment shall be made of non-flammable materials.

Synthetic or natural fibre ropes may be only used if the risk assessments indicate it is safe to do so.

5.4.2 Load bearing lines

5.4.2.1 Wire ropes

Wire rope which complies with EN 12385-1, EN 12385-2, EN 12385-4, and EN 12385-5 may be used as load bearing lines.

Wire ropes used as load bearing lines shall meet the requirements for a safety factor of at least 10 at characteristic load, and for a safety factor of at least 2 at load at failure, where the safety factor is the quotient of the minimum breaking load and the partial tensile force acting at characteristic load or load at failure respectively.

When wire-ropes do not travel over pulleys or drums, a lesser safety-factor may be used following a risk assessment.

Wire ropes shall be provided with a type 2.2 inspection document as in EN 10204 confirming testing as in EN 12385-4.

If a cover (plastic or textile) is used it shall be possible to inspect the entire length of the wire rope.

Jacketed wire ropes shall not be used as part of the machinery installation.

5.4.2.2 Chains

If round steel chains are used in machinery installations, these are to be calibrated and tested as in EN 818-7. Round steel chains used to carry loads shall meet the requirements for a safety factor of at least 8 at characteristic loading, in relation to the breaking force as specified in EN 818-7. Load at failure shall not give rise to permanent deformation.

Chains shall be provided with a type 2.2 inspection document as in EN 10204 confirming testing as in EN 818-7. Other types of chain (e.g. roller chains) shall meet the above requirements by analogy. Type-specific characteristics are to be taken into consideration.

5.4.3 Load bearing lines terminations

5.4.3.1 Wire rope terminations

Terminations shall be such that at least 80 % of the rope's minimum breaking force is maintained.

The rope end connection shall be designed so that its condition can be checked by inspection. End connections shall meet the requirements of EN 13411.

Use of grips as in EN 13411-5 is not allowed as a means to terminate load bearing lines.

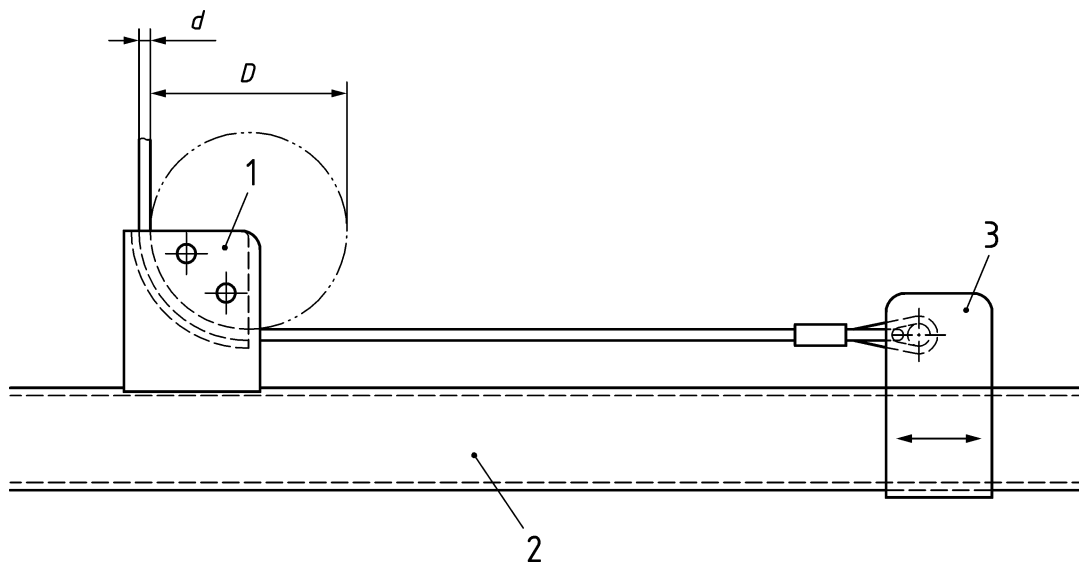
5.4.3.2 Detachable wire rope terminations

Detachable wire rope terminations may be:

- a) asymmetric wedge socket as in EN 13411-6;
- b) symmetric wedge socket in EN 13411-7.

Detachable terminations shall be secured against self-detachment, for instance by using grips as in EN 13411-5, which may only be attached to the free end of the rope termination (see Figure 5 and Figure 6 for examples).

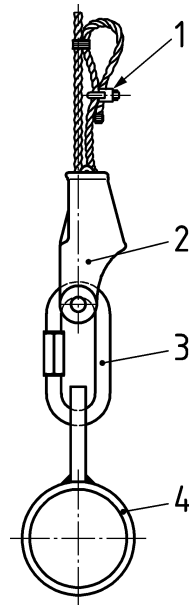
The connection to the fly bar shall allow free movement in all horizontal directions (see Figure 5).



Key

- 1 wire rope deflection
- $D : d$ ratio shall maintain 100 % of the wire rope integrity according to the manufacturer's specification, or, where the manufacturer's specification is not available, the rope deflection $D : d$ ratio shall not be less than 7
- D diameter of deflection
- d diameter of rope
- 2 fly bar
- 3 sliding clip

Figure 5 — Sliding pipe clip as an example of a device for compensating the length of a wire rope



Key

- 1 grip as in EN 13411-5
- 2 asymmetric wedge socket
- 3 quick link with screw caps
- 4 fly bar with welded lug

Figure 6 — Example of a means of suspending a fly bar

5.4.3.3 Fixed or Non-detachable wire rope terminations

Examples of non-detachable terminations for wire rope are:

- a) splices as in EN 13411-2;
- b) ferrules as in EN 13411-3;
- c) swage terminals as in EN 13411-8.

5.4.3.4 Load Hooks

Hooks shall be designed in accordance with the state of the art, e.g. in accordance to EN 14492-1 and EN 14492-2.

Hooks shall be such that the unintentional detachment of the load is prevented. This can be achieved by:

- a) a safety device; or
- b) the shape of the hook.

Hooks equipped with a safety-latch fulfil these requirements.

5.4.3.5 End connections for steel chains

Chain end terminations shall be designed and manufactured in such a way that they shall withstand 100 % of the chain's minimum breaking force before failure occurs. Roller chain terminations shall be designed and calculated with clear indications of the limits of bending in the unfavourable plane. The