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Supersedes
DIN 56950:2005-04
See start of application

Entertainment technology – Machinery installations – Part 1: Safety requirements and inspection, English translation of DIN 56950-1:2012-05

Veranstaltungstechnik –
Maschinentechnische Einrichtungen –
Teil 1: Sicherheitstechnische Anforderungen und Prüfung,
Englische Übersetzung von DIN 56950-1:2012-05

Technique événementielle –
Équipement pour machinerie scénique –
Partie 1: Exigences et examens relatifs à la sécurité,
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Start of application

The start of application of this standard is 2012-05-01.

DIN 56950:2005-04 remains valid until 2012-10-31.

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Foreword

This standard includes safety requirements within the meaning of the *Produktsicherheitsgesetz* (ProdSG) (German Product Safety Act).

Machinery installations complying with this standard, provided this standard has been identified by the *Ausschuss für Produktsicherheit* (German Product Safety Commission) and reference to it has been published in the *Gemeinsames Ministerialblatt* (Joint Ministerial Gazette) by the *Bundesanstalt für Arbeitsschutz und Arbeitsmedizin* (Federal Institute for Occupational Safety and Health), shall be presumed to comply with the relevant safety requirements and does not put the health and safety of persons at risk.

Under the conditions set down in Article 5 of the *Produktsicherheitsgesetz* such installations may be marked with the German "GS mark" (for *Geprüfte Sicherheit* ("Tested Safety")) when so granted to the manufacturer by an independent, accredited GS testing body.

This standard has been prepared by Working Committee NA 149-00-05 AA *Maschinen* of the *Normenausschuss Veranstaltungstechnik, Bild und Film* (NVBF) (Entertainment Technology, Photography and Cinematography Standards Committee) in DIN. Representatives of the DGUV (German Social Accident Insurance) association participated in the work carried out in NA 149-00-05 AA.

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

DIN 56950 consists of the following parts under the general title *Entertainment technology — Machinery installations*:

— *Part 1: Safety requirements and inspection*

— *Part 2: Design of and safety requirements for studio hoists*[1)]

— *Part 3: Design of and safety requirements for stands*[1)]

— *Part 4: Design of and safety requirements for serially manufactured projection screens*[1)]

Amendments

This standard differs from DIN 56950:2005-04 as follows:

a) the standard has been brought in line with CWA 15902-1;

b) an Annex giving information on visual and functional checks is now included;

c) an Annex giving information on performance levels is now included;

d) the normative references have been updated;

e) this standard is now Part 1 of a series, as further parts are being developed.

1) Under development.

Previous editions
DIN 56919: 1960-10, 1970-08, 1982-06
DIN 56921-1: 1955-10, 1960-10, 1965-05, 1980-05, 1999-10
DIN 56921-2: 1955-10, 1955-12, 1960-10, 1965-05
DIN 56921-11: 1980-05, 1997-07
DIN 56925: 1997-06
DIN 56940: 2003-02
DIN 56950: 2005-04

Introduction

This standard summarizes the information contained in previously valid standards for product groups relevant to the field of entertainment technology, and lays down specific design measures for machinery lying within the scope of Directive 2006/42/EC, the “Machinery Directive”, as well as for machinery lying outside the scope of this directive.

This standard deals with the safety of machinery within the meaning of the Machinery Directive, has been drawn up along the lines of CEN Guide 414, and is a “type C standard”.

The purpose of the standard is to ensure a consistent level of safety as regards the planning, construction, design, maintenance and inspection of machinery installations for use in staging and production facilities in the entertainment industry, taking into consideration the operations particular to such facilities. The present standard thus contains verifiable criteria for tendering procedures and for the inspection of machinery installations .

In the new EU Machinery Directive (Directive 2006/42/EC) the previous term “theatre elevators” has been replaced by the expression “machinery intended to move performers during artistic performances”. Such machinery is excluded from the scope of the new Machinery Directive, which is implemented in Germany by the *9. Verordnung zum Produktsicherheitsgesetz* (*Maschinenverordnung* – 9. ProdSV) (9th Ordinance of the German Product Safety Act — (Machinery Ordinance — 9th ProdSV)).

However, such machinery is not only used to “move performers during artistic performances”, but also to move or hold loads over persons, and to more or hold the persons themselves, not only during “artistic performances”, but also during stage construction, setting up scenery, and rehearsals.

The aim of this standard is to provide a consistent level of safety also for machinery which is excluded from the Machinery Directive.

Machinery installations can in certain circumstances also be classed as “work equipment” in the sense defined in the *Betriebssicherheitsverordnung* (BetrSichV) (German Ordinance on Industrial Safety and Health).

1 Scope

This standard applies to machinery and machinery installations 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; facilities in:

- concert halls,
- schools,
- exhibition halls,
- bars,
- discotheques,
- open-air stages and
- other rooms for shows and events.

For the purposes of this document, 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 may also be used to move persons, and persons may stand under such equipment while the loads are at rest or in motion.

This standard applies to machinery and machinery installations with guided or unguided load bearing and load carrying equipment.

Typical machinery installations include but are not limited to the following:

- auditorium elevators;
- cycloramas;
- fly bar systems (manual, motor driven);
- guiding tracks;
- lighting bars;
- movable lighting towers;
- movable stage platforms (stage wagons);
- movable proscenium arches;
- orchestra elevators;
- performer flying systems;
- point hoists;
- portable scaffolds;
- projection screens (manual or motor-driven);
- revolving stages and turntables;
- scenery storage elevators;
- side stage and rear stage shutters;
- stage elevators;
- stage wagons (stage trucks);
- tiltable stage floors.

This standard also applies to safety-related equipment used to protect against imminent hazards and which are used for similar safety purposes in the facilities listed above.

Examples of safety-related equipment include:

— smoke extractors;

— safety curtains.

For safety-related equipment the safety functions take priority.

This standard also applies to machinery installations based on new technologies or specially designed installations which are not expressly mentioned here but which nevertheless operate in an identical manner to the equipment listed above.

This standard does not apply to:

— machinery installations which are used for artistic purposes only, or to

— manual hoists (load capacity < 20 kg).

This standard also deals with the information to be exchanged by the manufacturer and user and the information necessary to use the machinery installation according to its intended purpose.

The significant hazards relating to this document are identified in Clause 4.

2 Normative references

The following referenced documents are indispensable for the application 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.

DIN 15061-1, *Lifting appliances — Groove profiles for wire rope sheaves*

DIN 15061-2, *Cranes — Groove profiles for wire rope drums*

DIN 18800-7, *Steel structures — Part 7: Execution and constructor's qualification*

DIN EN 349, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body*

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

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

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

DIN EN 1993-1 (all parts), *Eurocode 3: Design of steel structures*

DIN EN 1994-1-1, *Eurocode 4: Design of composite steel and concrete structures — Part 1-1: General rules and rules for buildings*

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

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

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

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

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

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

DIN EN 12644-1, *Cranes — Information for use and testing — Part 1: Instructions*

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

DIN EN 13411-2, *Terminations for steel wire ropes — Safety — Part 2: Splicing of eyes for wire rope slings*

DIN EN 13411-3, *Terminations for steel wire ropes — Safety — Part 3: Ferrules and ferrule-securing*

DIN EN 13411-5, *Terminations for steel wire ropes — Safety — Part 5: U-bolt wire rope grips*

DIN EN 13411-6, *Terminations for steel wire ropes — Safety — Part 6: Asymmetric wedge socket*

DIN EN 13411-7, *Terminations for steel wire ropes — Safety — Part 7: Symmetric wedge socket*

DIN EN 50172 (VDE 0108-100), *Emergency escape lighting systems*

DIN EN 50310 (VDE 0800-2-310), *Application of equipotential bonding and earthing in buildings with information technology equipment*

DIN EN 60034-1 (VDE 0530-1), *Rotating electrical machines — Part 1: Rating and performance*

DIN EN 60204-1 (VDE 0113-1), *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

DIN EN 60204-32 (VDE 0113-32), *Safety of machinery — Electrical equipment of machines — Part 32: Requirements for hoisting machines*

DIN EN 60529 (VDE 0470-1), *Degrees of protection provided by enclosures (IP code)*

DIN EN 60947-4-1 (VDE 0660-102):2011-01, *Low-voltage switchgear and controlgear — Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters*

DIN EN 60947-5-1 (VDE 0660-200), *Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices*

DIN EN 61000-6-2 (VDE 0839-6-2), *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments*

DIN EN 61000-6-4 (VDE 0839-6-4), *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments*

DIN EN 61131-1, *Programmable controllers — Part 1: General information*

DIN EN 61131-2 (VDE 0411-500), *Programmable controllers — Part 2: Equipment requirements and tests*

DIN EN 61439-1 (VDE 0660-600-1), *Low-voltage switchgear and controlgear assemblies — Part 1: General rules*

DIN EN 61508 (VDE 0803) (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

DIN EN 62061 (VDE 0113-50), *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

DIN EN 62079 (VDE 0039), *Preparation of instructions — Structuring, content and presentation*

DIN EN 81346-1, *Industrial systems, installations and equipment and industrial products — Structuring principles and reference designations — Part 1: Basic rules*

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

DIN EN ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

DIN EN ISO 13849-2, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

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

E DIN IEC 60364-5-54 (VDE 0100-540):2008-01, *Low-voltage electrical installations — Part 5-54: Selection and erection of electrical equipment — Earthing arrangements, protective conductors and protective bonding conductors (IEC 64/1610/CD:2007)*

DIN VDE 0100-718 (VDE 0100-718), *Erection of low-voltage installations — Requirements for special installations or locations — Part 718: Installations for gathering of people*

ISO 4301-1, *Cranes and lifting appliances — Classification — Part 1: General*

BGI 575, *Auswahl und Anbringung elektromechanischer Verriegelungseinrichtungen für Sicherheitsfunktionen* (Selection and mounting of electro-mechancial interlocking devices for safety functions)[2)]

BGG/GUV-G 912, *Grundsätze für die Prüfung maschinentechnischer Einrichtungen in Bühnen und Studios* (Principles of the testing of machinery installations in stages and studios)[2)]

BGV C 1/GUV-V C 1, *Veranstaltungs- und Produktionsstätten für szenische Darstellung* (BG regulations for staging and production facilities for the entertainment industry)[2)]

3 Terms and definitions

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

3.1 General terms

3.1.1
manual counterweight system
flying bar which is manually operated by means of an operating rope, where the load is directly counterbalanced by a guided counterweight

[DIN 56921-1:2010-03, 3.4]

3.1.2
stage elevator platform
part of a stage elevator which bears the load

3.1.3
backup safety nut
in a spindle drive, a non-loadbearing rotary nut used to track the wear of the supporting nut

3.1.4
load carrying device
part of stage machinery which directly carries the intended load

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2) Represented in the "*DITR-Datenbank*" maintained by *DIN Software GmbH*, obtainable from: *Carl Heymanns Verlag KG*, Luxemburger Str. 449, 50939 Cologne, Germany

EXAMPLES Hook of a chain hoist, fly bar of a bar hoist, platform of a stage elevator

NOTE This term is defined differently here as compared with the EU Machinery Directive.

3.1.5
fly bar system
fly bar (e.g. bar hoist or truss) having several load bearing lines for lifting, lowering, and suspending loads > 20 kg, with the load being either uniformly distributed or concentrated (point load)

NOTE 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)

3.1.6
point hoist
lifting equipment having one load bearing line for lifting, lowering, and suspending loads > 5 kg, where the load is concentrated (point load)

3.1.7
“Schleppboden” (suspended lift platform)
platform which is not permanently fixed to the load bearing device (stage elevator) and whose distance to the fixed platform of the stage elevator does not remain constant, and which serves as an additional device for bearing the load

3.1.8
securing device
<entertainment technology> mechanical device which prohibits unintentional movements

EXAMPLES: Brakes, shut-off valves

3.1.9
structural element
element between the load carrying device and the point of attachment within the machine limits, which bears both the load and the self-weight, including dynamic forces, of the machine, and which is permanently fixed to the machine

3.1.10
load bearing equipment
<entertainment technology> lifting equipment, including the drive mechanism, which bears loads

3.1.11
drive system
<entertainment technology> part of load bearing equipment that executes the raising, lowering and holding motions

3.1.12
stage elevator
stage lift
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).

3.2 Loads and forces

The terms used in Tables 1 and 2 are defined below.

Table 1 — Loads and forces in normal use

Loads and forces in normal use	
	Safe working load (SWL) (3.2.4)
+	Weight of load carrying device
=	System load (3.2.8)
+	Dynamic forces
=	Characteristic load (3.2.3)

Table 2 — Loads and forces occurring at failure

Loads and forces occurring at failure	
	Safe working load (SWL) (3.2.4)
+	Weight of load carrying device
=	System load (3.2.8)
+	Dynamic forces at failure
=	Load at failure (3.2.7)

3.2.1
manual force
force applied by a person via their hand, either as a tensile or compressive force (pulling or pushing)

3.2.2
load pressure
<entertainment technology> in a hydraulic system, the pressure generated by the external characteristic load

3.2.3
characteristic load
<entertainment technology> sum of the system load and the dynamic forces occurring during operation

3.2.4
safe working load (SWL)
<entertainment technology> useful load which is borne by the load carrying or securing device, or directly by the load bearing equipment, and which can be moved

NOTE The safe working load is equal to the system load minus the weight of the load securing and carrying devices and, in the case of stage elevators, minus the self-weight of the parts being moved with the load.

3.2.5
resulting test load
<entertainment technology>
resulting load during testing, equal to the sum of the applied test load and the dynamic forces

3.2.6
test load
load used when testing a lifting device, load bearing equipment, or load carrying or securing devices

NOTE 1 The test load is equal to the SWL multiplied by the test load factor.

NOTE 2 The test load factor for machinery installations is 1,25. For stage elevators with friction-locked stopping equipment, loading tests shall be carried out with the highest allowable load.

3.2.7
load at failure
sum of the system load and the dynamic forces occurring at failure

NOTE 1 Failure may occur due to

a) the activation of a safety device;

b) failure of a component or power failure.

NOTE 2 The maximum load at failure occurs during an uncontrolled stop (STOP category 0), unless demonstrated to be otherwise.

3.2.8
system load
load capacity
maximum load which can be safely handled by the machinery installation under normal operating conditions, not taking dynamic forces into consideration

NOTE The system load/load capacity can relate to a lifting device, load bearing equipment, or load carrying or securing devices.

3.2.9
overload factor
factor used to determine the limit value (i.e. value at which the characteristic load is exceeded) at which the equipment is to be shut-down

NOTE The shutdown limit is given by the characteristic load multiplied by the overload factor (1,2).

3.3 Electrical equipment

3.3.1
live part
conductor or conductive part intended to be energized in normal use, including a neutral conductor, but, by convention, not the combined protective and neutral conductor (PEN)

NOTE This concept does not necessarily imply a risk of electric shock.

[IEV 442-01-40]

3.3.2
failure
the termination of the ability of an item to perform a required function

NOTE 1 After failure the item has a fault.

NOTE 2 “Failure” is an event, as distinguished from “fault”, which is a state.

NOTE 3 This concept as defined does not apply to items consisting of software only.

[IEV 191-04-01]

NOTE 4 In practice the terms “failure” and “fault” are often used synonymously.

3.3.3
actuator
the part of the actuating system to which an external actuating force is applied

NOTE 1 The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

[IEV 441-15-22, modified]

NOTE 2 There are some actuators that do not require an external actuating force but only an action.

3.3.4
direct contact
contact of persons or livestock with live parts

[IEV 195-06-03, modified]

3.3.5
electrical/electronic/programmable electronic (E/E/PE)
based on electrical (E) and/or electronic (E) and/or programmable electronic (PE) technology

NOTE The term is intended to cover any and all devices or systems operating on electrical principles.

EXAMPLE Electrical/electronic/programmable electronic devices include

a) electro-mechanical devices (electrical);

b) solid-state non-programmable electronic devices (electronic);

c) electronic devices based on computer technology (programmable electronic).

[DIN EN 61508-4 (VDE 0803-4):2009-06, 3.2.13]

3.3.6
required performance level
PL_r
performance level (PL) applied in order to achieve the required risk reduction for each safety function

[DIN EN ISO 13849-1:2008-12, 3.1.24]

3.3.7
EUC control system
system which responds to input signals from the process and/or from an operator and generates output signals causing the EUC [“equipment under control”] to operate in the desired manner

NOTE The EU control system includes input devices and final elements.

[DIN EN 61508-4 (VDE 0803-4):2009-06, 3.3.3]

3.3.8
fault
the 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 A fault is often the result of a failure of the item itself, but may exist without prior failure.

[IEV 191-05-01]

NOTE 2 In the field of machinery, the English term “fault” is commonly used in accordance with the definition in IEV 191-05-01, 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 In practice, the terms “fault” and “failure” are often used synonymously.

[DIN EN ISO 12100-1:2004]

3.3.9
extraneous conductive part
conductive part not forming part of the electrical installation and liable to introduce a potential, generally the earth potential

[IEV 195-06-11]

3.3.10
hazard
potential source of harm

[DIN EN ISO 12100:2011-03, 3.6

3.3.11
concurrent
acting in conjunction

NOTE Used to describe a situation wherein two or more control devices exist in an actuated condition at the same time, but not necessarily synchronously.

3.3.12
power circuit
circuit used for supplying power from the supply network to units of electrical equipment used for productive operation and to transformers supplying control circuits

[DIN EN 60204-11 (VDE 0113-11):2001-05, 3.33]

3.3.13
indirect contact
contact of persons or livestock with exposed conductive parts which have become live under fault conditions

[DIN EN 60204-1 (VDE 0113-1):2007-06, 3.29, modified]

3.3.14
exposed conductive part
conductive part of electrical equipment, which can be touched and which is not normally live, but which may become live under fault conditions.

[DIN EN 50122-1 (VDE 0115-3):2011-09, 3.1.12, modified]

3.3.15
supply switch
<entertainment technology> disconnecting and switching device used to switch off and disconnect the machinery installation from the incoming supply

3.3.16
STOP category 0
uncontrolled stop
<entertainment technology> stopping of machine motion by switching off power to the machine actuators, all brakes and/or other mechanical stopping devices being activated

3.3.17
STOP category 1
controlled stop
stopping of machine motion with electrical power to the machine actuators maintained during the stopping process

[DIN EN 60204-1 (VDE 0113 -1):2007-06, 3.11]

3.3.18
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

[DIN EN ISO 13849-1:2008-12, 3.1.23]

3.3.19
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality

[IEV 195-01-10]

3.3.20
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

[DIN EN 60204-32 (VDE 0113-32):2009-03, 3.57]

3.3.21
risk
combination of the probability of occurrence of harm and the severity of that harm

[DIN EN ISO 12100:2011-03, 3.12]

3.3.22
safety device
<entertainment technology> electric circuit or electro-mechanical device which monitors operational conditions and functions

NOTE 1 Safety devices serve to protect persons and the machinery installation itself.

NOTE 2 In particular, safety devices include monitoring devices to control the drive systems and the electrical equipment used for starting and stopping.

3.3.23
Safety Integrity Level
SIL
discrete level (one out of a possible four), corresponding to a range of safety integrity values, where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest

[DIN EN 61508-4 (VDE 0803-4):2009-06, 3.5.8]

3.3.24
control circuit
<entertainment technology>
circuit used for the operational control of stage machinery and for protection of the power circuits

3.3.25
protective conductor (PE)
conductor provided for purposes of safety, for example protection against electric shock

[IEV 826-13-22]

NOTE For example the protective conductor can electrically connect any of the following parts:

— exposed conductive parts;

— extraneous conductive parts;

— main earthing terminal;

— earth electrode;

— earthed point of the source or artificial neutral.

[DIN EN 61439-1 (VDE 0660-600-1):2010-08, 3.7.4]

3.3.26
safeguard
guard or protective device

[DIN EN ISO 12100:2011-03, 3.26]

3.3.27
protective bonding circuit
the whole of the protective conductors and conductive parts used for protection against electric shock in the event of an insulation failure

[DIN EN 60204-11 (VDE 0113-11):2001-05, 3.34]

3.3.28
direct opening action of a contact element
achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (for example not dependent upon springs)

[DIN EN 60947-5-1 (VDE 0660-200):2010-04, K.2.2]

3.4 Tolerances relating to movement

3.4.1
group synchronization tolerance
agreed permissible deviation in the position in relation to one another of the machinery installations within a group, or permissible deviation from the travel curve calculated for the installation

3.4.2
group synchronization tolerance in the event of failure
agreed permissible deviation in the position in relation to one another of the machinery installations within a group, or permissible deviation from the travel curve calculated for the installation in the event of failure

3.5 Machine group travel

3.5.1
asynchronous travel with group deactivation
after a simultaneous start, travel of all machinery installations in a group where these move in an interdependent and coordinated manner

3.5.2
asynchronous travel without group deactivation
after a simultaneous start, travel of all machinery installations in a group where these move independently of one another

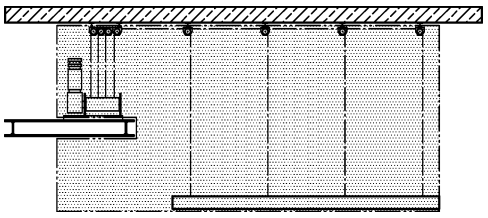
3.5.3
group
<entertainment technology> system of machines/machinery installations which are driven by the same control device

3.5.4
route-synchronized travel
travel during which all machines/installations in a group simultaneously travel the same distance over the same period of time

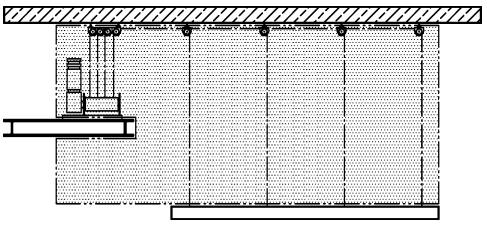
3.5.5
time-synchronized travel
travel during which, after a simultaneous start, all machines/installations in a group travel various distances over the same period of time

3.6 Examples of machinery installations

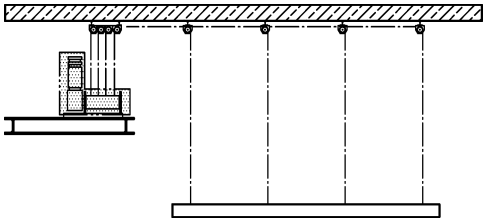
Figures 1 and 2 illustrate the terms defined in 3.1.



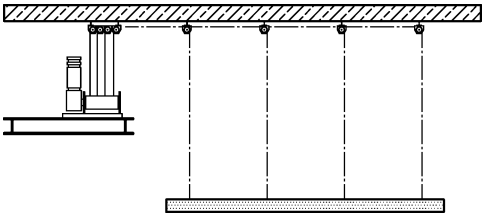
a) Machinery installation



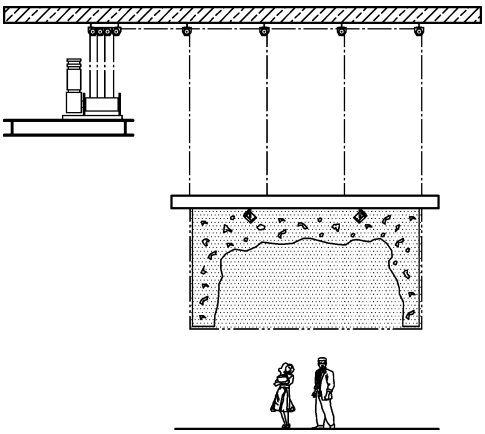
b) Load bearing equipment



c) Drive system

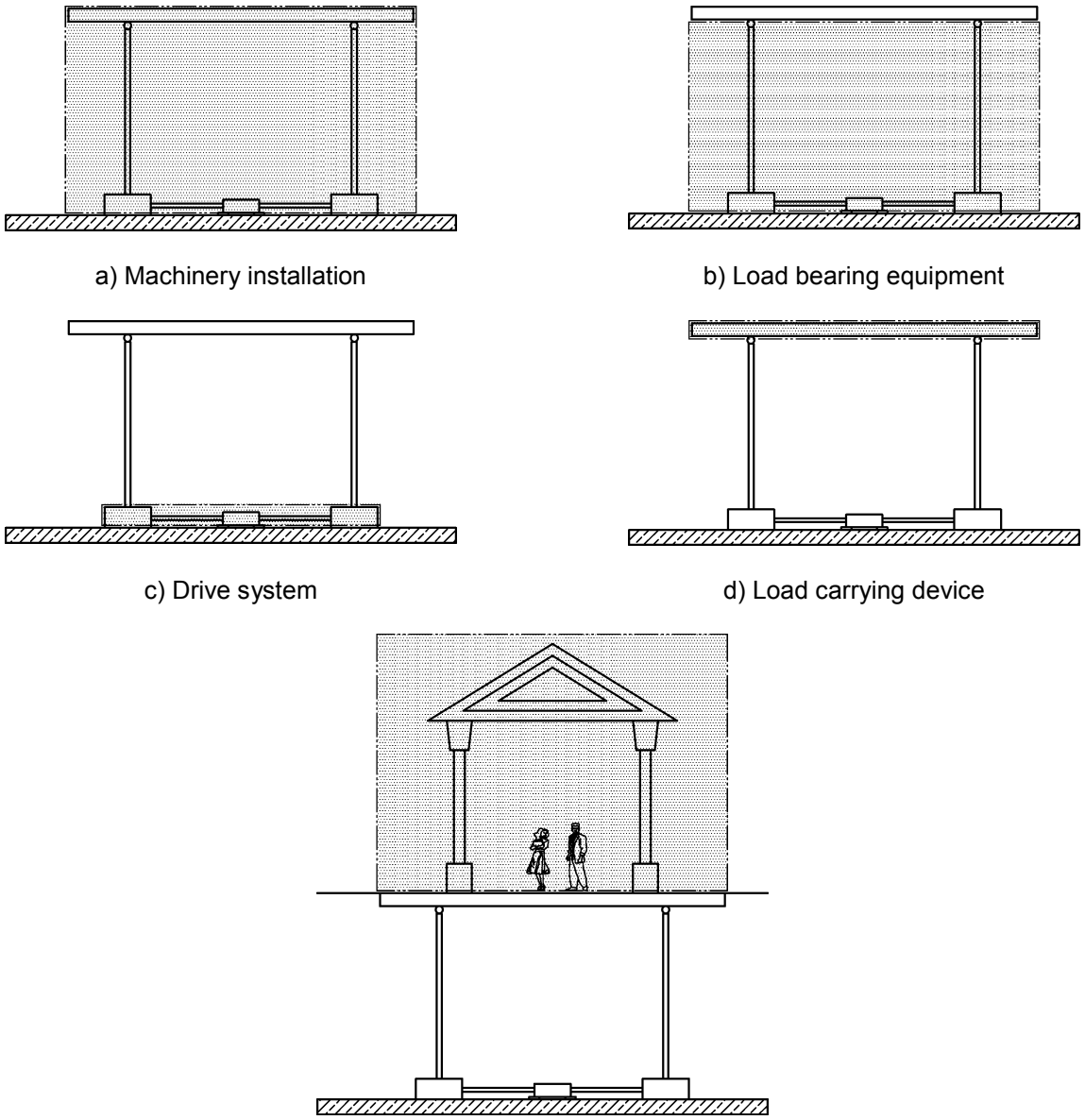


d) Load carrying device



e) Scenic element

Figure 1 — Schematic representation of a fly bar system



a) Machinery installation

b) Load bearing equipment

c) Drive system

d) Load carrying device

e) Scenic element

Figure 2 — Schematic representation of a stage elevator

4 Hazards

When designing stage machinery all foreseeable hazards, hazardous situations and hazardous events associated with the operation of that machinery shall be identified (see Figure 3).

After risk estimation has been carried out, the appropriate measures to be taken shall be established for specific hazards.

This analysis shall be carried out on the basis of the significant hazards listed in DIN EN ISO 12100. Examples of significant hazards relating to stage technology are given in Annex B of this standard.

Suitable facilities and measures for evacuating persons in the event of a hazard occurring shall be provided.

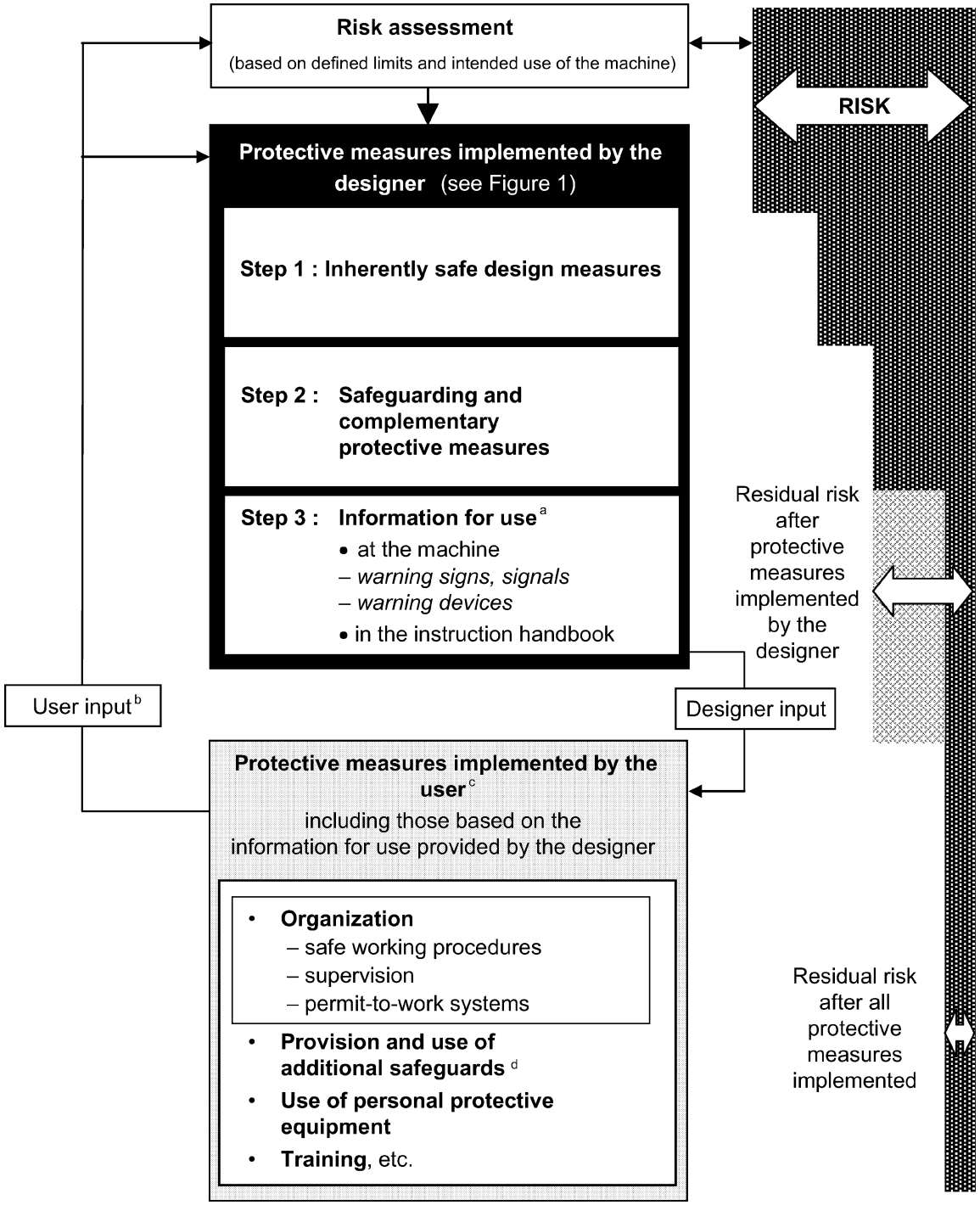
The following strategy shall be used when selecting protective measures:

— specify the limits of the product (intended use, reasonably foreseeable misuse, space limits, the foreseeable life limit, and wear factors);

— identify hazards and estimate risks;

— avoid hazards by means of inherently safe design measures and reduce risks as much as possible;

— inform users of any residual risks (information for use).



a Providing proper information for use is part of the designer's contribution to risk reduction, but the protective measures concerned are only effective when implemented by the user.

b The user input is that information received by the designer from either the user community regarding the intended use of the machine in general or that which is received from a specific user.

c There is no hierarchy between the various protective measures taken by the user. These protective measures are outside the scope of this standard.

d Those protective measures required due to specific process(es) not envisaged in the intended use of the machine or to specific conditions for installation that cannot be controlled by the designer.

Figure 3 — Relationship between designer and user, showing the risk reduction process (from DIN EN ISO 12100)

5 Design requirements

5.1 Load assumptions

5.1.1 General

The basic safety concept laid down in this standard 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 within the system limits of stage machinery shall be designed to accommodate twice the characteristic load (see Figure 4).

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 to accommodate a load equivalent to the load at failure (see Figure 4). Such loads can be more than twice the characteristic load, particularly at high speeds.

Structural elements of steel shall be designed in accordance with DIN EN 1993-1 (all parts) and DIN EN 1994-1-1, and constructed in accordance with DIN 18800-7 and DIN EN 1090-2. DIN EN 1999-1-1 and DIN EN 1090-3 apply to structural elements of aluminium.

The relevant generally applicable working coefficients or safety factors, e.g. as used in structural engineering and steel construction, apply to general structures outside the system limits of the stage machinery.

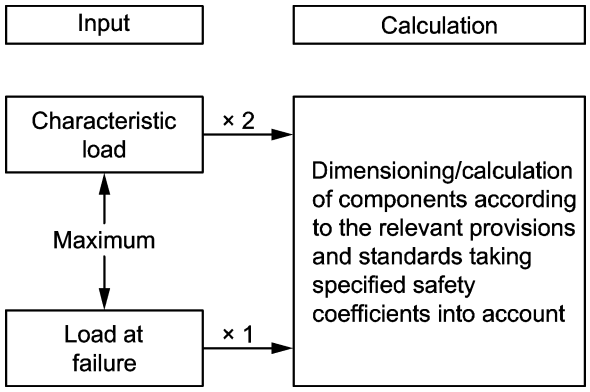


Figure 4 — Design requirements

5.1.2 Load assumptions for stage elevators

The following loads shall be assumed when making calculations:

a) the safe working load with the elevator at rest as part of the stage floor shall be at least 500 kg/m^2;

b) the safe working load in motion shall be agreed.

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 stiffness a horizontal force of at least 1/20th of the safe working load with the elevator at rest shall be applied at the platform level.

5.2 Load bearing equipment and structural elements

5.2.1 General

For load calculations, one load bearing device per suspension is permitted. Where several load bearing devices lift a suspended element, the assumed load may be distributed proportionately. The distribution of loads shall be ensured by means of suitable design measures.

All structural elements shall be secured against unintentional loosening.

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

All structural elements between the load carrying device and its attachment to the machinery installation shall be made of non-combustible materials.

This requirement does not apply to platform floor coverings.

5.2.2 Load bearing equipment

5.2.2.1 Wire ropes

Wire rope which complies with DIN EN 12385-1, DIN EN 12385-2, DIN EN 12385-4 and DIN EN 12385-5 may be used as load bearing lines. All wire ropes shall be provided with a device for length compensation.

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

A type 2.2 inspection document as in DIN EN 10204 confirming testing as in DIN EN 12385-4 or DIN EN 12385-5 shall be provided for each wire rope.

If a wire rope is replaced it shall be replaced by a rope of at least an equivalent construction.

Plastic covered or coated wire rope shall not be used to carry loads.

5.2.2.2 Chains

In stage machinery as in this document, the chains used to carry loads are primarily of the round steel type. These are to be calibrated, and tested as in DIN 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 DIN EN 818-7. There shall be no plastic deformation under load at failure.

A type 2.2 inspection document as in DIN EN 10204 confirming testing as in DIN EN 818-7 shall be provided for each chain.

Other types of chain (e.g. roller chains) shall meet the above requirements by analogy. Type-specific characteristics are to be taken into consideration.

5.2.2.3 Fibre ropes

Fibre ropes shall not be used to carry loads greater than 20 kg.

5.2.3 Wire rope terminations

5.2.3.1 General

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

The requirements in DIN EN 13411 (all parts) apply to components of wire rope terminations.

Wire rope terminations shall be such that their condition can be visually checked.

Load-bearing terminations shall not be formed using U-bolt wire rope grips.

5.2.3.2 Detachable terminations

Detachable wire rope terminations may be

a) asymmetric wedge sockets as in DIN EN 13411-6 or

b) symmetric wedge sockets as in DIN EN 13411-7.

Detachable terminations shall be secured against self-detachment, for instance by using grips as in DIN EN 13411-5, which may only be attached to the free end of the rope termination. Examples are shown in Figures 5 und 6.

Where wedge sockets, wedge clamps or turnbuckles are used for unguided attachment to the load bearing device (fly bar), the termination is to be gimballed.

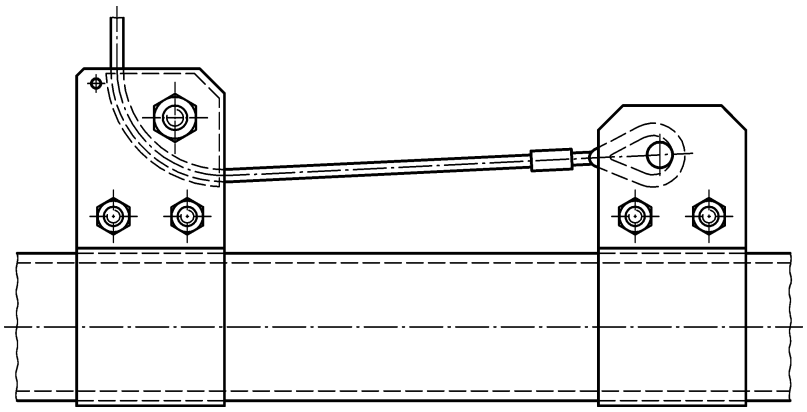
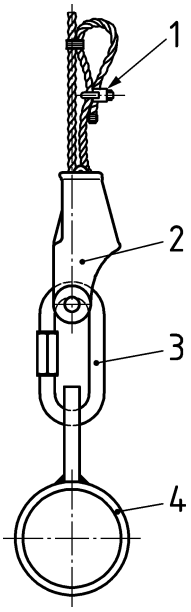


Figure 5 — Sliding pipe clip as an example of a device for compensating the length of a wire rope



Key

1 U-bolt wire rope grip as in DIN EN 13411-5
2 Asymmetric wedge socket DIN EN 13411-6
3 Quick link with screw caps
4 Fly bar with welded lug

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

5.2.3.3 Fixed or non-detachable terminations

Examples of non-detachable terminations for wire rope that meet the requirements of 5.2.3.1 are:

a) splices as in DIN EN 13411-2;

b) ferrules as in DIN EN 13411-3 or

c) swage terminals, where proof of their load capacity is provided, e.g. in the manufacturer's documentation.

5.2.4 End terminations for steel chains

End termination for steel chains shall be designed and manufactured as structural elements.

5.2.5 Winding devices and diverter pulleys

5.2.5.1 Winding devices for wire ropes

Where round ropes are used, a wire rope drum with a helical groove as in DIN 15061-2 shall be used to take up the rope.

Round wire rope may only be wound in one layer, except when using bobbin winders (see Figure 7).

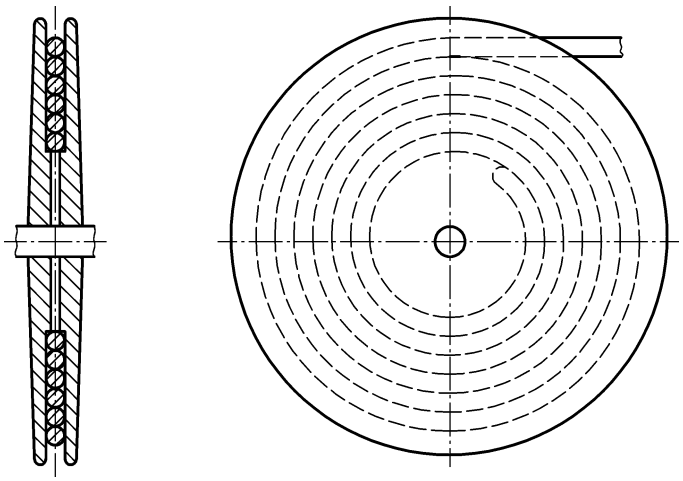


Figure 7 — Example of a bobbin winder

When using bobbin winders or pile wind drums, each rope shall have its own winding chamber and it shall be ensured that the rope is layered in such a manner that the rope centrelines line up.

The attachment of the rope to the drum shall be designed to take up 80 % of the rope's minimum breaking force.

NOTE This can be achieved either by means of the friction of the remaining turns on the drum or by using clamps or through a combination of both.

When clamps are used to attach the rope, it shall be ensured that the failure of a screw does not lead to the attachment becoming ineffective.

Design measures shall ensure that there is no sideways deflection of the rope from the grooves of the drum or pulley when it is being pulled up or down, even when it is underloaded or slack. Thus the fleet angle shall never exceed 4° on either side, and should preferably not exceed 1,5°.

The rope drum diameter, measured from the rope centreline to centreline, shall be equal to at least 18 times the rope diameter.

5.2.5.2 Diverter pulleys for round wire ropes

The diverter pulley diameter, measured from the rope centreline to centreline, shall be equal to at least 20 times the rope diameter.

The groove radius of the pulley shall be designed as in DIN 15061-1. It may be greater than as specified in that standard, but shall be no greater than the rope diameter.

5.2.5.3 Diverter pulleys for fibre ropes

The bottom of the rope groove shall be a circular arc with an opening angle of 180°

Grooves shall be smooth with radiused/chamfered edges.

5.2.5.4 Drive and idler sprockets for steel chains

The pitch circle of idler sprocket wheels shall be not less than 10 times the chain pitch.

When lifting and lowering in all operating modes, at least three chain links shall be form-locked in the sprocket.

The chain is to be fed onto the sprocket in such a manner that it does not twist and that feeding and run-out is controlled.

5.2.6 Drive systems

5.2.6.1 General

Drive systems shall be designed so as to preclude unintentional hazardous movements.

This can be achieved by means of:

— movement-operated self-locking (dynamic self-locking);

— at least two independently functioning securing devices.

An independently functioning securing device may be, for example, two brakes which function independently in all operating modes; in some cases there may be a delayed engagement of the second brake.

If brakes are used, the braking and clamping forces may only be generated by means of weight forces or guided compression springs. In the event of a compression spring breaking, coils of springs shall not become twisted within each other, leading to a shortening of the spring.

Each of these securing devices shall be capable of bringing the resulting test load to rest. It shall be possible to check the effectiveness of each securing device separately.

Where brakes (in hydraulic drive systems, valves or clamps as well) are used for emergency stops, these are to be engaged by means of two independent devices, which may be the same as the devices used to shut-off the system.

Stage elevators at rest may be held by means of an interlocking mechanism.

Only fail-safe, non-switchable clutches may be used between the load carrying and the securing devices.

NOTE 1 If risk assessment shows that one securing device is sufficient for achieving the required safety, there may be a deviation from the requirement for two independently functioning securing devices in the drive system. However, this can only be the case when one load is being moved by a group of several drive systems and when one drive system fails, the other systems are capable of safely holding the load.

NOTE 2 If risk assessment shows that one securing device is sufficient for achieving the required safety, horizontal movements (e.g. stage wagons, revolving stages, curtain systems, chassis) one securing device may be sufficient even with only one drive system.

Between the load carrying and the securing devices:

a) all components of drive systems shall be designed for loads twice the characteristic load, taking 400 operating hours as the basis for calculations, unless a longer operating time is to be taken into consideration (see ISO 4301-1);

b) all components of drive systems for stage elevators shall be designed for loads 1,5 times the system load with the load at rest.

To account for failure conditions, all drive system components between the load carrying device and securing devices shall be designed to accommodate a load equivalent to the load at failure.

Guided loads or load carrying devices shall have a component that initiates an automatic stop and interrupts their movement when the guide is blocked.

5.2.6.2 Screw jack systems (spindle drives)

Screw jacks shall have a greater wear resistance than the supporting nut.

In screw jack drives, the supporting nut shall be designed to accommodate a load twice the characteristic load. The wear of the supporting nut shall be monitored by means of a wear measuring device, e.g. a backup safety. A residual load capacity of at least 1,6 times the characteristic load shall be maintained.

In the case of stage elevator platforms with a maximum lifting height of 400 mm, the wear measuring device may be dispensed with if the permissible wear can be established visually, although in this case, the supporting nut shall still be designed to accommodate a load twice the characteristic load.

Screw jacks with ball screw nuts do not need a wear measuring device.

5.2.6.3 Hydraulic systems

Components of hydraulic systems shall be designed using twice the load pressure for calculations.

Compression or flared joints, joints using a conical ring fitting, and other similar joints, as well as hose assemblies, shall not be used between a hydraulic drive system and securing device.

In the case of commercially available components, e.g. pipe connections or valves, which are placed between the cylinder and the securing device, the nominal pressure as stated by the manufacturer shall be at least twice the value of the load pressure.

For the rest of the hydraulic system, calculations shall be based on the unfactored operating pressure when designing components between the securing device and the pressure generating equipment.

The operating pressure shall be limited by means of a pressure limiting device. It shall be possible to measure the system pressure.

Hydraulic systems shall be provided with manual isolating valves with which the drive can be cut off from the rest of the system.

If the pressure is generated by means of a gaseous cushion which has a direct influence on the hydraulic fluid, all drive systems shall automatically switch off once the fluid reserve goes below the minimum level.

5.2.6.4 Auxiliary drive systems

When a hand crank or auxiliary drive equipment is engaged, the power drive shall be automatically interrupted. The direction of travel (upwards or downwards) of the machinery installation shall be clearly indicated.

5.2.6.5 Manual systems

Manual drive systems, e.g. manual winches, shall comply with all design requirements specified in Clause 5.

Manual counterweight hoists shall have a locking device which can withstand the manual force (force applied by a person, either as a tensile or compressive force (pulling or pushing)) of at least two persons (2 × 200 N) in both directions. This device may be located on the line being handled by the operator.

5.3 Load carrying devices

When designing load carrying devices, the unfactored characteristic load shall be assumed for calculations.

When designing stage elevator platforms, the maximum permissible deflection with the safe working load at rest shall be agreed.

Hoist bars shall be dimensioned so that the calculated deflection between two suspension points due to the safe working load is not greater than 1/200 of the length between the two points.

In the case of point hoists, load carrying devices shall be considered as structural elements for design purposes.

6 Safeguarding hazardous areas

6.1 Protective spaces

Protective spaces shall be provided for persons carrying out inspection and maintenance work in spaces underneath the machinery installation (e.g. underneath a stage elevator). It shall be possible to lower stage elevators only so far so as to allow for the protective space to be formed underneath the entire platform area. The vertical distance from the lowest point of the elevator platform shall be at least:

a) 0,8 m to the bottom of the protective space;

b) 0,5 m to any permanent constructions, disregarding limit stops, above or below the space;

c) 0,12 m between the elevator apron and the bottom of the protective space.

The protective space may be formed by means of hinged supports, for example.

Guides, including permanent constructions, are to be disregarded, as long as the protective space has a floor area of at least 0,8 m × 1,5 m.

Hinged supports shall have securing devices to prevent them from being unintentionally moved.

The use of hinged supports during inspection and maintenance work shall be indicated by means of signs.

It shall be possible to enter and exit a protective space safely regardless of the stage platform position.

Access openings to protective spaces shall be at least 0,6 m × 0,8 m.

Permanent lighting shall be provided in maintenance areas under stage elevator platforms.

6.2 Safeguarding at crushing, shearing and trapping points, and fall protection

Crushing, shearing and trapping points are to be avoided. Where such points are unavoidable, they are to be safeguarded by means of effective devices or other safety measures. Such devices include (pressure) sensitive edges, light beams and light curtains.

Gaps in the stage floor due to design elements such as stage elevators shall not be wider than 20 mm. If operating conditions make wider gaps necessary, it shall be possible to cover them.

If heights from which a person can fall are unavoidable within the travel range of stage machinery (e.g. a stage elevator), then fall protection shall be provided at these areas by means of effective devices or other safety measures, including safeguards.

6.3 Accessibility of maintenance areas

Walkways between drive systems and controlgear/switchgear which are used during maintenance work or when monitoring machinery operations should be 0,7 m wide and have a clearance height of at least 2 m.

Where the distance between the bottom of a protective space and the highest operating position of a stage elevator platform is no greater than 3 m, the space may be entered through the elevator platform.

Hinged flaps in the stage floor at accesses to drive systems or controlgear/switchgear shall have a clearance of at least 0,6 m × 0,8 m and open upwards. It shall be possible to open the flaps into a stable position, or they shall be provided with an automatic hold-open device. Guards against falls and access aids shall be provided. Floor flaps shall be secured against unintentional lifting.

Maintenance walkways shall be clearly and permanently identified by means of a sign saying “Zutritt für Unbefugte verboten” (“Authorized personnel only”).

6.4 Elevator shaft walls, openings and landing doors

6.4.1 General

If stage machinery (e.g. a stage elevator) moves along walls, the openings in these walls shall have elevator landing doors, the clearance height of which shall be at least 2,0 m.

Elevator shaft walls and doors shall be even and smooth on the shaft side. The distance to the machinery installation shall be no greater than 20 mm.

On the shaft side, swing doors shall be flush when closed. Crushing or shearing points at projections or recesses near sliding doors shall be avoided or safeguarded.

Doors along escape routes shall be swing doors, and shall not project into the shaft.

6.4.2 Interlocking doors

It shall not be possible for the machinery (e.g. stage elevator) to start until all elevator shaft doors are closed and locked.

Door closures shall be provided with an electrical safety device as in subclause 7.6.4.

It shall only be possible to open elevator shaft doors when the drive system is switched off and the distance between the platform and the stopping point is no greater than 0,15 m.

Door closures shall be designed so that the interlock cannot engage when the door is not closed.

6.5 Counterweights

Multiple counterweights shall be secured by means of a frame (counterweight cradle) which prevents the weights from falling out.

The use of mechanical springs instead of counterweights is not permitted.

Where counterweights travel through work areas and traffic areas, safety distances as in DIN EN ISO 13857 and DIN EN 349 shall be maintained, or suitable guarding shall be provided to ensure that any falling counterweights are contained.

7 Electrical equipment and control systems

7.1 General requirements

7.1.1 General

The fundamental health and safety requirements laid down in Annex I of the Machinery Directive 2006/42 EC are to be observed when designing and installing electrical and electronic systems, including any safety components, of machinery installations as in this document. The following standards are also to be used:

- DIN EN 60204-1 (VDE 0113-1);
- DIN EN 60204-32 (VDE 0113-32);
- DIN EN 50172 (VDE 0108-100);
- DIN VDE 0100-718 (VDE 0100-718);
- DIN EN 61508 (VDE 0803) (all parts);
- DIN EN 62061 (VDE 0113-50);
- DIN EN ISO 13849 -1 and DIN EN ISO 13849-2.

This clause specifies additional requirements for particular equipment to supplement the requirements of the above-mentioned standards.

NOTE In this standard the term “electrical” includes both electrical and electronic matters (i.e. “electrical equipment” means both the electrical and the electronic equipment).

The equipment covered by this standard commences at the point of connection of the power supply to the machine.

When installing the power supply system, including the electrical control system, and when selecting electrical equipment, steps shall be taken to ensure that hazardous operating conditions are prevented in the event of failure.

Risks due to hazards associated with the electrical equipment shall be considered when carrying out risk assessment of the machinery installation as in this standard.

To avoid faults, for each safety function and on the basis of hazard identification and risk assessment, the necessary Performance Level (PL_r) as in DIN EN ISO 13849-1 or Safety Integrity Level (SIL) as in the DIN EN 61508 (VDE 0803) series shall be determined in order to specify the required safety requirements.

The electrical equipment shall be designed by selecting suitable safety measures for the relevant SIL or PL (see Annex C, for example).

Safety measures are a combination of the measures incorporated at the design stage and the measures to be implemented by the user.

7.1.2 Selection of equipment

Electrical components and devices shall be suitable for their intended use and shall conform to the relevant standards.

7.1.3 Electrical supply

The electrical equipment shall be designed to operate correctly under the conditions of supply specified in DIN EN 60204-1 (VDE 0113-1).

7.1.4 Physical environment and operating conditions

7.1.4.1 General

The electrical equipment shall be suitable for use in the physical environment and operating conditions specified in DIN EN 60204-1 (VDE 0113-1).

7.1.4.2 Electromagnetic compatibility (EMC)

The individual components of electrical/electronic equipment shall not

— exceed the limits for EMC emission specified in DIN EN 61000-6-4 (VDE 0839-6-4) and

— shall meet the requirements for EMC immunity specified in DIN EN 61000-6-2 (VDE 0839-6-2).

Requirements for electromagnetic emission and immunity apply within the frequency range of 0 Hz to 400 GHz.

Methods of measurement and limits are specified in DIN EN 61000-6-4 (VDE 0839-6-4) for EMC emissions and in DIN EN 61000-6-2 (VDE 0839-6-2) for EMC immunity.

The user is to be informed of any special measures needed to fulfil the above-mentioned requirements (e.g. use of shielded or special cables).

7.1.4.3 Ambient air temperature and relative humidity

All electrical equipment shall be capable of operating correctly at

— an ambient air temperature of + 5 °C up + 40 °C;

— a relative humidity at + 40 °C of ≤ 50 %.

Higher relative humidities are permitted at lower temperatures (e.g. 90 % at 20 °C).

Harmful effects (e.g. of condensation in control cabinets) shall be avoided by the provision of built-in heaters and air conditioners. Any special measures needed to fulfil the requirements specified above are to be agreed upon.

7.2 Incoming supply conductor terminations and devices for disconnecting and switching off

7.2.1 Incoming supply conductor terminations

As in DIN EN 60204-32 (VDE 0113-32).

7.2.2 Terminal for connection to the external protective earthing system

As in DIN EN 60204-32 (VDE 0113-32).

7.2.3 Supply disconnecting (isolating) devices

As in DIN EN 60204-32 (VDE 0113-32).

7.2.4 Devices for switching off for prevention of unexpected start-up

As in DIN EN 60204-32 (VDE 0113-32).

Each machine shall be provided with a device for disconnecting the machine from power for the prevention of unexpected start-up.

7.2.5 Devices for disconnecting electrical equipment

As in DIN EN 60204-32 (VDE 0113-32).

7.2.6 Protection against unauthorized, inadvertent and/or mistaken connection

As in DIN EN 60204-32 (VDE 0113-32).

7.3 Protection against electric shock

Persons shall be protected against electric shock:

— under normal conditions (basic protection);

— under single-fault conditions (fault protection);

— additional protection may be specified as part of the measures taken under specific conditions as protection against external influences and in special areas of application.

DIN EN 60204-32 (VDE 0113-32) describes recommended protective measures.

7.4 Protection of equipment

7.4.1 General

Recommended design criteria for safety devices are described in DIN EN 60204-32 (VDE 0113-32).

According to DIN EN 60204-32 (VDE 0113-32), the equipment is to be protected against the effects of:

— overcurrent arising from a short circuit;

— overload current;

— abnormal temperature;

— loss of or reduction in the supply voltage;

— overspeed of motors;

— earth fault;

— incorrect phase sequence;

— overvoltage due to lightning and switching surges.

If one of these malfunctions causes the operation of a protective device resulting in the stopping of a machine, an automatic restart shall be prevented.

7.4.2 Protection under fault conditions

If a fault in the electrical equipment can result in hazardous conditions, suitable measures shall be taken to prevent such hazards, e.g. providing:

— additional safety-related control circuits;

— redundancy (with monitoring).

When a fault occurs, safety-related control circuits shall restore safe conditions.

7.4.3 Equipotential bonding

In addition to the requirements for equipotential bonding and earthing systems specified in DIN IEC 60364-5-54 (VDE 0100-540), the specifications of DIN EN 60204-32 (VDE 0113-32) and DIN EN 50310 (VDE 0800-2-310) (for IT equipment) shall also be observed.

Each component of the electrical equipment or machinery installation may be used as part of the protective bonding system, provided it meets the requirements of E DIN IEC 60364-5-54 (VDE 0100-540).

7.5 Control circuits and control functions

7.5.1 Control circuits

As a rule, control circuits for machinery installations as in this standard shall be designed in accordance with DIN EN 60204-32 (VDE 0113-32) (see Figure 8 and Figure 9 of this standard).

7.5.2 Control functions

7.5.2.1 General

As a rule, control functions for machinery installations as in this standard shall be selected in accordance with DIN EN 60204-32 (VDE 0113-32) (see Figure 8 and Figure 9 of this standard).

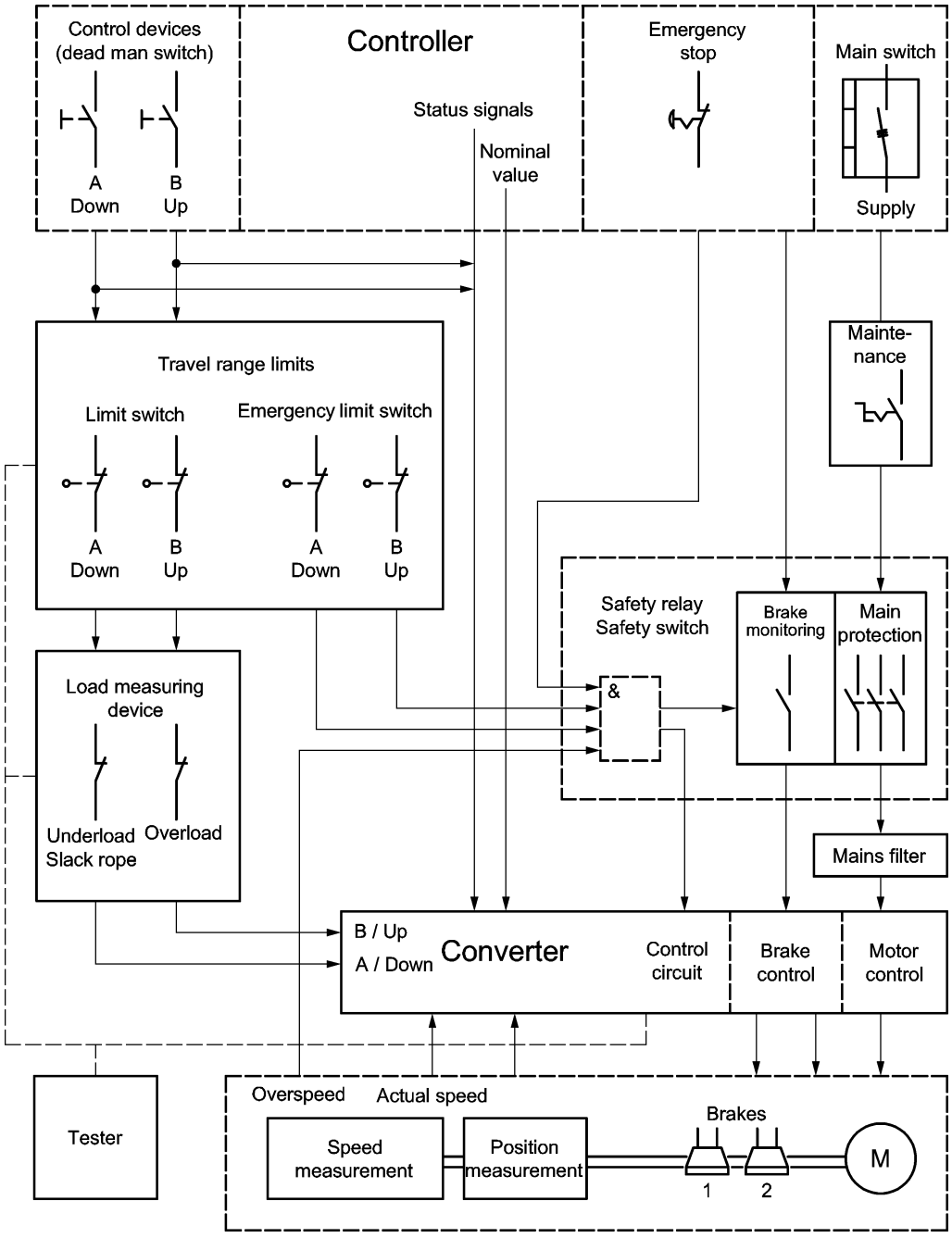


Figure 8 — Block diagram of a regulated drive system

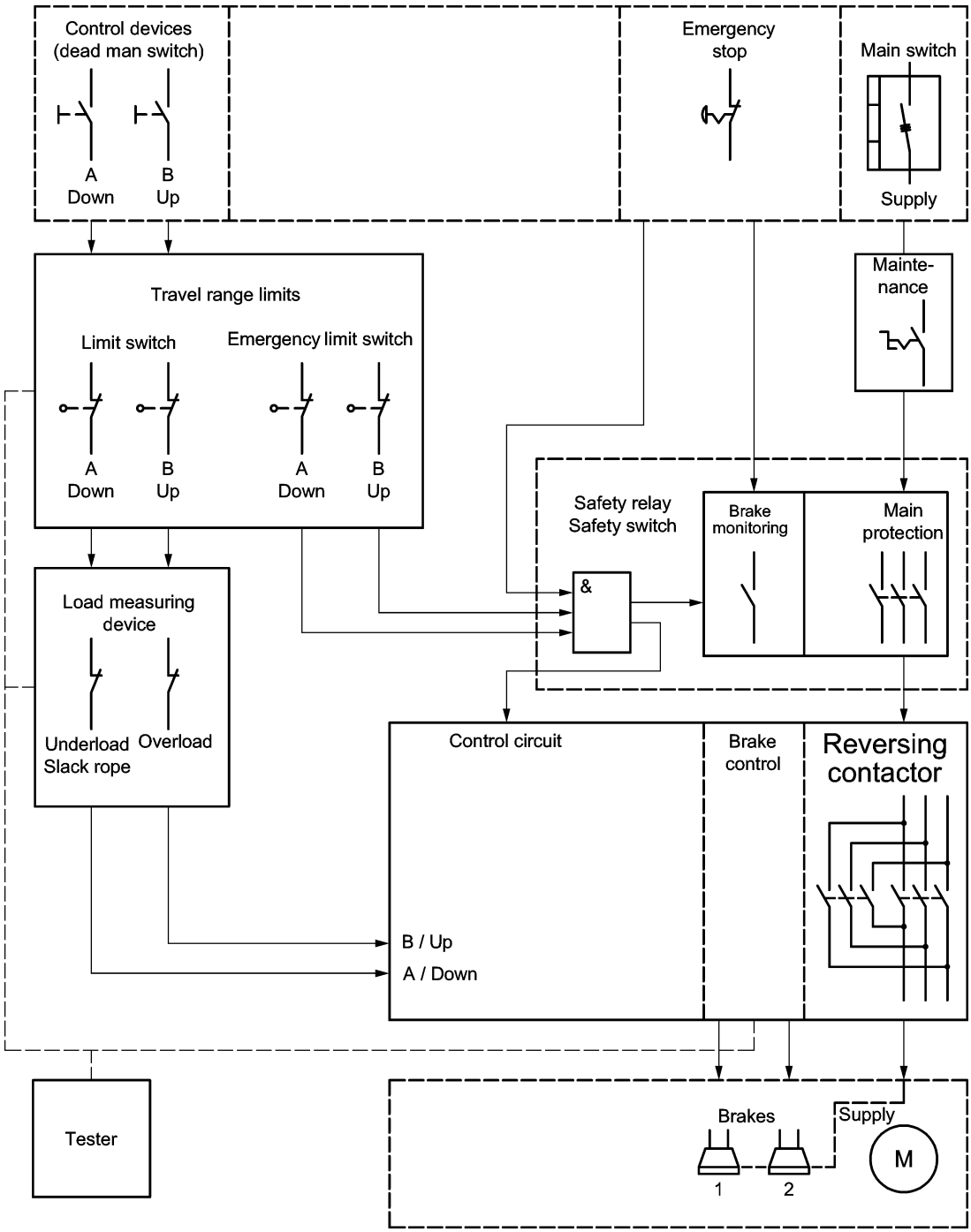


Figure 9 — Block diagram of a controlled drive system

7.5.2.2 Control devices

All movements shall be initiated and ended by means of a control device.

The direction of movement shall be clearly indicated to the operator.

If it is possible to initiate contrary movements concurrently, this function shall be clearly indicated.

The movement shall stop as soon as the control device is released.

Control devices shall be protected against unintentional actuation (e.g. by means of protective shrouds or blocking devices) and unauthorized actuation (e.g. by means of key-operated switches).

Control devices shall be located so that the operator can safely monitor danger zones from the operating position. This can be ensured, for instance, by providing additional mobile control devices.

Where a system has multiple control stations, interlocks (hardware or software) shall prevent the simultaneous control of an axis or group of axes by more than one control device.

7.5.2.3 Overtravel limits (limit switches)

The maximum allowable travel range shall be limited at both ends, with any mechanical limit switches designed as a break contact unit based on the closed-circuit principle. Encoder position sensors may also be used, provided the overtravel indication is absolute-mode digital or analogue. These switches or encoders shall have an interlocking connection to the drive shaft.

Overtravel limit switches shall meet the requirements of 7.6.4.

The maximum travel range may also be limited by means of end-of-travel switches, provided the requirements specified above for overtravel limit switches are met.

Where a hydraulic cylinder is used, overtravel may be limited by means of fixed, damped limit stops if a shut-off is ensured by additional means, such as a pressure switch.

For machinery which can be reconfigured, it shall be possible to set limit switches and end-of-travel switches for the relevant travel range.

7.5.2.4 Enabling devices

An enabling device may be necessary, for instance, when it is not possible to monitor the machine's movements from the operator's position.

Design features of enabling devices are specified in detail in DIN EN 60204-32 (VDE 0113-32).

7.5.2.5 Wire-less controls

Wire-less controls may be used if they meet the safety requirements of this standard.

They shall also meet the relevant requirements specified in DIN EN 60204-32 (VDE 0113-32). The transmission and processing of start command and emergency stop and/or switching off signals shall meet the requirements for at least the required performance level (PL_r) as in DIN EN ISO 13849-1 or the required safety integrity level (SIL) as in DIN EN 61508 (VDE 0803) (all parts) (see Table C.1).

7.5.3 Travel of groups of machines

7.5.3.1 Asynchronous travel

7.5.3.1.1 Asynchronous travel without group deactivation

In the case of asynchronous travel without group deactivation, only the relevant machine shall come to a stop when the overtravel limit is reached or when a relevant safety device is activated.

7.5.3.1.2 Asynchronous travel with group deactivation

In the case of asynchronous travel with group deactivation, it shall be ensured that the entire group comes to a stop when the overtravel limit is reached or when a relevant safety device is activated. The system shall easily identify which machine has caused the error condition

7.5.3.2 Synchronous travel of a group of machines

Synchronous travel (that is, when all of the machines in a group travel interdependently (route- or time-synchronized travel)) shall be monitored. The permissible group synchronization tolerances shall not be exceeded in any operating mode.

The group shall be stopped when a safety device is activated, limits are exceeded (e.g. when monitoring travel curves), or in the event of failure. The specified group synchronization tolerances in the event of failure shall not be exceeded.

If a machinery installation is driven by several drive systems, or where several installations are used to lift the same load, synchronism is to be ensured. The permissible group synchronization tolerances shall not be exceeded in any operating mode. When a safety device is activated, the permissible group synchronization tolerance in the event of failure shall not be exceeded.

7.5.3.3 Travel of several groups

Where several groups and/or single installations travel simultaneously and are controlled by a single control device, the travel modes of the various groups/installations shall be maintained.

7.6 Safety functions and control functions in the event of failure

7.6.1 General

Safety functions for an E/E/PES shall be selected on the basis of hazard analysis.

NOTE Where the supplier of the E/E/PES is not responsible for designing the entire system (E/E/PES and drive equipment), the system developer shall specify the functional safety requirements for the E/E/PES based on hazard analyses carried out in accordance with DIN EN 61508 (VDE 0803) (all parts), DIN EN ISO 13849-1 or DIN EN 62061 (VDE 0113-50).

Functions integrated into the E/E/PES may also serve as safety functions.

Such functions include:

— stop functions;

— emergency stop functions;

— start functions;

and functions regarding

— speed limits;

— overloading and underloading;

— position limits;

— deviations in speed;

— exceeding specified travel limits in the case of synchronous travel;

— deviations from specified trajectories;

— overtravel;

— acoustic signals;

— override functions.

General requirements for control functions in the event of failure are described in detail in DIN EN 60204-32 (VDE 0113-32).

Where faults or disturbances in the electrical equipment can result in a hazardous condition or damage to the machinery, suitable measures shall be taken to minimize the probability of such hazards occurring. The required measures and the extent to which they are to be implemented, either individually or in combination, will depend on the level of risk associated with the respective application.

Measures to minimize risk and risk reduction in the event of failure are also described in DIN EN 60204-32 (VDE 0113-32).

7.6.2 Providing redundancy

By providing partial or complete redundancy, it is possible to minimize the probability that a single fault in the electrical circuit can result in a hazardous condition.

As a rule, redundancy is to be designed-in for switching devices (e.g. contactors, relays, valves) in safety devices, and such devices are to be monitored separately. Redundancy is also to be provided for any contactor relays (intermediate relays) in safety circuits (that is, if a fault in such a relay could disable a safety device).

Where the drive mechanism and brakes have separate power supply, they are to be provided separately with the above-mentioned redundancy measures.

7.6.3 Hazardous operating conditions

Faults in the installation shall not lead to hazardous operating conditions.

Such conditions exist, for example, when:

a) the prescribed speed is exceeded;

b) the barriers of door closures on stage elevator doors are not engaged;

c) load bearing lines become overloaded or slacken;

d) the wear limit of spindle drives is reached;

e) the floor of a stage elevator exceeds travel limits;

f) the permissible group synchronization tolerance is exceeded;

g) the prescribed trajectories are not maintained.

Faults in the control or regulating system shall not hinder stopping. Logic on the load side shall not impair the functioning of a safety device.

7.6.4 Safety devices and safety functions

7.6.4.1 General

The technical measures needed to perform these functions will depend on their functioning under failure conditions within the E/E/PES, and are to be selected on the basis of risk assessment (see 7.8).

If a safety device is activated, the machine shall stop at least in the direction of movement. Where a safety device at crushing or shearing points is activated, movement in the direction contrary to that of the hazardous movement shall be possible.

It shall be possible to check the functioning of all safety devices.

The activation of a safety device shall be indicated as long as the activation is in effect.

When a safety device is activated, there shall be an emergency stop of the appropriate category selected on the basis of risk assessment.

Electrical safety devices shall either be:

a) position switches, or

b) safety circuits.

Position switches shall be designed as in DIN EN 60947-5-1 (VDE 0660-200), used as in BGI 575, and shall have a degree of protection of IP 55 as in DIN EN 60529 (VDE 0470-1).

Safety circuits shall be configured in such a manner that the required SIL or PL determined by means of risk assessment can be achieved even without position switches.

Safety circuits which register the exceeding of specified travel paths, speeds, or loads, or unacceptable deviations from specified trajectories, which could cause a hazardous condition or damage the machinery installation shall initiate an emergency stop when activated. The stop category shall be established on the basis of risk assessment for the machinery installation in question.

7.6.4.2 Providing protection when speed regulators fail

Speed regulators in drive systems of machinery installations shall be capable of automatically identifying unallowable deviations in speed which could cause a hazardous condition. The power supply to the drive system shall be cut off by means of emergency switching off of an appropriate stop category established by means of risk assessment, and the mechanical brakes shall be applied.

7.6.4.3 Providing protection when limit switches fail

If a limit switch fails, the emergency limit switch shall bring the machinery installation to a stop. This does not apply where the overtravel of a hydraulic cylinder is limited by means of fixed, damped limit stops, and a shut-off is ensured by additional means, such as a pressure switch.

Emergency limit switches shall be located in such a manner that — at maximum speed and taking the expected system delay time into consideration — the machinery installation can come to a stop safely before it collides with fixed elements (e.g. grid, spindle ends).

Emergency limit switches shall be automatically self-locking and shall be based on the closed-circuit principle. In the case of friction drive systems, the emergency limit switch shall be activated directly by the travelling components of the installation.

Electronic components and measuring devices may be used instead of mechanical limit switches, as long as these are of an equivalent safety level as a mechanical switch.

If an emergency limit switch is activated, the drive and braking systems of the machinery installation shall be shut off by means of two independent measures.

It shall be possible to set the emergency limit switches of reconfigurable installations for the relevant travel range(s).

7.6.4.4 Providing protection when characteristic loads are exceeded

The machinery installation shall be stopped no later than when the characteristic load is exceeded by 1,2 times its value (overload factor); a safety-related system shall be used for this purpose.

The machine shall be stopped in the direction of travel, although movement in the contrary direction may be possible.

For stage elevators, if the safe working load will be exceeded by 1,2 times its value during movement, this shall become evident before the elevator moves and any movement thus prevented.

7.6.4.5 Providing protection when guided lines are blocked

In machinery installations in which loads or load carrying devices are guided, the drive shall be stopped when the guided load or load carrying device is blocked. A stop may also be necessary where underload situations can lead to a hazardous situation (e.g. due to slackening of lines).

The machine shall be stopped in the direction of travel, although movement in the contrary direction may be possible.

7.6.4.6 Providing protection when wear limits of spindle drives (screw jacks) are reached

The machinery installation shall stop when the wear limit is reached (see subclause 5.2.6).

7.6.4.7 Providing protection when nominal speeds are exceeded

When the speed of a drive system is greater than the nominal speed, the machinery installation shall stop no later than when a speed 1,25 times the nominal speed is reached.

7.6.4.8 Providing protection when the group synchronization tolerance is exceeded

During group travel, the entire group shall come to a stop when the permissible group synchronization tolerance is reached.

The system shall easily identify which drive system led to the stopping of the group.

The effectiveness of friction drive and positive drive systems shall be monitored.

Switchable clutches between the load and brakes are not permitted.

7.6.4.9 Stopping when overtravel limits are exceeded

The machinery installation or group shall come to a stop when overtravel limits are exceeded.

During group travel, it shall be possible to recognize which machine has led to a stop.

7.6.4.10 Stopping when given trajectories are not maintained

During group travel, the entire group of machines shall come to a stop when the specified and tested trajectories are not maintained.

7.6.4.11 Interlocking devices

Safeguards for danger zones shall be interlocking so as to prevent the hazardous movement and bring it to a stop.

For example, the safeguards required in Clause 6 of this standard are to be interlocking. For danger zones which are safeguarded by means of operational measures for artistic reasons, safeguards or other interlocking devices may be temporarily rendered inoperable.

7.6.4.12 Cutting off power

To cut off power safely, the supply of power to the drive system shall be safely interrupted, that is, it shall not be possible for the drive system to continue to generate torque, thus leading to hazardous movements.

Electronic equipment shall have the same safety level as electromechanical equipment.

Suitable measures for power cut-off include combinations of the following measures:

— providing contactors between the power supply and drive system (mains protection);

— providing contactors between the power unit and the drive motor (motor protection);

— safely blocking the control pulse of the semiconductor device.

7.6.4.13 Providing protection when brakes fail

Where brakes are used as a safety device, suitable measures shall ensure that the brakes are not damaged, e.g. by monitoring air gaps.

7.6.5 Devices for testing safety functions

Each machinery installation shall be provided with the following devices for the prescribed functional testing of safety devices and securing devices:

a) device for checking securing devices individually (it shall be possible to check the effectiveness of each securing device individually);

b) device for bypassing individual overtravel limits;

c) device for bypassing activated safety switches and interlocking movement out of the range of the ultimate limit stop to enable movement in the opposite direction (it shall be possible to check the effectiveness of each safety switch individually);

d) device for bypassing a stop due to overloading (in order to move the test load).

The above-mentioned devices shall be secured against unauthorized actuation (e.g. by means of key-operated switches).

7.7 Emergency stop and emergency switching-off functions

7.7.1 Emergency stop

Machinery installations shall have an emergency stop function which stops the drive system.

The emergency stop system shall implement either a Category 0 or a Category 1 stop, with the category being selected on the basis of the risk assessment carried out for that particular machine.

See DIN EN 60204-32 (VDE 0113-32) for requirements.

7.7.2 Emergency switching off

See DIN EN 60204-32 (VDE 0113-32) for requirements.

7.8 Electronic and programmable electronic systems (E/PES)

7.8.1 General

General requirements which apply to all types of electronic control devices are described in DIN EN 60204-32 (VDE 0113-32).

7.8.2 Programmable controllers

Programmable controllers shall fulfil the relevant ergonomic and general safety requirements specified in DIN EN 61131-1 and DIN EN 61131-2 (VDE 0411-500).

It shall be possible to prevent unauthorized persons from making changes to the memory.

7.8.3 Use of programmable controllers with safety functions

Programmable controllers with safety-relevant tasks may take on the functions of safety devices (control functions in the event of failure) if measures for fault avoidance and fault control are taken for the required Performance Level (PL_r) as in DIN EN ISO 13849-1 or the relevant safety integrity level (SIL) as in DIN EN 61508 (VDE 0803) (all parts).

The safety integrity level (SIL) or required Performance Level (PL_r) shall be determined on the basis of a safety assessment of the use case carried out with the help of a risk graph.

Complex control systems such as programmable electronic systems (PES) for safety functions shall be designed in accordance with DIN EN 61508 (VDE 0803) (all parts).

NOTE Complex systems control installations which are equipped with the following functions:

— software-based automatic operation (PES-based drive control);

— speeds > 200 mm/s.

An E/PES shall be designed so that a single fault in a safety-related component does not lead to a loss of the safety function.

Hardware and software in safety-related equipment shall be designed so that when a fault occurs in or near a safety device its effectiveness is maintained, or the machinery installation is brought to a safe condition.

Single-channel programmable electronic controllers shall not be used for safety functions.

Dual-channel programmable electronic systems (E/PES) may be used for safety functions if they meet the requirements for at least SIL 3 as in DIN EN 61508 (VDE 0803) (all parts) or, for less complex systems, at least Performance Level C as in DIN EN ISO 13849-1.

7.9 Use of programmable electronic systems (E/PES) without safety functions

There are no particular requirements for programmable control systems (e.g. for selection functions such as group formation), if they do not perform safety-relevant tasks.

If the programmable control system performs selection functions, the successful selection of a function shall be indicated by means of an off-line feedback signal. The computer shall not have any influence on the effectiveness of the safety device.

Speed and position values may also be processed by the computer if they are not used to reach an arrival point specified for safety reasons.

7.10 Operator interfaces, control devices and contactors

7.10.1 General

General requirements regarding

— the location and mounting of control devices, and

— their protection against outside influences

are specified in DIN EN 60204-32 (VDE 0113-32).

7.10.2 Actuators (start devices) and indicators

Design criteria for actuators, start devices, and indicator lights and displays are described in detail in DIN EN 60204-32 (VDE 0113-32).

7.10.3 Devices for emergency stop and switching off

The location, type, function and activation of devices for emergency stop and switching off are described in detail in DIN EN 60204-32 (VDE 0113-32).

7.10.4 Requirements for contactors

The co-ordination of the contactors with the associated short-circuit protective devices shall be a “type 2” co-ordination as in DIN EN 60947-4-1 (VDE 0660-102):2008-10, 8.2.5.1.

Contactors which fulfil the stop function of drive systems and which are controlled by control devices with a safety function shall be selected and combined with other equipment in such a manner that contact welding is either avoided or does not affect the emergency stop function.

7.11 Conductors and cables

Conductors and cables shall be selected so as to be suitable for the operating conditions (e.g. in terms of voltage levels, currents, protection against electric shock, grouping of cables and conductors) and any external influences (e.g. ambient temperature, presence of water or corrosive substances, mechanical stresses, fire hazards) that can exist.

The minimum requirements regarding

— insulation;

— current-carrying capacity;

— voltage drops;

— minimum cross-sectional areas

of conductors and cables are specified in DIN EN 60204-32 (VDE 0113-32).

7.12 Wiring practices

The minimum requirements for

— connections and routing;

— identification of conductors;

— wiring inside and outside enclosures;

— ducts, connection boxes and other boxes

are specified in DIN EN 60204-32 (VDE 0113-32).

7.13 Electric motors and associated equipment

Electric motors should meet the requirements of DIN EN 60034-1 (VDE 0530-1).

The characteristics of motors and associated equipment shall be selected in accordance with the anticipated service and physical environmental conditions (see also DIN EN 60204-32 (VDE 0113-32)).

7.14 Accessories and lighting

The minimum requirements for accessories and lighting are specified in DIN EN 60204-32 (VDE 0113-32).

7.15 Marking, warning signs and reference designations

Electrical equipment shall be marked with the supplier's name and the reference designation in accordance with DIN EN 81346-1.

Design features of markings, warning signs and reference designations are specified in DIN EN 60204-32 (VDE 0113-32).

7.16 Technical documentation

The information to be included in technical documentation for electrical equipment, and the presentation of that information are specified in DIN EN 60204-32 (VDE 0113-32).

7.17 Testing and verification of characteristics

7.17.1 General

Tests to verify the characteristics of equipment shall be carried out on all switchgear/controlgear assemblies in accordance with DIN EN 61439-1 (VDE 0660-600-1) and the results documented. Such tests include:

— type tests;

— routine tests.

Type tests are carried out to establish whether the requirements of DIN EN 61439-1 (VDE 0660-600-1) have been met, and shall be performed by the switchgear/controlgear assembly manufacturer.

Routine tests are intended to detect any faults in materials and workmanship. They are to be carried out on every new switchgear/controlgear assembly after it has been assembled or on each transport unit, by the firm which has assembled the assembly.

The performance of the routine tests at the manufacturer's works does not relieve the firm installing the assembly of the duty of checking it after transport and installation.

7.17.2 Scope of routine testing

The continuity of the protective bonding circuit shall always be verified.

In addition, the following tests are to be carried out in the order shown:

— verification that the electrical equipment agrees with the technical documentation;

— inspection of the assembly, including inspection of wiring and, if necessary, electrical operation testing;

— insulation resistance tests;

— checking of protective measures and of the electrical continuity of the protective conductors.

General requirements for the required tests are described in detail in DIN EN 60204-32 (VDE 0113-32) and in DIN EN 61439-1 (VDE 0660-600-1).

8 Information for use

8.1 General

Information for use is an integral part of the scope of delivery of a machinery installation and shall facilitate and support the correct use of the machinery.

The manufacturer shall supply information for use in German which shall provide instructions for the intended use of the machinery taking all operating modes into consideration. The information shall contain all directions required to ensure safe and correct use of the machine. With this in view, it shall inform and warn the user about residual risk. The information for use shall be drawn up according to the principles laid down in DIN EN ISO 12100 and DIN EN 62079 (VDE 0039) (and DIN EN 12644-1 where applicable).

The information for use comprises at least:

— all data agreed upon during the planning stage or at the time of order;

— documentation;

— markings and signs;

— maintenance instructions;

— instruction handbook.

8.2 Data to be agreed

The following data shall be agreed for the machinery installation during the planning stage or at the time of order:

a) intended use;

b) intended time of use;

c) ambient conditions such as temperature and humidity;

d) other operating conditions;

e) maximum number of simultaneously moving machines;

f) duty type of drive systems as in DIN EN 60034-1 (VDE 0530-1);
g) safe working load at rest and in motion;
h) maximum concentrated and area loads;
i) travel speeds;
j) acceleration and deceleration values under normal operating conditions and under failure conditions;
k) travel path;
l) operating modes (synchronization tolerances and overtravel limits);
m) synchronization tolerances in the event of failure;
n) type of group travel as in 7.5.3;
o) type of control system.

This information is to be included in the information for use (documentation and instruction handbook).

8.3 Documentation

The documentation shall include:

a) a description of the machinery's functions;
b) factors affecting loading that have been taken into consideration;
c) drawings showing the general layout of the machinery;
d) information on materials used and the relevant certificates;
e) design and calculation verification;
f) components used, including information on make and type;
g) information on replacement parts;
h) consumables, operating fluids, lubricants;
i) data and values set at the time of commissioning of the machinery;
j) circuit diagrams;
k) maintenance instructions, including the expected life of safety-relevant components;
l) instruction handbooks;
m) information relating to transportation and storage;
n) instructions and criteria for routine tests;
o) instructions for decommissioning;
p) instructions for dismantling, disabling and scrapping.

8.4 Maintenance instructions

The information for use shall include all information necessary to maintain the functionality and safe condition of the machinery installation.

This information shall include:

a) the type and frequency of visual and functional checks, inspections and maintenance;
b) hazards relating particularly to inspection and maintenance;
c) the qualification of persons responsible for inspection and maintenance;

d) values and data to be set;

e) instructions for repairs and adjustments;

f) description of any built-in diagnostic systems which can help in finding errors;

g) cleaning and care methods;

h) scope of inspections and maintenance actions which do not require professional expertise and hence may be carried out by persons trained for this purpose;

i) a clear statement as to whether the user can carry out maintenance or deal with faults himself, or whether a qualified person is necessary for this;

j) contact information for the party installing the machinery and who can provide technical support.

8.5 Marking

The name of and contact information for the party installing the machinery, and the year of manufacture shall be placed at a suitable location.

A permanently fixed, easily recognizable nameplate bearing the following information shall be provided at load carrying devices, and on components of the machinery installation or other suitable locations:

a) designation of the machinery installation;

b) manufacturer, importer or distributor;

c) year of manufacture;

d) machine type;

e) plant or serial number.

Depending on the type and function of the relevant component, the plate may include additional information, such as:

f) self-weight in kg;

g) speed;

h) nominal torque;

i) gear ratio;

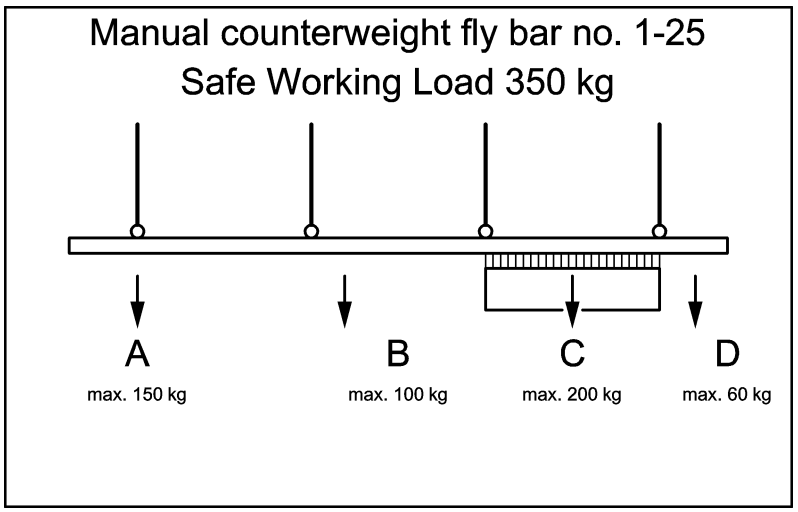
j) operating voltage, frequency;

k) SWL at rest and in motion;

l) nominal speed in m/s;

m) travel range in m.

A sign giving the maximum allowable concentrated loads, line loads and loading points shall be placed within view of the operator (e.g. near the control station). An example showing four loading points is given in Figure 10.



Key

A max. concentrated load under one wire rope, depending on rope dimensions

B max. concentrated load between two wire ropes, at mid-span, depending on bar dimensions and max. load A

C max. uniformly distributed load between two wire ropes, depending on bar dimensions and max. load A

D max. concentrated load at bar end, depending on bar dimensions and max. load A

Figure 10 — Load sign giving maximum allowable loads (example)

8.6 Instruction handbook

The manufacturer, importer or distributor shall provide an instruction handbook as part of the information for use.

The instruction handbook shall state whether or not

— special training or expertise is necessary to operate the machinery,

— the use of personal protective equipment is necessary.

The instruction handbook shall contain all possible uses that can be reasonably foreseen based on the designation and description of the machinery; it shall also warn against the risks generated when the machinery is not used as intended, taking into account reasonably foreseeable misuse.

The instruction handbook shall contain the following information:

a) instructions regarding all possible intended uses of the machine and intended operating modes;

b) possible hazards relating to intended use, as well as possibilities of misuse;

c) detailed instructions relating to the use of the machine;

d) description of all technical safety measures, as well as any necessary organizational safety measures where technical measures were not possible;

e) behaviour during normal operation;

f) behaviour under failure conditions.

9 Testing prior to commissioning

Prior to commissioning, the machinery shall be subjected to testing as specified in BGV C 1/GUV-V C 1.

The principles specified in BGG/GUV-G 912 for testing safety-related equipment and machinery installations as in this standard shall be observed. A test log shall be compiled comprising the manufacturer's documentation for the machinery installation and the test reports.

Annex A
(normative)

Checklist for visual and functional checks

Table A.1 — Checklist for visual and functional checks

	Item being checked	Criteria
1	Information for use	
1.1	General markings (signs)	
	Nameplates Characteristic data Information, notices Load diagrams	Fixing Legibility Completeness Durability
1.2	Markings (signs) relating to safety and health	
	Prohibition signs Warning signs Mandatory signs Hazard warning signs Fire safety signs	Condition Legibility
1.3	Instruction handbook	
	Range of applicability Content Circuit diagrams	Legibility Condition Availability
1.4	Signals	
	Communication signals	Condition Function Recognisability
2	Control devices	
2.1	Protection against unauthorized use	
	Main control devices and their actuators	Condition Function Accessibility Labelling Shut-off possibility
2.2	Control devices for starting and stopping, i.e. devices for	
	Lifting, lowering	Condition

Table A.1 *(continued)*

	Item being checked	**Criteria**
	Slanting, tilting Turning, swivelling Pushing, pulling Opening, closing Travelling Stopping	Function Accessibility Automatic reset Clearly arranged Direction of travel permanently marked Protection against unintentional activation and unauthorized use Interlocking of controls where there are multiple control stations
2.3	Emergency stops and their actuators	
		Condition Function Accessibility Clearly arranged
3	Supporting structures	
		Condition Cracks Deformation, corrosion Accessibility of guides, pulleys, links, joints, telescopic components Wear of guides, pulleys, bearings, links, joints Attachment and securing of detachable elements (e.g. ropes, chains) Effectiveness of locking devices
4	Drive systems	
4.1	Gear mechanisms	
		Leaks Function Connection between drive components Noise Lubrication Effectiveness, where appropriate self-locking functions
4.2	Clutches	
		Condition Function Wear

Table A.1 *(continued)*

	Item being checked	**Criteria**
4.3	Brakes	
		Condition Function
4.4	Drive shafts	
		Condition Function Connection between drive components
5	Load bearing equipment	
5.1	Wire rope	
	Wire rope Wire rope terminations Pulleys Drums Guides Sheaves Draw rolls Guard brackets Compensating devices Winding devices Securing of take-up points	Condition Function Rope diameter, reduction of diameter Wear Corrosion Bushings Crushing areas Looseness of outer layer Kinking, birdcaging Cracks Burrs in grooves of drums Correct alignment of pulley
5.2	Steel bands	
	Bands Compensating devices Terminations	Condition Function Durability Nicking Kinking Cracks Corrosion
5.3	Steel chains	
	Chains End connections Rollers Sprockets Tensioner Securing of take-up points	Condition Function Accessibility Wear Elongation / spacing Cracks

Table A.1 *(continued)*

	Item being checked	**Criteria**
		Securing bolts (e.g. using rivet heads, rings)
5.4	Screw jacks (spindles)	
	Screw jacks Supporting nuts Lock nuts	Condition Function Mounting Deformation Fouling Notching, scoring, grooves Burring Effectiveness of covers Thread wear (amount of play)
5.5	Toothed racks, lantern pinions	
	Pinions Lantern bolts	Condition Function Attachment Wear Joints of composite racks Cracks Shaft play Lubrication Fouling
5.6	Cylinders	
	see number 9 “Hydraulic systems”	
5.7	Load hooks	
		Deformation Wear Cracks Corrosion Crushing of hook opening Securing of hook nut Securing of hooks
6	Load carrying devices	
6.1	Stage elevator platforms	
	Safety barriers Fall protection Protection of closing edges	Condition Function corrosion

Table A.1 *(continued)*

	Item being checked	**Criteria**
	Floors, openings	Deformation
	Steps	Attachment and securing of detachable elements
		Effectiveness of interlocks
		Accessibility of moving parts
		Secure foothold
		Wear
		Cracks
		Damage
6.2	Fly bar systems for scenery (manual or motor-driven)	
	Bars	Condition
	Connections/terminations of load-bearing equipment	Manoeuvrability
	Tensioning devices	Effectiveness
	Telescopic extensions	Securing against detachment
6.3	Traverse systems	
	Tubes	Condition
	Welds	Cracks
	Connection points	Notching
		Bends
7	Securing devices	
	Round steel chains	Condition
	Shackles	Function
	Quick links	Corrosion
	Wire rope	Wear
	Fibre rope	
8	Placing devices	
	Supports	Condition
	Interlocks	Cracks
		Deformation
		Corrosion
		Accessibility of guides, pulleys, links, joints, telescopic components
		Wear of guides, pulleys, bearings, links, joints
		Attachment and securing of detachable elements (e.g. ropes, chains)
		Effectiveness of interlocks

Table A.1 *(continued)*

	Item being checked	**Criteria**
9	Hydraulic systems	
	Pressure generators	Condition
	Control valves	Function
	Non-return valves	Leaks
	Reservoirs	Leaktightness
	Pressure fluids	Ventilation
	Shut-off valves	Condition and legibility of indications
	Ventilation devices	Pressure fluid level control
	Shut-off devices	Effectiveness of shut-off device when pressure fluid level is too low
	Pipelines	Connections
	Pipeline connections	Fixtures
	Level indicators	Damage
	Characteristic data	Deformation
	Hoses	Corrosion
	Hose connections	Ageing
	Measuring points	Brittleness
	Cylinders	Porosity
	Piston rods	Cracks
	Dampers	Scoring, grooves
	Filters	Fouling
	Pressure relief valves	Settings
	Seals	
	Pipe and hose connections	
	Clamping heads	
	Pipe burst protection	
10	Chassis	
	Service brakes	Condition
	Holding devices	Function
	Restraints	Wear
	Guide rails	Effectiveness
	Anti-derailment devices	Deformation
		Cracks
		Corrosion
11	Access points and control stations	
	Ladders, platforms	Condition

Table A.1 *(continued)*

	Item being checked	**Criteria**
	Steps, rungs, bars	Function
	Fall protection	Effectiveness
	Railings, guards	Secure foothold
	Platforms, ladders, handholds	Deformation at platforms
	Floor flaps	Damage
	Protection at closing edges	Corrosion
	Baseboards	Securing of detachable elements
	Coverings	Stability
	Lighting	
12	Protective spaces	
	Folding supports	Condition
	Lighting	Function
	Electrical outlets	Accessibility
	Drive service switch	Effectiveness
	Information, warnings	Legibility
13	Special safety devices	
	Signals	Condition
	Limit switches	Function
	Emergency limit switches	Completeness
	Slack rope switches	Effectiveness
	Slack chain switches	Attachment
	Emergency bars	Deformation
	Protection against restarts	Accessibility of switching elements
	Anti-tilt devices	Fouling
	Arresting devices	Condition of compression springs
	Speed limitation devices	Positive locking
	Indicating devices	
	Load limiting devices	
	Door locks	
14	Locking devices	
		Condition
		Function
		Effectiveness
15	Stage lifts with free travel	
	Positioning aids	Condition
	Guards	Function

Table A.1 *(continued)*

	Item being checked	**Criteria**
	Access points	Effectiveness
	Markings	Completeness
	Lighting	
	Signals	
	Safeguarding of exposed edges	
16	Projection screens (manual or motor-driven, having a width or height greater than 5 m)	
	Hanging mechanism	Condition
	Arresting devices	Function
17	Electrical and electronic equipment	
	Cables	Condition
	Running of cables	Function
	Movable cables	Effectiveness
	Tension relief	Damage, wear
	Cable glands	Attachment
	Equipotential bonding	Tolerances are met
	Shut-down methods	
	Group travel	
	Safeguards	
	RCDs	
	Switchgear/controlgear	
	Limit switches	
	Insulation and enclosures	

Annex B
(normative)

Examples of hazards, hazardous situations and hazardous events associated with machinery installations as in this standard

Table B.1 — Examples of hazards, hazardous situations and hazardous events associated with machinery installations as in this standard

	Hazards	Examples of hazards	Examples of protective measures	Relevant subclause of this standard
1	**Mechanical hazards due to**			
1.1	crushing	Stage wagon travels to parked position, persons stand in travel path; Feed area of drive chains is not narrow enough, so that a person can unintentionally reach in	Design measures; Organizational measures	6.2
1.2	shearing	As elevators pass each other, body parts protrude off the platform	Design measures; Organizational measures	6.2
1.3	entanglement	Material or pieces of clothing get caught as ropes are wound onto the drum; Distance between rope drum or chain sprocket is too great; Drive shaft is not sufficiently covered	Use of enclosures; Organizational measures; Distance of rope drum edge to safeguard to be max. 0,5 × rope diameter	5.2, 6.2
1.4	impacts	Stage wagons or towers are driven too quickly and run into persons	Marking danger zones; Organizational measures	6.2
1.5	surface geometry	Gaps or steps are too wide, persons could get caught on sharp edges of steps	Observe specified max. gap widths and step heights; Avoid sharp edges	6.2

Table B.1 *(continued)*

	Hazards	Examples of hazards	Examples of protective measures	Relevant subclause of this standard
1.6	drawing-in or trapping	Hazards at winding devices and diverter pulleys	Use of enclosures and covers	5.2, 6.2
2	Additional hazards and hazardous events due to lifting procedures, falling loads, collisions, machine tipping, due to:			
2.1	lack of stability	Overloading of platforms; Danger of falling where height differences are great; Screwed connections fail leading to scenery falling down or over; Incorrect dimensioning of structural elements and components	Take into account moving self-loads and dynamic influences	5
2.2	incorrect arrangement of machinery parts	Incorrect installation and combination of components	Follow proven design principles; Provide protection against extreme wear	5
2.3	incorrect loading, overloading, exceeding specified overturning moments	Above-stage machinery: Large loads (scenery) underneath the fly grid; Stability calculations not carried out for critical pieces of scenery; Improper force or load transmission, e.g. via incorrect suspension points; Overload shut-off incorrectly adjusted and motor is overloaded	Determine safe working loads and mark them on signs; Adjust overload shut-off correctly	5
2.4	unintentional movement due to mechanical failure	Unintended turning, tilting, hanging, falling, uncontrolled lowering; Failure of drive system or locking device	Interlocking designs, following well-established design principles; Designing in redundancy or overdesigning; Self-locking designs, ensuring against loosening and detachment	5
2.5	uncontrolled movements	Unintentional drive start-up; Exceeding specified travel limits; Lighting bars deviate from the horizontal position; Uncontrolled speeds	Design requirements; Use of 2 independent brakes, actuators with automatic reset, emergency limit switches, and control systems proven to be reliable	5

Table B.1 *(continued)*

	Hazards	Examples of hazards	Examples of protective measures	Relevant subclause of this standard
2.6	unsuitable connectors, holding devices or accessories	Incorrect rope terminations, or terminations dimensioned too small, leading to the load carrying device or scenery falling; Detachable terminations are not secured against self-detachment and they detach	Use positive locking and holding devices that are suitable for the load; Observe requirements regarding permissible rope terminations and securing devices, safety factors, and securing against self-detachment	5
2.7	collision of machinery components	Distance between fly bars too small; Extended bars collide with panorama hoist, leading to a collision and scenery falling	Use deflector devices; Organizational measures	5
2.8	unsuitable design of load carrying devices and rope drums	Suspension lines kink or become twisted, or are destroyed and the load falls; Rope falls off side of drum; Rope wear due to incorrectly dimensioned drum grooves; Use of hook types which make unintentional hanging possible	Observe design requirements for radii, grooves, etc.; Reel rope feed; Use hooks with safety catches	5
2.9	unsuitable selection of chains, ropes, lifting devices and equipment, and incorrect integration to machinery	Use of load carrying devices which are dimensioned too small, e.g. spring clips instead of quick links	Observe design requirements; Use hooks with safety catches	5
2.10	incorrect installation, testing, use and maintenance	Persons work in the immediate vicinity of a danger zone; Persons work on machinery which is being operated by a second person unaware of the first; Instructions for use are incomplete	Observe requirements for switches, safety devices; Emphasize necessity of protective spaces; Come to procedural agreements; Inform and train personnel; Complete instructions for use; Maintain inspection and test intervals	6.1, 6.3
2.11	effects of loads on persons (impacts from load or counterweights)	It is possible for persons to stand in path of counterweights; Persons can stand under elevators, e.g. orchestra elevator, without being able to step outside this space	Provide enclosures, safety distances/clearances, protective spaces under elevators	6
3	Electrical hazards due to			

Table B.1 *(continued)*

	Hazards	**Examples of hazards**	**Examples of protective measures**	**Relevant subclause of this standard**
3.1	contact of persons with live parts (i.e. parts which are normally live)	Electric shock due to direct contact	Provide covers, enclosures, maintenance	7.3
3.2	contact of persons with parts which have become live under faulty conditions	Electric shock due to indirect contact, e.g. due to faulty or inadequate insulation or lack of equipotential bonding, e.g. defect lights on lighting bar	Electrical safety measures, e.g. earthing, equipotential bonding, monitoring insulation, maintenance	7.3
3.3	electrostatic phenomena	Electric shock due to persons coming in contact with charged parts	Earthing, equipotential bonding	7.3
4	Hazards generated by noise, resulting in			
4.1	hearing loss (deafness), other physiological disorders (e.g. loss of balance, loss of awareness)	(Noise generated in) machinery rooms or pump rooms	Noise control measures, Providing protective equipment, Organizational measures	-
5	Hazards generated by vibration			
5.1	indirectly, due to loosening of components	Loosening of screws; eigen frequencies cause resonance	Determine eigen frequencies; Provide lock washers, self-locking nuts; Control engineering	-
6	Hazards generated by neglecting ergonomic principles in machinery design, e.g. hazards from			
6.1	unhealthy postures or excessive effort	Unsuitable arrangement of controls; Excessive holding or actuating forces required	Auxiliary equipment, aids, favourable design of workplaces	7.10
6.2	inadequate local lighting	Insufficient working light for operations such as motor repairs; Operations during lighting rehearsals	Use working lights of adequate intensity and glare protection	7.10, 7.14
6.3	inadequate design, location or identification of manual controls	Levers too far apart, cannot be operated by one person simultaneously; Controls do not reset automatically and hoist continues to travel unintentionally	Suitable design measures; Use automatically resetting controls	6, 7.10

Table B.1 *(continued)*

	Hazards	Examples of hazards	Examples of protective measures	Relevant subclause of this standard
6.4	inadequate design of visual display units	Displays which are too small lead to reading errors; Inadequate software ergonomics	Suitable arrangement of visual displays; Use of clearly recognizable displays; Ergonomic design principles	7.10
6.5	inadequate design or location of visual display	Displays which are too small lead to reading errors	Suitable arrangement, Use of clearly recognizable displays	7.10
7	Hazards due to unintentional movements, e.g. due to			
7.1	failure/malfunctioning of the control system	Unintentional start-up, stop command is not carried out, e.g. wrong hoist starts up; Scenery falls; Synchronous travel is no longer ensured; Overloading or destruction of scenery on several hoists; Emergency stop occurs too late; Increase in travel speed; High braking acceleration	Provide safeguards and redundancy, fault avoidance measures, off-line feedback/checkback signals; Consider failure conditions in component design; Undervoltage protection; Categorize components into SIL levels; Use category 0 emergency stop or switching off functions	7.6, 7.7
7.2	interruption/restoration of energy supply	Unintentional start-up, stop command is not carried out, e.g. after power failure, uncontrolled start-up of hoist, leading to injury of persons standing underneath	Provide safeguarding, electrical energy storage, undervoltage protection, uninterruptible power systems (UPS)	7.2, 7.5, 7.6, 7.7
7.3	external influences on electrical equipment	Minimum distances between power lines and signal lines, and requirements regarding inductances and malfunctions (EMC) not maintained	Maintain minimum distances between electrical power supply lines and control lines	7.11, 7.12
7.4	software errors	Unintentional start-up, stop command is not carried out due to program error, e.g. wrong hoist starts up, or hoist goes in wrong direction, scenery falls	Carry out failure mode and effects analysis, cyclical testing; Provide diverse redundancies, dual-channel systems and watchdogs	7.5, 7.6, 7.7, 7.8, 7.9,

Table B.1 *(continued)*

	Hazards	Examples of hazards	Examples of protective measures	Relevant subclause of this standard
8	Hazards due to failure in the power supply			
8.1	Hazards due to failure in the power supply	Synchronization tolerances are exceeded; Power storage runs out and scenery falls; When power supply is interrupted, movement is not stopped and is no longer controlled	Provide buffer storage; Automatic engaging of brakes when power supply is interrupted	7.6, 7.7
9	Hazards due to installation errors			
9.1	Hazards due to improper installation	Connections/terminations which are inadequately secured loosen or detach; Instructions for use give insufficient information regarding maintenance; Wire rope incorrectly installed	Provide adequate training and instructions, acceptance testing, maintenance intervals, sufficiently detailed instructions for use	8.4, 8.6
10	Hazardous situations and events due to improper use			
10.1	Slipping, tripping or falling of persons (related to machinery)	Open gaps which cannot be secured for artistic reasons; Persons trip over drive ropes or belts	Maintain orderliness, calm in working areas; Organizational measures	8.4, 8.5, 8.6
10.2	Unauthorized start-up/use	Unauthorized use of machinery; If a machine operator is ill, an unauthorized person is allowed to operate stage elevator	Organizational measures (only authorized personnel allowed); Use key switch controls	7.6, 7.7
10.3	Drift of a machine component away from its stopping position	Limit switch is defect or incorrectly set; Hoist bar collides with grid or touches stage floor	Use two limit switches (operational and emergency limit switches)	7.5
10.4	Lack or inadequacy of visual or acoustic warning signals	Lowered elevator does not have sufficient barriers; Technical personnel leave stage during intermission; Singers step onto stage and fall; When lighting is low, edges of exit stairs not illuminated and performers fall down stairs	Safeguard danger zones by means of warning devices	6, 7.15, 8.4, 8.5, 8.6
10.5	Hazards due to improper operation	Intended uses of machinery are disregarded; Factors which can lead to damage are not recognized; Failure to observe travel areas of machinery and suspended loads	Provide personnel with adequate training and instructions; Observe maintenance and testing intervals; Observe travel limits of machinery and hanging loads; Carry out risk assessment	8.3, 8.4, 8.5, 8.6

Annex C
(normative)

Designing safeguards on the basis of risk assessment

C.1 General

The mechanical and electrical equipment of machinery installations as in this standard shall at times perform safety functions.

The safety requirements for equipment which performs safety functions, and the measures needed to fulfil those requirements, can vary considerably. A combination of technical and non-technical measures (e.g. organizational measures) can be employed to realize the safety functions to be performed by the system.

As a rule, the greater the risk, the more stringent the necessary safety requirements and measures will be. By combining electrical and non-electrical protective measures, the risk can be reduced at least to a tolerable level.

The risk reduction possible by means of safeguarding will depend on the solution selected and, theoretically, can lie between 0 % and 100 % of the necessary minimal risk reduction for one and the same application. This means that various equivalent measures can be taken to cover the risks associated with the electrical system.

The methods described in this Annex for assessing risks associated with safety-related equipment:

a) are independent of the application and technology upon which the electrical protective system is based (that is, they can be used for electro-mechanical, electronic or hydraulic systems alike);

b) cannot be used for complete systems (installations), but only for the particular safety function under consideration.

C.2 Risk assessment as in DIN EN 61508 (VDE 0803) (all parts)

C.2.1 General

The requirements for a safeguard covering a partial risk are determined based on various parameters describing the nature, type and extent of the hazardous situations which can arise when an electrical safeguard fails or is not available.

The following four risk parameters have been introduced for determining safety requirements on a case-by-case basis, and the measures to be taken to fulfil these requirements:

a) consequence risk parameter (C); (see C.2.2);

b) frequency and exposure time risk parameter (F); (see C.2.3);

c) possibility of avoiding the hazard risk parameter (P); (see C.2.4);

d) probability of the unwanted occurrence risk parameter (W); (see C.2.5).

The risk graph shown below combines the selected parameters into various outputs leading to one of the four safety integrity levels defined in DIN EN 61508-4 (VDE 0803-4).

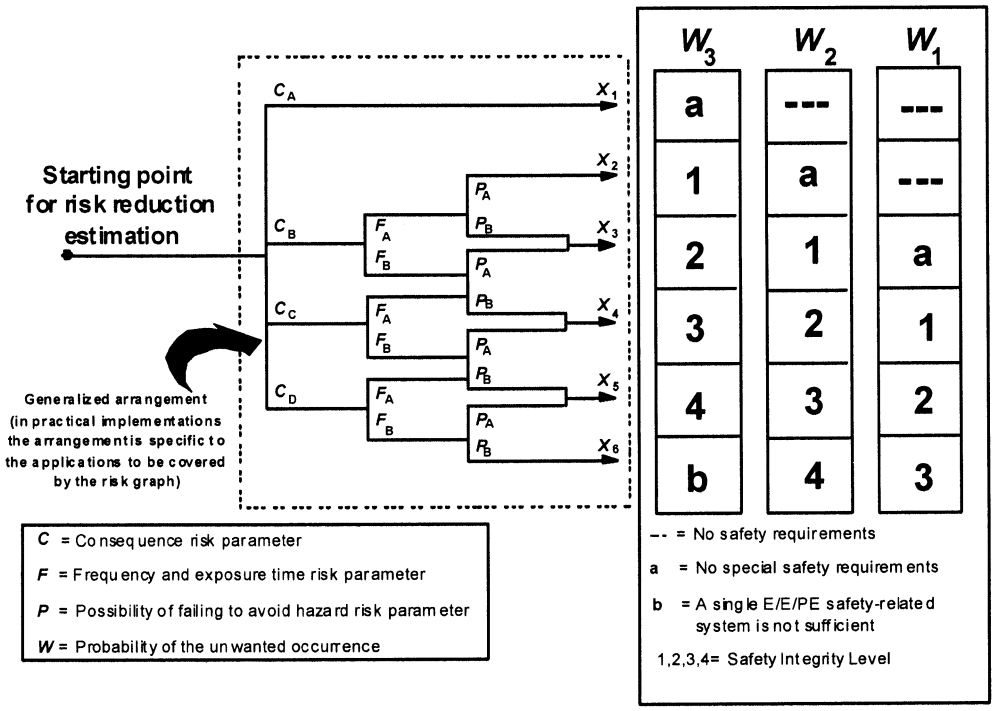


Figure C.1 — Risik graph as in DIN EN 61508-5 (VDE 0803-5): general scheme

C.2.2 Consequence risk parameter (C)

Generally, this parameter deals solely with consequences involving personal injury according to the following criteria:

a) C_A (C_1): minor injury;

b) C_B (C_2): serious permanent injury to one or more persons; death to one person;

c) C_C (C_3): death to several people;

d) C_D (C_4): very many people killed.

C.2.3 Frequency and exposure time risk parameter (F)

The following criteria are considered in this parameter:

— Frequency and duration of exposure in the hazardous zone;

— F_A (F_1): Rare to more often exposure in the hazardous zone;

— F_B (F_2): Frequent to permanent exposure in the hazardous zone.

C.2.4 Possibility of avoiding the hazard risk parameter (P)

The following criteria are considered in this parameter:

— Possibility of avoiding the hazard;

— P_A (P_1): Possible under certain conditions;

— P_B (P_2): Almost impossible.

C.2.5 Probability of the unwanted occurrence risk parameter (W)

The following criteria are considered in this parameter:

The purpose of the W factor is to estimate the frequency of the unwanted occurrence taking place without the addition of any safety-related systems (E/E/PE or other technology) but including any other risk reduction measures.

W_1: A very slight probability that the unwanted occurrences will come to pass and only a few unwanted occurrences are likely.

W_2: A slight probability that the unwanted occurrences will come to pass and few unwanted occurrences are likely.

W_3: A relatively high probability that the unwanted occurrences will come to pass and frequent unwanted occurrences are likely. See Table C.1 for an example of data relating to the risk graph (Figure C.1).

Table C.1 — Example of data relating to the risk graph (see Figure C.1)

Risk parameter		Classification	Comments
Consequence (C)	C_1	Minor injury	1 The classification system has been developed to deal with injury and death to people. Other classification schemes would need to be developed for environmental or material damage.
	C_2	Serious permanent injury to one or more persons; death to one person	
	C_3	Death to several people	2 For the interpretation of C_1, C_2, C_3 and C_4, the consequences of the accident and normal healing shall be taken into account.
	C_4	Very many people killed	
Frequency of, and exposure time in, the hazardous zone (F)	F_1	Rare to more often exposure in the hazardous zone	3 See comment 1
	F_2	Frequent to permanent exposure in the hazardous zone	

Table C.1 *(continued)*

Risk parameter		Classification	Comments
Possibility of avoiding the hazardous event (P)	P_1 P_2	Possible under certain conditions Almost impossible	4 This parameter takes into account — operation of a process (supervised (i.e. operated by skilled or unskilled persons) or unsupervised); — rate of development of the hazardous event (for example suddenly, quickly or slowly); — ease of recognition of danger (for example seen immediately, detected by technical measures or detected without technical measures); — avoidance of hazardous event (for example escape routes possible, not possible or possible under certain conditions); — actual safety experience (such experience may exist with an identical EUC or a similar EUC or may not exist).
Probability of the unwanted occurrence (W)	W_1 W_2 W_3	A very slight probability that the unwanted occurrences will come to pass and only a few unwanted occurrences are likely. A slight probability that the unwanted occurrences will come to pass and few unwanted occurrences are likely. A relatively high probability that the unwanted occurrences will come to pass and frequent unwanted occurrences are likely.	5 The purpose of the W factor is to estimate the frequency of the unwanted occurrence taking place without the addition of any safety-related systems (E/E/PE or other technology) but including any other risk reduction measures. 6 If little or no experience exists of the EUC, or the EUC control system, or of a similar EUC and EUC control system, the estimation of the W factor may be made by calculation. In such an event a worst case prediction shall be made.

C.3 Risk assessment as in DIN EN ISO 13849-1

C.3.1 General

The risk assessment assumes a situation prior to provision of the intended safety function. Risk reduction by other technical measures independent of the control system (e.g. mechanical guards), or additional safety functions, can be taken into account in determining the PL_r of the intended safety function; in which case, the starting point of Figure C.2 can be selected after the implementation of these measures. The severity of injury (denoted by S) is relatively easy to estimate (e.g. laceration, amputation, fatality). For the frequency of occurrence, auxiliary parameters are used to improve the estimation. These parameters are:

— frequency and time of exposure to the hazard (F) and

— possibility of avoiding the hazard or limiting the harm (P).

Experience has shown that these parameters can be combined, as in Figure C.2, to give a gradation of risk from low to high. It is emphasized that this is a qualitative process giving only an estimation of risk.

C.3.2 Guidance for selecting parameters S, F and P for the risk estimation

C.3.2.1 Severity of injury S1 and S2

In estimating the risk arising from a failure of a safety function only slight injuries (normally reversible) and serious injuries (normally irreversible) and death are considered.

To make a decision the usual consequences of accidents and normal healing processes should be taken into account in determining S1 and S2. For example, bruising and/or lacerations without complications would be classified as S1, whereas amputation or death would be S2.

C.3.2.2 Frequency and/or exposure times to hazard, F2 and F2

A generally valid time period to be selected for parameter F1 or F2 cannot be specified. However, the following explanation could facilitate making the right decision where doubt exists.

F2 should be selected if a person is frequently or continuously exposed to the hazard. It is irrelevant whether the same or different persons are exposed to the hazard on successive exposures, e.g. for the use of lifts. The frequency parameter should be chosen according to the frequency and duration of access to the hazard.

Where the demand on the safety function is known by the designer, the frequency and duration of this demand can be chosen instead of the frequency and duration of access to the hazard.

The period of exposure to the hazard should be evaluated on the basis of an average value which can be seen in relation to the total period of time over which the equipment is used.

C.3.2.3 Possibility of avoiding the hazard P1 and P2

It is important to know whether a hazardous situation can be recognized and avoided before leading to an accident. For example, an important consideration is whether the hazard can be directly identified by its physical characteristics, or recognized only by technical means, e.g. indicators. Other important aspects which influence the selection of parameter P include, for example:

— operation with or without supervision;

— operation by experts or non-professionals;

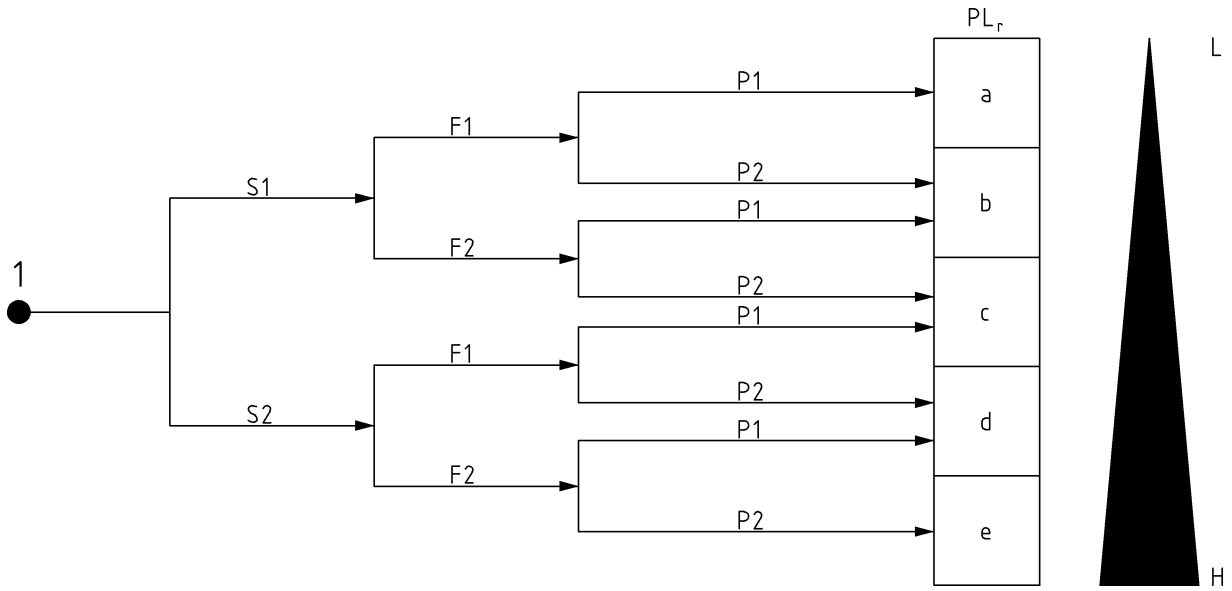
— speed with which the hazard arises (e.g. quickly or slowly);

— possibilities for hazard avoidance (e.g. by escaping);

— practical safety experiences relating to the process.

When a hazardous situation occurs, P1 should only be selected if there is a realistic chance of avoiding an accident or of significantly reducing its effect; P2 should be selected if there is almost no chance of avoiding the hazard.

Figure C.2 provides guidance for the determination of the safety-related PL_r depending on the risk assessment. The graph should be considered for each safety function. The risk assessment method is based on DIN EN ISO 12100.



Key

1 starting point for evaluation of safety function's contribution to risk reduction

L low contribution to risk reduction

H high contribution to risk reduction

PL_r required performance level

Risk parameters:

S severity of injury

S1 slight (normally reversible injury)

S2 serious (normally irreversible injury or death)

F frequency and/or exposure to hazard

F1 seldom-to-less-often and/or exposure time is short

F2 frequent-to-continuous and/or exposure time is long

P possibility of avoiding hazard or limiting harm

P1 possible under specific conditions

P2 scarcely possible

Figure C.2 — Risk graph for determining required PL_r for safety function

Annex D
(informative)

Examples of using the risk graphs

D.1 General

The following two examples in D.2 and D.3 show that risk assessment is to be carried out for each safety-relevant component. In addition, knowledge of the operating conditions is necessary and is to be taken into consideration during the assessment.

The examples below illustrate the use of risk assessment as specified in DIN EN ISO 13849-1 and DIN EN 61508 (VDE 0803) (all parts) to identify hazards relating to equipment with safety functions.

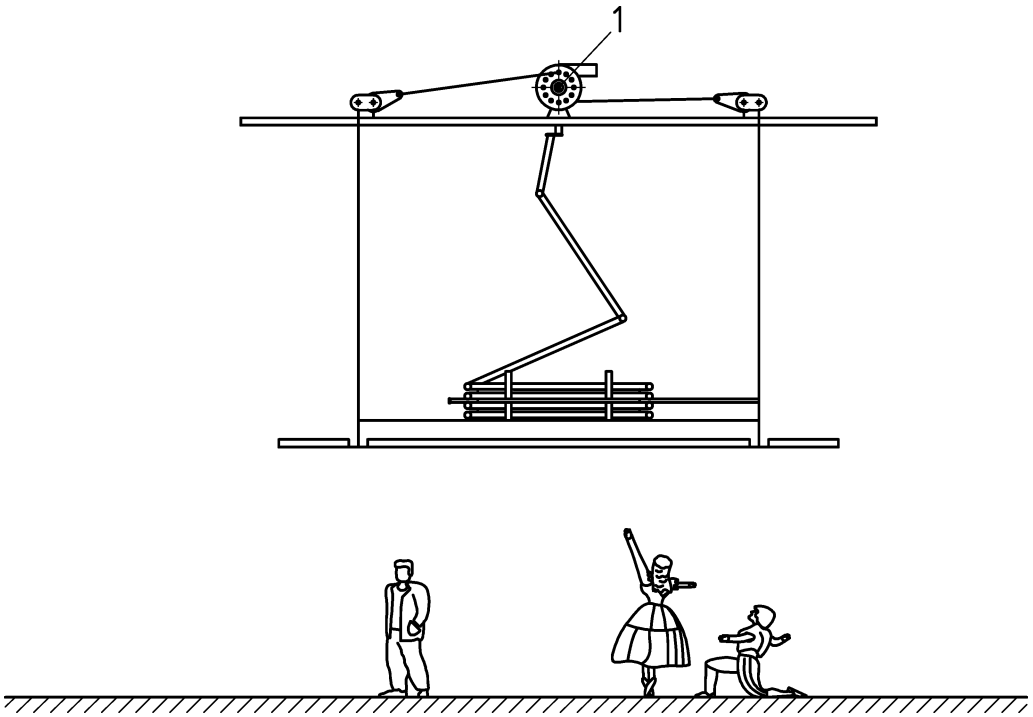
EXAMPLE 1 Use of an unregulated three-phase asynchronous motor, with double brake, for moving loads at a speed of 0,15 m/s (see D.2).

EXAMPLE 2 Use of computer control to provide protection when the synchronization tolerance is exceeded during the automated synchronized travel of a group of hoists at a speed of 1,2 m/s (see D.3).

D.2 Use of an unregulated three-phase asynchronous motor, with double brake, for moving loads at a speed of 0,15 m/s

D.2.1 Illustration

Figure D.1 illustrates the example described in this subclause.



Key
1 Double brake

Figure D.1 — Use of an unregulated three-phase asynchronous motor for moving loads, with double brake, selected on the basis of a risk graph

D.2.2 Requirements

The occurrence of a fault in the electrical system shall not lead to hazardous operating conditions, as specified in 7.6.3.

D.2.3 Risk assessment

The unwanted occurrence to be avoided is the load falling due to an outage of a phase in the power supply to the motor (motor can no longer handle the load). The control system should identify the phase outage and safely engage the brakes.

D.2.4 Consequence (C or S)

This unwanted occurrence would take place above the stage surface, and in the event of failure, serious injuries to one or more persons, or even death to a person could be expected, thus the consequence risk parameter is:

DIN EN 61508-5 (VDE 0803-5)	DIN EN ISO 13849-1
C_2	S2

D.2.5 Frequency of, and exposure time in, the hazardous zone (F)

On the stage, people are often in the danger zone, thus the risk parameter is :

DIN EN 61508-5 (VDE 0803-5)	DIN EN ISO 13849-1
F_2	F2

D.2.6 Possibility of avoiding the hazardous event (P)

The hazardous event can be avoided by initiating an emergency stop. Because of the low speed, P_1 can be assumed.

DIN EN 61508-5 (VDE 0803-5)	DIN EN ISO 13849-1
P_1	P1

D.2.7 Probability of the unwanted occurrence (W)

Because there is no reliable experience regarding this parameter, the parameter W_3 shall be assumed.

DIN EN 61508-5 (VDE 0803-5)	DIN EN ISO 13849-1
W_3	no equivalent

On the basis of the parameters C_2, F_2, P_1 and W_3, the risk graph according to DIN EN 61508-5 (VDE 0803-5) shows that SIL 2 is to be selected for the safety function “phase monitoring”.

On the basis of the parameters S2, F2, P1, according to DIN EN ISO 13849-1 the required performance level PL_r shall be “d” for the safety function “phase monitoring”.

D.3 Use of computer control to provide protection when the synchronization tolerance is exceeded during the automated synchronized travel of a group of hoists at a speed of 1,2 m/s

D.3.1 Illustration

Figure D.2 illustrates the example described in this subclause.

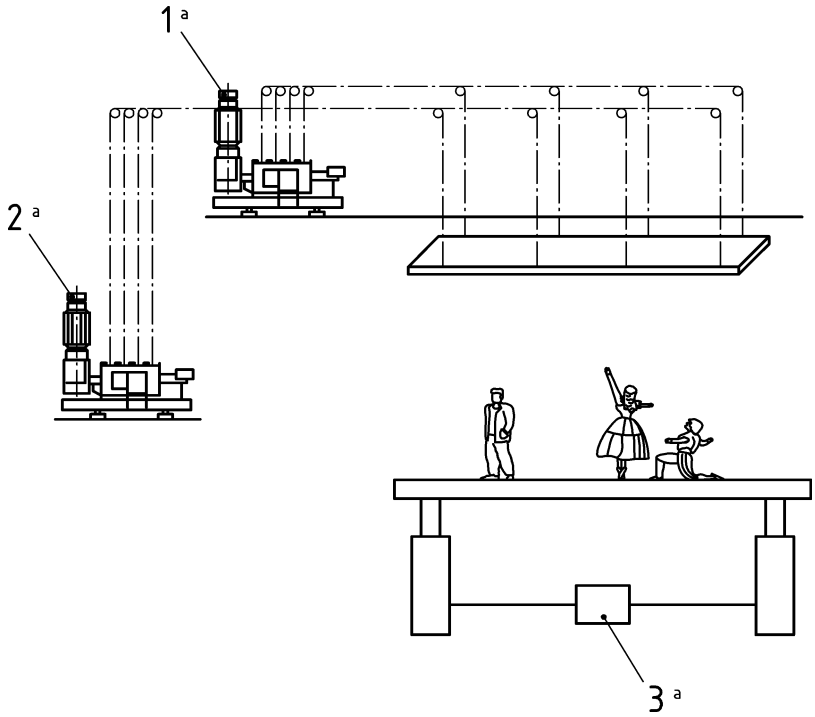


Figure D.2 — Use of computer control to provide protection when the synchronization tolerance is exceeded during the automated synchronized travel of a group of hoists at a speed of 1,2 m/s

D.3.2 Requirements

The computer control system is to fulfil a safety function, namely monitoring compliance with synchronization tolerances during the synchronized group travel of hoists as in 7.5.3.2.

The group of hoists shall stop moving once the synchronization tolerance is reached, and it shall be clearly indicated which hoist has exceeded the tolerance.

NOTE DIN EN ISO 13849-1 cannot be used for this example because it involves the complex PES described below and not only the safety-related components of control systems covered by DIN EN ISO 13849-1.

D.3.3 Risk assessment

The unwanted occurrence to be avoided in this case is a situation where hoists carrying the same load (e.g. a ceiling, truss beam) fall out of synchronization, the result of which would be the destruction and/or falling of the load.

D.3.4 Consequence (C)

This unwanted occurrence would take place above the stage surface, and in the event of failure, serious permanent injury to one or more persons, death to one person, or even death to several people could be expected, thus the consequence risk parameter is:

C_2

D.3.5 Frequency of, and exposure time in, the hazardous zone (F)

On the stage, people are often in the danger zone, thus the risk parameter is:

F_2

D.3.6 Possibility of avoiding the hazardous event (P)

It is nearly impossible to avoid this hazardous event due to the high speed, thus the risk parameter is:

P_2

D.3.7 Probability of the unwanted occurrence (W)

Because there is no reliable experience regarding this parameter, the parameter W_3 shall be assumed.

W_3

On the basis of the parameters C_2, F_2, P_2, W_3, SIL 3 is to be selected.

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3) Included in the *DITR Datenbase* maintained by *DIN Software GmbH*, obtainable from *Beuth Verlag GmbH*, 10772 Berlin