BS EN 13135:2013

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Cranes — Safety — Design — Requirements for equipment

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National foreword

This British Standard is the UK implementation of EN 13135:2013. It supersedes BS EN 13135-1:2003+A1:2010 and BS EN 13135-2:2004+A1:2010 which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MHE/3/1, Crane design.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Krane - Sicherheit - Konstruktion - Anforderungen an die Ausrüstungen

This European Standard was approved by CEN on 5 January 2013.

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Foreword

This document (EN 13135:2013) has been prepared by Technical Committee CEN/TC 147 “Cranes - Safety”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2013, and conflicting national standards shall be withdrawn at the latest by August 2013.

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

This document supersedes EN 13135-1:2003+A1:2010 and EN 13135-2:2004+A1:2010.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

Since the previous edition, major changes have been made in 5.2.8, 5.3.3.2, 5.3.3.5, 5.3.6.2, 5.6.2, 5.7.2, 5.9 and in Annex D, which deals with a new issue. There are several updates in standard references, and a number of clauses have been redrafted for reasons of clarity and technical and editorial accuracy.

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

Introduction

This European Standard is a type C standard as stated in EN ISO 12100.

This European Standard has been prepared to provide one means for equipment of cranes to conform with the essential health and safety requirements of the Machinery Directive.

The machinery concerned and the extent to which hazards, hazardous situations and events are covered are indicated in the scope of this document.

When provisions of this type C standard are different from those which are stated in type A or B standards, the provisions of this type C standard take precedence over the provisions of the other standards, for machines that have been designed and built according to the provisions of this type C standard.

1 Scope

This European Standard specifies requirements for the design and selection of electrical, mechanical, hydraulic and pneumatic equipment used in all types of cranes and their associated fixed load lifting attachments with the objectives of protecting personnel from hazards affecting their health and safety and of ensuring reliability of function.

NOTE Specific requirements for particular types of cranes, and for load lifting attachments, are given in the appropriate European Standard.

The electrical equipment covered by this European Standard commences at the point of connection of the supply to the crane (the crane supply switch) including systems for power supply and control feeders situated outside the crane, e.g. flexible cables, conductor wires or bars, electric motors and cableless controls.

The principles to be applied for cranes transporting hazardous loads are given in this standard. Particular requirements are given for cranes transporting hot molten metal.

The standard does not cover the detail design of individual items of equipment except with regard to their selection for specific aspects of use.

In general, the proof of competence calculations and related strength requirements or safety margins of equipment and components are not covered by this standard. These questions are covered in EN 13001 parts 1 and 2, and in the EN 13001-3 series that is partly under preparation (see Annex A). Exceptionally, some safety margins are given here for items not covered in EN 13001-series.

Hazards due to noise are not covered by this standard. They are addressed in safety standards specific to each type of crane.

The specific hazards due to potentially explosive atmospheres, ionising radiation, and operation in electromagnetic fields beyond the range of EN 61000-6-2 are not covered by this European Standard.

The significant hazards covered by this European Standard are identified in Clause 4.

This European Standard is not applicable to cranes, which are manufactured before the date of publication by CEN of this standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

EN 1037, *Safety of machinery — Prevention of unexpected start-up*

EN 1561, *Founding — Grey cast irons*

EN 12077-2, *Cranes safety — Requirements for health and safety — Part 2: Limiting and indicating devices*

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

EN 12644-2, *Cranes — Information for use and testing — Part 2: Marking*

EN 13001-1, *Cranes — General design — Part 1: General principles and requirements*

EN 13001-2, *Crane safety — General design — Part 2: Load actions*

EN 13001-3-1, *Cranes — General design — Part 3-1: Limit states and proof competence of steel structure*

CEN/TS 13001-3-2, *Cranes — General design — Part 3-2: Limit states and proof of competence of wire ropes in reeving systems*

CEN/TS 13001-3-5, *Cranes — General design — Part 3-5: Limit states and proof of competence of forged hooks*

EN 13155, *Cranes — Safety — Non-fixed load lifting attachments*

EN 13411-1, *Terminations for steel wire ropes — Safety — Part 1: Thimbles for steel wire rope slings*

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

EN 13411-4, *Terminations for steel wire ropes — Safety — Part 4: Metal and resin socketing*

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

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

EN 13557, *Cranes — Controls and control stations*

EN 60034-1:2010, *Rotating electrical machines — Part 1: Rating and performance*

EN 60204-11, *Safety of machinery — Electrical equipment of machines — Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

EN 60204-32:2008, *Safety of machinery — Electrical equipment of machines — Part 32: Requirements for hoisting machines*

EN ISO 4413, *Hydraulic fluid power — General rules and safety requirements for systems and their components (ISO 4413)*

EN ISO 4414, *Pneumatic fluid power — General rules and safety requirements for systems and their components (ISO 4414)*

EN ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction (ISO 12100:2010)*

EN ISO 13732-1, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 1: Hot surfaces (ISO 13732-1)*

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

EN ISO 13850, *Safety of machinery — Emergency stop — Principles for design (ISO 13850)*

IEC 60364-4-41, *Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock*

ISO 4306-1:2007, *Cranes — Vocabulary — Part 1: General*

ISO 4309, *Cranes — Wire ropes — Care and maintenance, inspection and discard*

ISO 4347, *Leaf chains, clevises and sheaves — Dimensions, measuring forces and tensile strengths*

ISO 6336-1, *Calculation of load capacity of spur and helical gears — Part 1: Basic principles, introduction and general influence factors*

ISO 6336-2, *Calculation of load capacity of spur and helical gears — Part 2: Calculation of surface durability (pitting)*

ISO 6336-3, *Calculation of load capacity of spur and helical gears — Part 3: Calculation of tooth bending strength*

ISO 6336-5, *Calculation of load capacity of spur and helical gears — Part 5: Strength and quality of materials*

ISO 10300-1, *Calculation of load capacity of bevel gears — Part 1: Introduction and general influence factors*

ISO 10300-2, *Calculation of load capacity of bevel gears — Part 2: Calculation of surface durability (pitting)*

ISO 10300-3, *Calculation of load capacity of bevel gears —- Part 3: Calculation of tooth root strength*

ISO 12482-1, *Cranes — Condition monitoring — Part 1: General*

ISO 12488-1, *Cranes — Tolerances for wheels and travel and traversing tracks — Part 1: General*

ISO/TR 14521, *Gears — Calculation of load capacity of wormgears*

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in EN ISO 12100:2010, ISO 4306-1:2007, EN 60204-32:2008 and the following apply.

3.1
backup brake
brake that is additional to the service brake that is able to stop and hold the load

Note 1 to entry: A backup brake can have fewer design cycles than the service brake.

Note 2 to entry: Such a brake is also known as emergency brake or safety brake.

3.2
backup limiter
limiter that is only activated if other (primary) limiting means fail to operate as intended

3.3
belt system
system for supporting and moving load or crane part via belt and wheel arrangement, comprising the belts and all the attachments and parts which are in contact with the belts

EXAMPLE Belt drive wheels, belts, belt reversing wheels, belt terminations and belt guides.

3.4
breakdown torque of an a.c. motor
maximum value of the steady-state asynchronous torque which the motor develops without an abrupt drop in speed, when the motor is supplied at the rated voltage and frequency

Note 1 to entry: In case of variable frequency drives, the breakdown torque can be defined in a similar manner for each combination of voltage and frequency.

[SOURCE: EN 60034-1:2010, 3.15]

3.5
chain system
system for supporting and moving load or crane part via chain and wheel arrangement, comprising the chains and all the attachments and parts which are in contact with the chains

EXAMPLE Chain drive wheels, chains, chain reversing wheels, chain terminations and chain guides.

3.6
compensating beam
beam to equalise forces at the ends of two ropes

Note 1 to entry: The amount of compensation is limited by the permitted movement of the beam.

3.7
compensating sheave
sheave which performs the function of compensating beam in a continuous rope system

Note 1 to entry: The amount of compensation is not limited by the movement of the sheave.

3.8
crane
machine for cyclic lifting, or cyclic lifting and moving, of loads suspended on hooks or other load lifting attachments

Note 1 to entry: "Suspension" can include additional means fitted to prevent swinging or rotation of the load.

3.9
hoisting mechanism
system for supporting and moving load or crane part against gravity, comprising all components from fixed load lifting attachment to the motor

3.10
load bearing chain
assembly of load bearing components

3.11
load bearing component
mechanical or structural component which is stressed by the hoist load

3.12
load hook
device attached to chain, rope, bottom block or lifting attachment from which the load, load handling devices or slings can be suspended

3.13
load suspension system
common term for belt, chain and rope systems employed to suspend a load

3.14
low-voltage electrical equipment
electrical equipment operating with voltages not exceeding 1 000 V a.c. or 1 500 V d.c.

3.15
maximum motor speed
maximum motor speed during operation between the rated speed and the mechanical limit speed

3.16
mechanical limit speed of the motor
speed above which the motor can suffer mechanical damage

3.17
multi-plate hook
load hook consisting of several plates

EXAMPLE Typically used for transporting hot molten substances.

3.18
rated capacity for lifting attachment
rated load for lifting attachment and maximum load that the lifting attachment is designed to lift

3.19
rated capacity
rated load
maximum **net load** that the crane is designed to lift for a given crane configuration, load location and operating condition

Note 1 to entry: For mobile cranes, replace **net load** in the definition by **hoist medium load**.

Note 2 to entry: For net load and hoist medium load, see ISO 4306-1.

3.20
rated speed of motor
speed corresponding to the rating of the motor used

Note 1 to entry: For variable speed drives, the following also applies: Maximum speed of the motor at which it is still able to supply its rated torque.

3.21
redundant
multiple arrangement of components and/or sub-assemblies arranged so that if one of the components or sub-assemblies fails, the function is still operational

Note 1 to entry: The function may be with limited performance.

3.22
rope anchorage
arrangement comprising the parts between the rope termination and the fixed load bearing structure

EXAMPLE Pins, bolts, compensating beams, tension rods.

3.23
rope sheave
wheel which supports the rope and can change the direction of the rope without change of the rope force, except minor losses due to the efficiency of the rope sheave system

3.24
rope system
system for supporting and moving load or crane part via rope and sheave arrangement, comprising the ropes and all the attachments and parts which are in contact with the ropes

EXAMPLE Wire ropes, sheaves, compensating sheaves, rope terminations and rope guides.

Note 1 to entry: Rope attachment on the drum is included but the rope drum itself is outside of this definition.

3.25
rope termination
equipment to connect the end of the rope to a rope anchorage

3.26
self-locking braking device
braking device whose braking effect is accomplished solely as a result of movement to be braked

3.27
single failure proof hoisting mechanism
hoisting mechanism comprising several parallel chains of components, arranged so that in case of failure of any single component in the total mechanism, the hoisted mass is not dropped

Note 1 to entry: After the failure, the mechanism is not necessarily functional as such.

3.28
single-plate hook
load hook made from a single steel plate

3.29
vertical movement
movement of hoist load or of a crane part, where the slope of the path of the moved mass is 5 % or steeper in relation to horizontal level

4 List of significant hazards

Table 1 contains all the significant hazards, hazardous situations and events, as far as they are dealt with in this standard, identified by risk assessment as significant for equipment within the scope of this standard, and which require action to eliminate or reduce the risk.

Requirements set for equipment included in this standard do not necessarily cover all hazards, which can occur due to installation of equipment into a crane. Such hazards should be evaluated and actions taken in the design of the crane.

Table 1 — List of hazards

No.	Type or group	Origin (sources)	Subclause of this standard
1	**Mechanical hazards**	Contact of a person with the crane or its moving parts	5.3.5.1; 5.4.2.1; 5.5.2.2; 5.5.2.3; 5.5.4.4.2; 5.5.5.5.1; 5.7.4; 5.7.8
		Contact of a person with a swaying or dropping load	5.3.4.4; 5.5.2.2; 5.6.1; 5.6.2; 5.7.8; 5.9.2.3
		Contact of a person with falling parts	5.4.2.1; 5.3.5.2
		Contact with moving transmission parts or other moving or rotating machine parts	5.3.6.1; 5.3.7.1; 5.3.8.1; 5.3.8.3; 5.5.2.2; 5.5.2.3
		Projection of high pressure fluids	5.5.1; 5.5.2.3; 5.5.4.4.2
		Sharp edges	5.3.6.6.1; 5.3.8.3;
		Rough or slippery surfaces	5.7.4; 5.7.7
		Contact of a person with bursting parts due to exceeding of kinetic energy	5.7.4
		Contact of a person with ejected objects	5.2.8.4; 5.5.2.3
		Loss of stability or overturning of crane	5.3.5.1; 5.4.2.3; 5.7.4; 5.7.5; 5.7.6; 5.7.7, 5.7.8
		Fitting together parts, which should not be fitted or fitting parts in a wrong order.	5.4.2.3
2	**Electrical hazards**	Contact of persons with live parts (direct contact)	5.2.1, 5.2.4
		Contact of persons with parts which have become live under faulty conditions (indirect contact)	5.2.1
		Contact of persons with electric arc	5.2.1
		Lightning	5.2.1
		Thermal radiation from molten particles and chemical effects from short-circuits, overloads, etc.	5.2.1; 5.5.4.5.2; 5.8.2; 5.9.3
3	**Thermal hazards**	Contact of objects or materials with a high or low temperature	5.5.5.5.2; 5.8.2.2; 5.8.2.3; 5.9.3.3.1
		Heat radiation, e.g. from hot molten substances	5.4.2.1; 5.9.1; 5.9.3.2.7; 5.9.3.3.1
5	**Vibration hazards**	Vibrations of the mechanisms and structures, causing: — whole body vibration, particularly when	5.2.1; 5.3.1; 5.4.1

		combined with poor postures — fatigue, loosening of connections or damage to electrical components, which may lead to further hazards	
6	**Radiation hazards**	External radiation	5.2.1
		Infrared, visible and ultraviolet light	5.8.1; 5.9.3.3.1
7	**Material and substances hazards**	Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes, and dusts or material of the crane	5.5.4.2
		Influence of harmful material of the ambient environment (or the load)	5.5.4.2; 5.9.3.3
		Fire or explosion in the operating area of the crane	5.5.4.4.2; 5.5.4.5.2; 5.9.3.3
8	**Ergonomic hazard**	Inadequate design, location or identification of manual controls	5.2.6; 5.5.1
9	**Hazards associated with the environment in which the machine is used**	Lightning, wind, snow, temperature, water	5.2.2; 5.5.4.1, 5.8.1; 5.8.2
10	**Unexpected start-up or uncontrolled movements**	Unexpected start-up of the crane due to a failure in the control system	5.2.1; 5.2.5; 5.5.1
		Uncontrolled movements of the crane due to a failure in the control system	5.2.1; 5.5.1
		Overspeed with load lowering (gravity)	5.2.3; 5.2.7; 5.2.8.4; 5.3.3; 5.5.4.5.1; 5.9.2
		Wind or a sloped track captures the crane	5.2.7; 5.2.8; 5.3.3.4; 5.7.4; 5.7.7
		Unexpected start-up or uncontrolled movement of the crane due to an error in the software	5.2.1; 5.7.1; 5.7.2; 5.7.4
		Unintended or unexpected use by a third person	5.2.1; 5.5.2.2; 5.5.2.3; 7
		Hazardous events following faulty adjustments made by the operator or a third person	5.2.1; 5.5.2.3; 7
		Leakage of pressurised fluid causes lowering of the load or the jib	5.5.4.3.1; 5.5.4.3.2; 5.5.5.5.3
		Hazardous movements due disconnection from the fluid power supply	5.5.2.2;
11	**Impossibility of stopping the**	A failure in stopping the crane, jib, trolley or hoist	5.2.8.2; 5.3.2; 5.3.3.5; 5.3.4; 5.5.2.1; 5.5.4.3.1; 5.5.5.2;

	machine in the best possible conditions	due to any failure in the crane (e.g. brake failure)	5.5.5.5.3; 5.9
		A failure of stopping the travel motion due to insufficient friction (e.g. oil on the runway)	5.2.8.2.3; 5.7.4; 5.7.7
12	**Failure of the power supply**	Dropping of the load or any object clamped by the crane	5.2.3; 5.3.3; 5.5.2.2; 5.5.4.3.1; 5.7.3
		Operator fails to move the crane because of an overall failure in power supply	5.2.3
13	**Failure of control circuit**	Operator fails to move the crane because of an overall failure in control circuit	5.2.1; 5.2.8
		Failure in emergency-stop circuit	5.2.1; 5.3.3.1; 5.3.3.2; 5.3.3.5; 5.5.2.1; 5.7.1; 5.7.2
		Failure in the overload or overspeed functions	5.2.8.4; 5.3.3.5; 5.5.2.1; 5.7.1; 5.7.2; 5.9.3.1
15	**Break-up during operation**	Dropping of the load due to a breakage of some component	5.2.8.4; 5.3.1; 5.3.2; 5.3.3; 5.3.4; 5.3.6; 5.3.7; 5.3.8; 5.3.9; 5.3.10; 5.4.1; 5.4.2.2; 5.5.3; 5.5.4; 5.5.5; 5.6.1; 5.6.2; 5.7.1; 5.7.2; 5.8.1; 5.9
		Dropping or ejection of any machine part	5.2.8.4; 5.3.5.2; 5.5.2.3; 5.7.8
		Failure to stop the crane, jib, trolley or hoist due to a breakage of some component	5.2.8; 5.3.3.1; 5.3.3.2; 5.3.3.4; 5.3.4; 5.7.1; 5.7.2; 5.7.4; 5.7.8; 5.8.1; 5.9.2.3
		Any hazard due to dropping of the crane or trolley from the track	5.3.5; 5.7.5; 5.7.7, 5.7.8
		Any hazard due to a failure of a limit switch or other protective devices	5.7.1; 5.7.2; 5.7.4; 7.3
		A whiplash hazard due failure of a hose assembly	5.5.4.4.2

5 Safety requirements and/or protective measures

5.1 General

Machinery shall conform to the safety requirements and/or protective measures of this clause. In addition, the machine shall be designed according to the principles of EN ISO 12100 for relevant but not significant hazards, which are not dealt with by this document.

5.2 Electrical equipment

5.2.1 General

The electrical equipment shall conform to EN 60204-32 as amended in this standard.

High voltage equipment (exceeding 1 000 V a.c. or 1 500 V d.c.) shall conform to EN 60204-11. All references to EN 60204-1 in EN 60204-11 shall be considered as references to the respective clauses in EN 60204-32:2008.

5.2.2 Physical environment and operating conditions

When the physical environment or the operating conditions are outside those specified in 4.4 of EN 60204-32:2008, the specification of the electrical equipment shall be amended accordingly.

Wind chill effects and solar heat gain shall be taken into account where appropriate.

5.2.3 Electrical supply

The electrical equipment shall be designed to operate correctly in the conditions specified in 4.3 of EN 60204-32:2008. Where the cabling distances would cause voltage drops in excess of those allowed under EN 60204-32, the selection of equipment shall be based on actual voltages.

When calculating the voltage drop, the most unfavourable position of the hoisting appliance in relation to its supply point shall be taken into account. The start-up (I_D) and rated (I_N) currents of the motors operating simultaneously shall be taken into account.

NOTE 1 The rated current (I_N) cannot necessarily be considered to mean the nameplate current of the motor but the current drawn by the motor at full rated load.

For squirrel-cage rotor motors I_D (start-up current), refer to the manufacturer's catalogue. In case the motor is controlled by an electronic drive (soft-starter, frequency converter etc), the maximum current occurring during any phase of operation should be considered as start-up current, although the highest current does not necessarily occur when starting the motion.

NOTE 2 With direct starting of squirrel cage motors, I_D is typically five to ten times I_N. For slip-ring motors, I_D is typically two times I_N. With electronic drives, the start-up current depends on the converter type and on its adjustments; with frequency converters in hoisting motions I_D is typically below two times I_N.

Where the crane-supply-switch is not readily accessible on the access way to the crane, the crane-disconnector and disconnectors for special circuits shall be capable of breaking the short circuit current of the associated circuits.

5.2.4 Protection against electric shock by direct contact

For each circuit or part of the electrical equipment, protection against electric shock by direct contact shall, whenever practicable, be provided by enclosures or insulation of live parts in accordance with EN 60204-32.

Where these measures are not practicable,

- protection by barriers according to IEC 60364-4-41, is acceptable in electrical operating areas and enclosed electrical operating areas;
- protection by placing out of reach in accordance with EN 60204-32 is acceptable only in the case of conductor bars and conductor wires.

5.2.5 Control circuits and control functions

Where means for temporary suspension of safeguarding (see EN 60204-32:2008, 9.2.4) is provided,

- the device for suspending shall be located inside an enclosure, access to which, requires special tools, or
- other means, not available for normal operation, e.g. a key-operated switch or password protection, shall be provided.

Suspension of safeguarding shall also limit the performance of the machine or have other means (e.g. automatic restoration of the safeguarding after power-off or a time delay) to avoid prolonged suspension.

Push-buttons and similar control devices that alternately initiate and stop an action, shall not be used for motion drives.

Cableless controls and control functions shall be in accordance with 9.2.7 of EN 60204-32:2008.

5.2.6 Operator interface and mounted control devices

The function of each control actuator shall be indicated on or adjacent to it.

The recommended colours of push-buttons are as follows:

Start/On	Green
Stop/Off	Black
Hold to Run	White
Reset	Blue
The stop button of a cableless control station	Red
Other functions	Yellow or grey

5.2.7 Power driven motions

All powered motions shall be power driven at all times during normal operation.

5.2.8 Selection of motors

5.2.8.1 General

Motors for a crane motion shall be designed such that the motors have enough capacity:

- to perform the specified, consecutive working cycles without overheating;
- to start the motion with a specified acceleration;
- to maintain the specified speed of the motion.

Decisive duty features for sizing of crane motors are short-term factors such as the starting period of the motion or a single work cycle. Consequently, the basic crane duty parameters of EN 13001-1 – the hoist load spectrum and total number of work cycles – are not relevant for sizing the motor as an electrical component. The average distance per work cycle of each motion (see EN 13001-1) shall be taken into account, when determining an appropriate rating type of the motor duty and thermal power rating requirement.

The following, related factors shall be taken into account together with the motor itself:

- features of the electrical drive system (rated current and voltage with resulting motor torque characteristics, speed regulation and type of braking);
- cyclic duration factor of the specified duty;
- number of cycles/hour;

- type of power feed;
- degree of protection (environment conditions);
- ambient temperature in the motor location;
- altitude of the operating site.

5.2.8.2 Loadings

5.2.8.2.1 General

The loads to be applied in 5.2.8.5 to 5.2.8.7 shall be in accordance with EN 13001-2, setting all the dynamic factors $\phi_i = 1$ and the partial safety factors $\gamma_p = 1$. The hoisted load shall be applied with the value of the rated load, unless otherwise specified. The wind state for an outdoor crane shall be that specified for the crane and applied in calculation of wind forces in accordance with EN 13001-2. Travel resistance shall be taken into account as an external load action.

In transforming the load actions to a motor torque, the internal efficiency (friction) of the mechanical system shall be taken into account.

For the thermal capacity calculation in 5.2.8.7, the load combinations A of EN 13001-2 shall be applied, with the addition of in-service wind force during controlled movement (see EN 13001-2) into each load combination.

For the torque calculations in 5.2.8.5 and 5.2.8.6, the load combinations B of EN 13001-2 shall be applied, applying the in-service wind force required for starting drive forces (see EN 13001-2).

5.2.8.2.2 Travel resistance

The total travel resistance due to rolling resistance and bearing friction in cases, where a wheel is running on a flat surface, shall be calculated by multiplying the wheel force perpendicular to the running surface by a rolling friction factor.

Values given in the Table 2 should be used as guidance for the rolling friction factors for a steel wheel equipped with roller bearings.

Table 2 — Rolling friction factors for steel-steel contact

Wheel construction	**Wheel diameter D_w [mm]**								
	50	**80**	**100**	**125**	**160**	**250**	**320**	**400**	**630 and larger**
Flanged wheels	0,013	0,011	0,01	0,009	0,008	0,006 5	0,006	0,005 5	0,005
Flangeless wheels	0,011	0,009 5	0,008 5	0,007 5	0,007	0,005 5	0,005 2	0,005	0,004 5

Note 1 Friction factors for intermediate values of D_w may be derived by interpolation.

Note 2 Wheel diameters less than 50 mm are not dealt with.

5.2.8.2.3 Wheel friction

The friction factor for a rail/wheel contact to calculate the traction and braking capacity of a drive mechanism shall be determined, taking into account the ambient conditions and the provisions for cleaning of the rail. Values given in the Table 3 should be used as guidance.

Table 3 — Friction factors

Wheel type	**Steel wheels and steel rails**				**Rubber tyres**
Rail condition	Indoor crane, clean environment	Indoor crane, contaminated environment	Outdoor crane, rail clean of ice, oil, loose dirt etc.	Outdoor crane, contaminated environment	Prepared ground surfaces
Friction factor	0,18	0,14	0,14	0,1	0,20

5.2.8.3 Multiple motors for a motion

In cases where two or more motors drive the same motion, the following shall be considered:

- synchronisation of the mechanisms, if required due to the needs of the application;
- division of external load actions to the motors, taking into account properties and geometric proportions of the mechanical configuration;
- effect on motors, limiting their capabilities to develop torque, e.g. due to slippage of driven wheels or due to current limit of a single or multiple drive system(s) supplying the motors.

5.2.8.4 Mechanical strength

The proof of mechanical strength of the motor components shall be done in accordance with the general principles specified for mechanical components. The rated load shall only be applied in the calculations, without consideration to variation of actual hoisted loads. Dynamic impacts in motor torque, e.g. due to change of direction of the torque, shall be taken into account.

Mechanical strength of the motor shafts and shaft gears, which are subject to metal fatigue under cyclic loading due to motor rotation, shall be designed for a fatigue limit under maximum torque.

The bearing housings of hoist motors shall be designed such that in case of failure of rolling elements of a bearing, the capability to hold the torque is not lost.

A motor and its possible overspeed protection shall be selected so that the maximum safe operating speed (see EN 60034-1:2010, 9.6) of the motor will not be exceeded under any foreseen conditions.

5.2.8.5 Torque requirement for vertical movements

5.2.8.5.1 General

In addition to primary hoisting of the load, this clause shall also be applied to combined vertical and horizontal movement of hoist load or dead weight of a crane part, where the slope of the path of the moved mass is 5 % or steeper in relation to horizontal level.

5.2.8.5.2 Determination of required torque

The maximum torque at the motor shaft (M_{max}) shall be calculated by transforming the external load actions determined in 5.2.8.2 to a torque at the motor shaft, applying the maximum values of load actions. The load action due to acceleration of the motion may be omitted. The configuration of the mechanical transmission and efficiency (friction) of the transmission shall be taken into account.

In order to be able to develop the necessary torque for lifting the rated load, for compensating for variations in the mains voltage and frequency and for compensating for variations in the motor characteristics, the torque developed by the motor shall satisfy the following condition:

$$M_D / M_{\max} \geq k_V \tag{1}$$

where

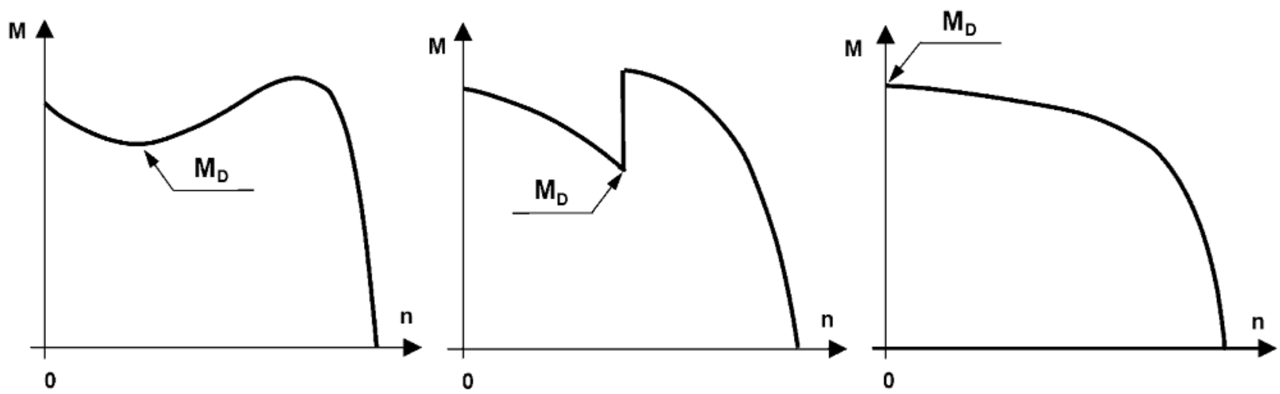
M_D is the design motor torque taken as the minimum torque developed by the motor and the drive system together during the starting period of the motion; see the Figure 1. The combined behaviour of the drive system and the motor shall be taken into account, when determining the torque.

For inverter drives with squirrel cage motors, M_D may be based upon the break-down torque (pull-out torque) of a motor, taking into account the characteristics of the drive system.

M_{max} is the maximum torque at the motor shaft resisting the movement;

k_V is the required safety factor in accordance with the Table 4.

Where the drive system characteristics vary by the value of hoisted loads (e.g. smaller loads at higher speeds with field weakening systems), the proof of the motor torque requirement shall be done, in addition to the rated load, also with any other hoisted load/motor torque combination, which is relevant to the safety and performance of hoist drive. In such cases, the torques M_D and M_{max} in Formula (1) shall be taken as those relevant for these special conditions.



Key

M motor torque

M_D design motor torque

n rotation speed of the motor

Figure 1 — Determination of torque M_D for different types of torque curves

Table 4 — Safety factors k_V for vertical motions

Type of motor and drive	Squirrel cage motors with direct starting and drive	Slip ring motors	DC motors and drives	Squirrel cage motors with inverter drives
Safety factor k_V	1,6	1,5	1,3	1,3

5.2.8.6 Torque requirement for horizontal motions

5.2.8.6.1 General

This clause shall be applied in cases, where the slope of the path of the moved mass is less than 5 % in relation to horizontal level. In general, the clause covers trolley traversing, crane travelling, slewing and level luffing movements.

The maximum external load actions - including the acceleration of the movement - with the magnitude they resist the motion shall be transformed to a torque at the motor shaft, taking into account the configuration of the mechanical transmission and efficiency (friction) of the transmission.

For movements driven through friction between driving wheels and a runway, the values of individual wheel loads and the limitation of transmissible torque due to friction shall be taken into account.

5.2.8.6.2 Determination of required torque

Account shall be taken of the sum of forces resisting the movement resulting from the dead weight, the hoisted load and operating conditions such as:

- deformation of the running surface;
- friction of the wheels on straight sections and in curves;
- wind forces;
- gradients in the track;
- necessary force to move the power supply system.

In order to guarantee the starting of the motion to the intended direction, at a reasonable acceleration and under specified wind conditions, the sum torque developed by the motors shall satisfy the conditions of Formulae (2) and (3).

For reaching the specified acceleration in average wind conditions, the drive system shall satisfy the requirement of the Formula (2).

$$\frac{M_D}{M_{tr} + M_{acc} + M_{w1} + M_{inc}} \geq k_H \qquad (2)$$

For reaching a reasonable acceleration in the maximum wind conditions, the drive system shall satisfy the requirement of the Formula (3).

$$\frac{M_D}{M_{tr} + 0{,}5 \times M_{acc} + M_{w2} + M_{inc}} \geq k_H \qquad (3)$$

where in Formulae (2) and (3)

M_D is the sum of the design motor torques, taken as the minimum torque developed by the motor and the drive system together during the starting period of the motion; see Figure 1. The combined behaviour of the drive system and the motor shall be taken into account, when determining the torques.

M_{tr} is the torque at the motor shaft due travel resistance;

M_{acc} is the torque at the motor shaft due to acceleration. Inertia of each component in the system, including the rotating parts of the motor, shall be taken into account.

NOTE In cases where the acceleration is not specified, acceleration time of 5 s is used in calculation of M_{acc}.

M_{w1} is the torque at the motor shaft due to wind force during controlled movement; see EN 13001-2;

M_{w2} is the torque at the motor shaft due to wind force required for starting drive forces; see EN 13001-2;

M_{inc} is the torque at the motor shaft due to inclination of the path of moved masses;

k_H is the safety factor for horizontal motions; k_H = 1,1 for all types of drive systems.

5.2.8.7 Thermal capacity requirement

5.2.8.7.1 Cyclic duration factor

Intensity of the motor duty is described through a cyclic duration factor ED. It is specified for a periodic, intermittent motor duty and for a period of no longer than 10 min. The factor is calculated as follows:

$$ED = 100 \times \frac{t_R}{t_R + t_O} \tag{4}$$

where

ED is cyclic duration factor, in %;

t_R is the running time of the motor within a 10 min period;

t_O is the idle time of the motor within a 10 min period.

The factor is used for thermal power rating of motors in S3-type intermittent duty.

5.2.8.7.2 Mean equivalent torque and power

The mean equivalent power is a power comparable to the thermal capacity of a motor. The power is derived through motor torques due to external loadings. The mean equivalent torque shall be determined as a function of the affecting torques during the working cycles.

When arranging a work cycle into different phases such as acceleration, deceleration and steady movement, the number of which is n, the mean equivalent torque shall be calculated using the following formula:

$$M_{med} = \sqrt{\frac{M_1^2 * t_1 + M_2^2 * t_2 + ... + M_n^2 * t_n}{t_1 + t_2 + ... + t_n}} \tag{5}$$

where

M_{med} is the mean equivalent torque;

M_1, M_2, M_n are the motor torques affecting in different phases of a work cycle. All relevant load actions described in the above clauses shall be taken into account, including acceleration and wind force during controlled movement;

$t_1, t_2, .t_n$ are the duration times of the torques affecting at the motor shaft within a work cycle; idle times, when both the motor speed and torque are zero, are not taken into account.

If the crane can perform several work cycles in a 10 min period, a variety of hoist loads may be taken into account so that the mean equivalent torque is calculated over a total period of approximately 10 min.

If an average work cycle takes 10 min or longer – including the idle times - the torques shall be calculated applying the rated load only, without consideration of variety in magnitude of loads.

For the calculation of the torques in Formula (5), the true characteristics of work cycles shall be taken into account with consideration of the following:

- loaded and return phases of a work cycle;
- lifting and lowering of the load;
- acceleration and deceleration loadings;
- mechanical efficiency, both increasing and decreasing the motor torque;
- wind loading in accordance with 5.2.8.2.1, both head wind and tail wind.

The mean equivalent power shall be calculated using the formula:

$$P_{med} = M_{med} \times \omega = M_{med} \times \frac{2 \cdot \pi \cdot n}{60} \qquad (6)$$

where

M_{med} is the mean equivalent torque, [Nm]

ω is the nominal angular speed of motor, [1/s]

n is the nominal rotational speed of motor given in rotations/min.

5.2.8.7.3 Motor power requirement in general

With the exception of 5.2.8.7.4, the thermal power rating of the motor shall meet the following requirement:

$$k \times P_{mot} \geq P_{med} \qquad (7)$$

where

P_{med} is the mean equivalent power calculated for the specified work cycles;

P_{mot} is the rated power of the motor in a standardized duty class S1, S2 or S3, applicable for the work cycles used in calculating M_{med} and P_{med}; in general specified for ambient temperature 40 °C and altitude 1 000 m above sea level;

k is the power correction factor to take into account decreased cooling speed of motors in high ambient temperatures and high altitudes. In cases where no other data is available, k shall be taken in accordance with 5.2.8.7.6. The motor manufacturer may specify the motor rated power for any specific ambient temperature and altitude, in which cases this power shall be used as P_{mot} with k = 1. In all cases it shall apply that k ≤ 1.

P_{mot} may be taken in accordance with S3-duty in cases where the motion is intermittent and repeated in periods of 10 min or shorter during an average work cycle. The power P_{mot} shall be that related to a cyclic duration factor ED fitting closest to the actual, average work cycle.

P_{mot} may be taken in accordance with S2-duty in cases where the motion is continuous for a considerable period of time, typically up to 1 h, and in between the work cycles the motion is in rest for a long period of time, for a minimum of several hours.

P_{mot} may be taken in accordance with S1-duty for any type of use, except what is given in 5.2.8.7.4.

5.2.8.7.4 S1-rated squirrel cage motors with direct starting

For calculation of thermal capacity of S1-rated squirrel cage motors with direct starting and in intermittent duty, high starting currents and consequent thermal impact shall be taken into consideration.

5.2.8.7.5 Motor requirements in driving to stowage position

In out-door cranes, which have only a limited number of stowage positions, the travelling drive system shall be capable of moving the crane from any working position to the nearest available stowage position. The following requirements in selection of motors apply:

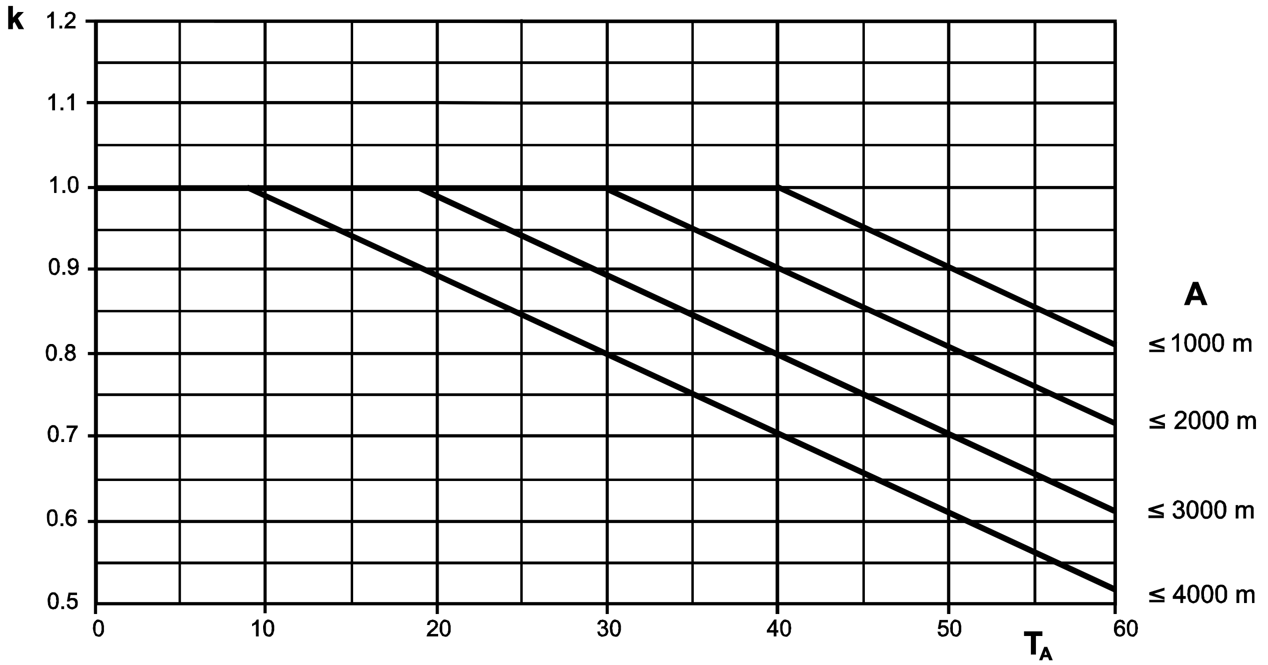
— the safety factor used with the Formula (3) is k_H = 1,3;

— the wind load applied with the Formula (3) is the in-service wind force required for starting drive forces;

— the motor power rating for Formula (6) shall be taken in accordance with S2-duty and duration comparable with the travelling time to the stowage position.

5.2.8.7.6 Power correction for ambient temperature and altitude

For the motor selection, the rated power of the motor P_{mot} shall be corrected as a function of altitude if this exceeds 1 000 m and the ambient temperature if this exceeds 40 °C. The correction factor k shall be taken from the Figure 2, unless other values are specified by the motor manufacturer.



Key

T_A ambient temperature (° C)

k power correction factor

A altitude above sea level

Figure 2 — Power correction factor k as function of ambient temperature and altitude

NOTE Figure 2 is based upon EN 60034-1 with motor insulation class F and integrated cooling in the motor. For other insulation and cooling arrangements, an applicable value can be received from the motor manufacturer.

5.2.8.7.7 Power conversion for low ED-factors in S3-duty

For intermittent duty of type S3 in cases where the thermal power of a motor is not given below ED-factor 40 %, the thermal motor power greater than those in Table 5 for lower ED-factors shall not be used for design.

Table 5 — Power conversion for low ED-factors

ED-factor	40 %	25 %	15 %	10 %
Thermal power, S3 duty	P_{40}	1,10 × P_{40}	1,16 × P_{40}	1,20 × P_{40}

5.3 Mechanical equipment

5.3.1 General

The following basic principles shall apply in the design of mechanism or selecting the components of the mechanisms:

— The rated characteristics of the components shall conform to the corresponding applicable loading conditions in terms of maximum loading, load spectrum and number of load cycles; test loads of cranes shall be taken into account as an exceptional loading.

  The component should bear information on design and usage parameters of the component, so that the crane manufacturer is able to choose the component with appropriate safety margins to loads and lifetime. Information on presentation of such parameters is given in informative Annex D.

— Deformation of structures due to loads and thermal expansion shall not introduce stresses in mechanisms or they shall be taken into account in design.

— Mechanisms and components shall be accessible for inspection, adjustment, maintenance and dismantling for repair.

— Vibrations of the mechanisms shall be limited so that they do not cause excess amount of discomfort for the crane driver, mal-operation of the functioning of the equipment or reduction in the life of the components; see e.g. ISO 1940-1.

5.3.2 Clutches and couplings

The type of clutch/coupling shall be selected on the basis of the general design of the driving mechanism and its operation.

The rated torque of the clutch/coupling, at the specified operating conditions, shall be greater than the maximum static torque on the shaft of the clutch/coupling.

The maximum permissible torque of the clutch/coupling, at the specified operating conditions, shall be greater than the peak torque occurring during operation, taking into account the peak frequency and the permissible wear.

Where elastic elements are used in couplings to transmit the torque, e.g. to dampen impacts or to compensate geometric differences, the system shall be so designed that the force flow is retained in case of a failure of such elements.

5.3.3 Brakes

5.3.3.1 General

The brakes shall be capable of bringing a fully loaded crane to rest, without excessive shock, from the highest speed it can attain.

Services brakes shall be such that it is not possible to affect the braking effect without the use of a tool.

Service brakes shall engage automatically in the following cases:

— the control device returns to its neutral position; the brakes may be engaged with delay, if the drive system brings the movement into stop;

— the power supply to the brake or associated motor is interrupted;

— the emergency stop is activated; in emergency stop category 0 the brakes shall engage immediately, in category 1 after electric braking has brought the motion into stop;

— the stop function of cableless control is activated;

— the safety related control system has initiated a stop function.

NOTE In a hydraulic system, this requirement is fulfilled, for example, by devices which prevent the motion from moving.

Where multiple service brakes are used in connection with a single drive motion, the application of any single brake shall activate all brakes.

In the case of 3-phase supply, brakes shall engage automatically when two phases of the power supply of the associated drive motion are interrupted.

In case of the failure of one phase, the system shall ensure that the load will not drop and other motions can be stopped by using the brakes or other means.

EXAMPLE Service brakes may be for example:

- frictional mechanical brake with brake linings;
- mechanical braking by self locking gears, such as worm gears;
- hydraulic braking system by braking valve;
- pneumatic braking system by braking valve.

5.3.3.2 Service brakes

Service brakes shall be of the frictional mechanical type or hydraulic/pneumatic locking type and shall be power released unless specified otherwise in the product standards.

The brakes shall maintain their ability to stop the motion, at all times, taking into account:

- the number of braking operations in a given period based on crane duty and type of operation, e.g. for determination of heating and heat dissipation under successive brake cycles;
- the type of drive control;
- the braking after interruption of power to the drive motor, e.g. due to activation of emergency stop;
- the kinetic energy of all rotating and linearly moving masses;
- the difference of potential energy of the lowered masses during braking;
- the load for dynamic tests;
- the action of maximum in-service wind from any direction.

With spring-loaded brakes, brake springs shall be compression springs and shall be guided.

If the braking force is applied by pre-stressed springs, the failure of any spring in the brake shall not reduce the available torque by more than 20 %.

If less than five springs are used, they shall be dimensioned such that the wire diameter is greater than half the coil pitch in the working condition to prevent screwing in of the two spring parts in the event of a wire break.

Brake linings shall be made of asbestos free material.

Bonding or riveting of brake linings shall take account of the heating and wear of the lining under all working conditions.

The coefficient of friction and other properties of the lining shall be suitable for the purpose during normal operation taking into account atmospheric conditions, temperature variations and the maximal peripheral speed at the friction surface.

Where the brakes are exposed to ingress of oil, grease and environmental conditions, which are likely to have a detrimental effect on the performance of the brake, the brakes shall be protected.

It shall be possible to check the wear of the brake lining(s) and to re-adjust the brake without the need to dismantle the brake. To ensure safe operation of the brake between such checks or maintenance periods, either sufficient torque reserve or a self-compensating system shall be provided.

Brakes shall be such that the user cannot adjust the preset braking effort without using a tool.

NOTE Where electrical braking systems are used, the associated mechanical brake is only subjected to limited use. Special attention therefore may be needed to maintain the required mechanical braking torque; see 7.3.

Fatigue design of the mechanical parts of the brake shall be based on the maximum torque setting of the brake and the number of brake cycles (on-off cycles), which is taken as a multiple of the specified number of work cycles for the crane. A number of brake cycles of 2 000 000 shall be used for fatigue design of mechanical parts of the brake unless a lower value is specified. See also Annex D.

Typically, the number of brake cycles is between four and eight times the number of work cycles of the crane. Other values may be used for a particular application, where justified by measurements.

5.3.3.3 Brakes for vertical movements

In addition to 5.3.3.2, the brakes shall be designed:

- to exert a restraining torque of at least 60 % greater than the maximum torque transmitted to the brake from regular loads in accordance with EN13001-2 with all dynamic factors ϕ_i and partial safety factors γ_p set to 1;

- to ensure the reaction time of the braking is such that it does not allow the load to accelerate to a lowering speed greater than 1,5 times the rated lowering speed, unless otherwise specified in the product standards.

  NOTE The specified speed limit 150 % is the final speed resulting from the triggering and braking sequence, considering all the response delays in the system.

In some applications, the brakes for hoisting may require a manual release facility, which allows the load to be brought to a safe position in a controlled manner or can be used to prevent tightening of hoist ropes in case of a jammed load. This release facility shall be such that it can only be operated by special equipment or tools which require active operation at all times. The instruction handbook shall provide information on the safe use of such equipment.

5.3.3.4 Brakes for horizontal movements

Brakes shall be designed so that they are capable of stopping the movement from its maximum speed with maximum specified slope of the crane support, maximum in-service wind speed and load. Braking distance shall not be longer than acceleration distance from start to maximum speed.

The brakes together with the rolling resistance and without assistance of powered braking:

- shall create a braking force that is 25 % higher than the drifting force due to maximum in-service wind;

- shall have the heat capacity to absorb the energy when stopping the travel motion from maximum speed in maximum in-service tail wind.

For movements due to friction between driving wheels and a runway, the values of individual wheel loads and the limitation of transmissible force due to friction shall be taken into account. The friction coefficient shall be taken in accordance with the Table 3.

The in-service wind drifting force shall be calculated applying the in-service wind force required for Starting Drive Forces in accordance with EN 13001-2.

Brakes of the self-locking type shall only be used as parking brakes.

5.3.3.5 Backup brakes for vertical movements

Where used, the backup brake shall be capable of stopping the hoisted masses falling from the speed reached after the failure of the first brake or of parts of the load bearing chain between the backup brake and the drive motor.

Backup braking shall be initiated immediately following a failure within the service brake system or within the load bearing chain which would result in descent of the load in an uncontrolled manner. In the case of an emergency stop, the backup brake shall be applied with a delay that allows the service braking system to bring the hoist movement to a stop, unless the repeated backup braking function has been taken into account in its design. When backup braking has been initiated in response to a system failure, its reset shall only be possible by using special means.

Generally, in the rope hoisting mechanisms, the backup brake shall be located on the rope drum, or in chain hoisting mechanisms on the sprocket drive shaft.

5.3.4 Gear drives

5.3.4.1 General

The type of connection between the driving and driven mechanisms shall be such that no impermissible and uncontrolled stresses or deformations are produced in the gears or bearings.

Where a self locking condition of a gear can occur, the dynamic shock-forces generated by this condition shall be taken into account in the design of the drive mechanism.

EXAMPLE This condition can occur for example with worm gears:

- at a high gear ratio, or
- at high ratio of driven masses at the output shaft of the gear versus rotating masses at the input shaft of the gear.

Gears and bearings shall be provided with lubrication that maintains the designed working conditions of these components.

When selecting the type of rolling bearings, the temperature limits of the bearings shall be taken into account.

Where drain plugs, breathers or oil level indicators with upper and lower limits are provided, they shall be easily accessible.

5.3.4.2 Gears

The proof of static and fatigue strength for cylindrical (i.e. spur and helical) gears shall be in accordance with ISO 6336:

- basic principles, introduction and general influence factors ISO 6336-1;
- calculation of surface durability (pitting) ISO 6336-2;
- calculation of tooth bending strength ISO 6336-3;
- strength and quality of materials ISO 6336-5.

The proof of static and fatigue strength for bevel gears shall be in accordance with ISO 10300:

- introduction and general influence factors ISO 10300-1;

- calculation of surface durability (pitting) ISO 10300-2;
- calculation of tooth root strength ISO 10300-3.

The proof of static and fatigue strength for worm gears shall be demonstrated using ISO/TR 14521.

5.3.4.3 Gear housing

The housing of the gear box shall have sufficient rigidity to ensure that the gear shaft alignments and centre distances are maintained under all working conditions and shall be supported on the structure and/or connected to the driving and driven mechanisms in such a way that no impermissible stresses or deformations are produced in the shafts, gears or bearings.

Regardless of the type of gear housing (cast or welded), measures shall be taken to ensure that residual stresses causing impermissible deformations have been eliminated.

5.3.4.4 Means preventing load drop during disconnection of drive torque

For certain applications, (e.g. hoist speed change by means of stage gear), it may be required to disconnect the motor shaft from the gear under load. This shall only be possible if the shaft on the load side has been locked.

5.3.5 Wheels on rails

5.3.5.1 Travel wheels

Wheels on rails shall incorporate features to prevent unintentional derailment if derailment is not prevented by other means. This requirement can be fulfilled by use of guiding devices such as guide rollers and/or wheel flanges.

Alignment of wheels on rails shall be in accordance with ISO 12488-1.

The height and thickness of a wheel flange shall be such that the flange can resist the horizontally acting wheel forces, with the specified wear limits taken into account.

NOTE Guidance on the nominal dimensions of wheels, when taken into use, is given in Annex B.

In order to prevent hazards when changing the wheels, the crane shall be fitted with jacking or slinging points or other arrangements made to support the crane during this operation.

5.3.5.2 Guide rollers

Measures shall be taken to prevent hazards resulting from falling components in the event of failure of a guide roller. This is achieved, for example, by selecting suitable materials and sufficiently dimensioning the components, taking into consideration the use for which they are intended.

The guide rollers of overhead travel or traverse drives shall be designed with additional load factor γ_s = 1,5 in relation to the load bearing capacity of the bearings (static and dynamic) or guarded so that falling of the roller is prevented in case of a failure.

Guide roller alignment shall be in accordance with ISO 12488-1.

5.3.6 Rope systems

5.3.6.1 General

In working and traffic areas to which personnel have unlimited access, the components of the rope systems and rope run-on points shall be installed or guarded in such a way that crane operations can be conducted with a minimised risk of trapping or drawing-in of hands or arms into jamming-prone areas.

The safety, operation and lifetime of the rope system components are strongly influenced by specific characteristics and properties of the system. Practical guidelines for choosing suitable parameters are provided in Annex C.

5.3.6.2 Rope drums

The thickness of the drum shell shall be determined by proof of competence calculation or by tests. If not covered by calculation or tests, a wear allowance shall be added to the drum thickness. The wear allowance shall take into account factors such as material hardness, environment and intended service conditions.

For maximum rope life, the drum should hold the rope in a single layer. In cases where a single layer is not possible due to space restrictions, provision shall be made for multi-layer coiling, ensuring correct coiling of the rope from each layer to the next and correct coiling for any rope position, if necessary with the aid of guides.

Rope drums shall be grooved or correct spooling of the rope on the drum ensured by other means. Grooving shall be smooth and free from surface defects liable to damage the rope and the edges shall be rounded. The groove shape, depth and pitch shall provide sufficient coiling, laying and clearance between adjacent rope turns on the drum, taking into account the rope tolerance, rope fleet angles and dynamic behaviour of the rope system and its suspension.

The drum shall be designed such that at an extreme operating position, a length of unclamped rope equivalent to at least two drum revolutions remains on the drum.

At an extreme operating position with maximum rope wound on the drum, the last (outermost) layer of rope shall have at least one empty revolution per layer of rope to compensate the effects of:

— the lengthening of the rope in service during the maintenance interval;

— displacement of the setting point of the limiter at the extreme operating position;

— the readjusting of the limiter for the minimum operating position as a result of lengthening of the rope.

Rope drums shall incorporate features that prevent the rope from coming off the end of the drum. Suitable measures are e.g. flanges or rope guides with end limiters.

Multi-layer drums shall be provided with a guide at each point where the rope enters the next layer.

When multi-layer coiling has to be used, it should be realised that after the first layer is coiled onto a drum, the rope has to cross the underlying rope in order to advance across the drum in the second layer. The points at which the turns in the upper layer cross those in the lower layer are known as the cross-over points, and the rope in those areas is susceptible to increased abrasion and crushing.

The flanges and other side limitations shall be flat and extend not less than 1,5 times the rope diameter beyond the outmost rope layer, measured from the outside of the rope.

The specified running direction of the rope onto the drum shall be clearly recognisable; if necessary, it shall be marked.

5.3.6.3 Ropes

Ropes shall be selected for the particular application and be made of suitable materials so that they withstand the design forces for the design life of the rope.

Account shall be taken of the operating environment and where necessary greasing, galvanising or special rope materials shall be considered.

When selecting ropes, the temperature limit of the rope shall be taken into account. In the case of steady-state temperatures exceeding 100 °C, ropes shall have cores of steel or other heat-resisting material.

Steel wire ropes for rope systems shall conform to EN 12385-4.

Ropes manufactured from material other than steel shall only be used if the wear conditions are known and the discard criteria are recognisable. The following safety requirements connected to the specific application shall be considered:

- fatigue;
- environment;
- structure of rope;
- terminations;
- elasticity and plasticity of the rope;
- rope drum;
- sheaves;
- guides/rope runs;
- fastening;
- anchorage.

Rope systems shall be designed in such a way that the inspections specified in ISO 4309 can be carried out over the whole length of the rope. The inspection interval specified by the manufacturer shall be related to the design life of the rope.

If deterioration of the rope is likely to advance at a greater rate internally than externally, such as would be expected when polymer sheaves are used exclusively in conjunction with single-layer spooling, the particular discard criteria and/or any additional inspection/testing method(s) shall be specified by the crane manufacturer in the instructions for use.

NOTE ISO 4309 does not include discard criteria for those crane ropes that run exclusively through polymer sheaves and spool on and off the drum in a single layer.

In the case of a load suspended by a single-fall rope system and not guided, rotation resistant ropes shall be used.

Where the rope is wound in several layers, the rope shall have a steel core.

5.3.6.4 Rope sheaves

Rope sheaves shall have protection against the ropes jumping out of the grooves (e.g. in the case of a slack rope). The distance between the edge of the sheaves and the protective means shall not exceed 1/3 of the rope diameter or 8 mm, whichever value is the smaller.

In case of a sheave failure, the rope shall not become detached from the sheaves suspension, even with cantilevered arrangements.

The strength of sheaves shall be determined by proof of competence calculation or by tests. The running surfaces for the rope shall be smooth and free from surface defects liable to damage the rope and the edges shall be rounded.

The groove shape, flange opening and depth shall provide sufficient laying of the rope taking into account the rope tolerance, rope fleet angles and dynamic behaviour of the rope system that the rope cannot come into contact with the edge of the groove section.

Where a rope sheave consists of more than one piece, the pieces shall have a positive engagement.

5.3.6.5 Rope guides and runs

Means shall be provided to avoid rope damage due to the rope moving out of its intended position on the drum.

Rope systems shall be arranged so that the ropes do not become damaged through contact with each other or with other crane parts.

Where the sheave is not in the vertical plane it shall be ensured that the rope contact will remain in the bottom of the sheave groove.

5.3.6.6 Rope terminations and fittings

5.3.6.6.1 General

The rope ends shall be such that the structural weave of the rope is maintained.

5.3.6.6.2 Rope fastening on drums

The fastening elements of the fixing point of the rope shall be selected, taking into account the rope and drum contours. The rope shall not be bent or compressed over sharp edges. The rope fastening shall not become detached even when the tension in the rope is zero.

The fixing point of the rope shall be accessible for maintenance and replacement of the rope.

Where two or more ropes lead from a drum to a single moving part, provision shall be made to accommodate unequal lengths of ropes.

Rope fastening on the drum together with at least two frictional revolutions of the rope shall be capable of withstanding not less than 2,5 times the maximum static force in the rope. In the verification calculation, the coefficient of the friction between the rope and the drum shall not be assumed greater than 0,1.

Where the rope fastening relies on the friction from two rope revolutions and clamping action, two or more clamps shall be used and shall be placed in line. The anchorage of the rope to the drum shall not decrease the breaking force of the rope by more than 20 %.

5.3.6.6.3 Rope anchorage

Rope anchorage shall be such that bending of the rope and other additional stresses on the rope are avoided. With ropes which are not of the rotation resistant type, the rope anchorage shall be made in such a way that it is not possible for the rope to twist about its longitudinal axis.

The following fittings may be used as rope anchorage:

a) asymmetric wedge socket according to EN 13411-6. The free end of the rope shall be secured to prevent it being pulled through the wedge socket with a device which shall be capable of holding 10 % of the maximum static force in the rope;

b) metal and resin socketing according to EN 13411-4;

c) ferrules and ferrule securing according to EN 13411-3 with thimbles in accordance with EN 13411-1.

Solid thimbles, rope eyes or rope grips shall not be used as rope anchorages.

If not otherwise specified in the above mentioned European Standards, the rope-end terminations shall withstand a force of at least 85 % of the minimum breaking force of the rope without rupture.

5.3.7 Chain systems

5.3.7.1 General

In working and traffic areas to which personnel have access, the components of the chain systems and chain run-on points shall be installed or guarded in such a way that crane operations can be conducted with a minimised risk of trapping or drawing-in of hands or arms into jamming-prone areas.

Chain systems shall have a device to ensure the correct running of the chain over the chain system components and to prevent the chain from jumping out, twisting and jamming. The components of the chain system (i.e. chain, chain sprockets, chain wheels and chain guides) shall match each other in terms of dimensions and materials in such a way that the chains are not overstressed by bending.

The chain system design shall be such that torsion in the chain does not occur.

NOTE Torsion in a chain can be avoided by use of a swivel bearing at the bottom block or by guiding the load and the chain arrangement appropriately.

The design and lubrication plan of the chain system shall ensure that the discard criteria of the chain and associated components due to wear is reached before fatigue rupture.

5.3.7.2 Chains

For hoisting mechanisms, short link chains shall be in accordance with EN 818-1 and EN 818-7.

Roller chains or leaf chains shall conform to ISO 4347. The working coefficient of roller chains shall be at least 4 for manual and at least 5 for powered hoisting applications. The breaking load shall be verified by testing.

NOTE Design characteristics of roller chain with associated sprocket are given in ISO 606.

5.3.7.3 Chain wheels and sprockets

Chain wheels and sprockets shall be such that the chains are not overstressed by bending.

With short link chains and roller chains, the chain wheels shall be of mono-bloc design.

Where a chain wheel or sprocket consists of more than one piece, the pieces shall have a positive engagement.

With short link chains and roller chains, positive chain movement shall be effective up to the discard limit of the chain sprocket.

5.3.7.4 Chain guides and runs

Chain systems shall be provided with devices, which ensure that the chain runs properly over chain drive sprockets and chain guide wheels and which prevent the chain from jumping out, twisting and jamming.

5.3.7.5 Chain anchorage and attachments

Chain anchorage and attachment devices shall withstand not less than four times the static chain tensile force at rated capacity without rupture.

The free end of an open chain shall be fitted with a chain end stop to prevent it from passing completely through the sprocket assembly housing. The end stop shall be capable of reliably absorbing the expected forces.

Threaded connections shall be secured against un-intentional disconnection. Provisions shall be provided to check the condition of the fastening.

5.3.8 Belt systems

5.3.8.1 General

In working and traffic areas to which personnel have access, the components of the belt systems and belt run-on points shall be installed or guarded in such a way that crane operations can be conducted with a minimised risk of trapping or drawing-in of hands or arms into jamming-prone areas.

The system shall be such that the belt is subject to uniform loading over its entire width under regular loading conditions.

If an inclined pull is possible, measures shall be taken to avoid excessive loading in the edge zones of the belt, e.g. moveable suspension of the lifting appliance.

Provisions shall be made to ensure tight winding of the belt on to the drum in case of slack belt situation.

5.3.8.2 Belt drums

The thickness of the drum shell shall be determined by proof of competence calculation or by tests.

Provisions shall be provided to ensure that the belt is not able to run off the side of the drum. Rims shall be such that they do not damage the belt that runs against them.

The ratio of the belt drum diameter to the nominal belt thickness shall be greater than or equal to 18.

5.3.8.3 Belts

Belts shall be selected for the particular application and be made of suitable materials so that they withstand the design forces for the design life of the belt.

Belt systems shall be designed in such a way that the inspections can be carried out over the whole length of the belt. Inspection interval specified by the manufacturer shall be related to the design life of the belt.

The materials of the belt shall be such that:

— environmental influences do not result in premature failure;

— damage caused by sharp edges or temperature influences do not lead to sudden failure of the belt;

— contact with the belt does not constitute a danger of injury due to the type of belt.

Belts with or without metallic inlay shall only be used if the wear conditions are known and the discard criteria are verifiable. The belts shall have a certificate giving the limit states as defined by the belt manufacturer.

5.3.8.4 Belt wheels

The strength of wheels shall be determined by proof of competence calculation or by tests. The running surfaces for the belt shall be smooth and free from surface defects liable to damage the belt and the edges shall be rounded.

Belt wheels shall be designed in a way that prevents the belt coming into contact with the edges of the wheel, taking into account the belt tolerance, belt fleet angles and dynamic behaviour of the belt drive system. Wheels shall have protection against the belts jumping out of the wheel (e.g. in the case of a slack belt).

In case of a wheel failure, the belt shall not become detached from the wheel suspension, even with cantilevered arrangements.

The ratio of belt wheel to the nominal belt thickness shall be greater than or equal to 18.

5.3.8.5 Belt guides and runs

Means shall be provided to avoid belt damage due to the belt moving out of its designed position on the drum or wheels.

Belt systems shall be arranged so that the belts do not become damaged through contact with each other or with other crane parts. In addition, account shall be taken of the gravitational force to ensure that belt edges do not come into contact with wheel or drum flanges.

5.3.8.6 Belt fastening on drums

The fastening elements of the fixing point of the belt shall be selected taking into account the belt and drum contours. The belt shall not be bent or compressed over sharp edges.

The fixing point of the belt shall be accessible for maintenance and replacement of the belt.

Where two or more belts lead from a drum to a single moving part, provision shall be made to accommodate unequal lengths of belts.

Belt fastening onto the belt drum shall be made in such a way that at least 2,5 times the remaining static force at the fastening device is accommodated when the rated capacity is applied to the hoist taking into account the friction effect of the winding on the drum. The specific friction values of the particular materials shall be considered for calculation of the friction torque. It shall be assumed that lubricants are present on the materials.

Belt drums shall incorporate features so that the belt can be securely attached to them without damage or bending.

A minimum of two windings shall always remain on the drum. Provision shall be provided to prevent the belt from being wound onto the drum in the wrong direction.

5.3.8.7 Belt anchorage and terminations

Belt anchorage and termination means shall withstand four times the static belt tensile force at rated capacity without destruction of the anchorage and its fastening elements.

Threaded connections on belt anchorage devices shall be locked to prevent un-intentional loosening. The state of the fastening shall be verifiable.

5.3.9 Adjustment rods

Rod length adjustment means shall incorporate locking against un-intentional loosening. The design of adjustment rod anchorages shall be such that they minimise possible bending stresses in the adjustment rod.

EXAMPLE A turnbuckle at the rope termination is an adjustment rod.

5.3.10 Compensating means

Where rope, chain or belt systems incorporate multiple leads from one or more driving mechanisms to the same load attachment and equal loading of leads is assumed, compensating means between the leads shall be provided.

EXAMPLE Suitable compensating means are for example beams or sheaves.

The working range of compensating beams shall be designed in such a way that the length differences of the two leads may be equalised without causing any impermissible misalignment of the beam. The compensating beam shall be fitted with a movement limitation stop.

Compensating means shall be accessible for inspection, including the leads with small movement in compensating sheaves. Special attention shall be given to systems with small movements in the sheaves due to the inherent risk of corrosion and the difficulty of its detection.

5.4 Structures associated with mechanical equipment

5.4.1 Structures

The configuration and flexibility of the load bearing structure shall ensure that the braked wheels have such contact with the rail or ground that safe stopping of the crane or the trolley can be achieved.

NOTE For guidance on crane and runway tolerances, see ISO 12488-1.

The deformation and vibration behaviour of structures shall be such that the associated equipment operates correctly. For limits, see standards for specific crane types.

Fasteners shall be secured in such a way that unintended loosening is prevented, e.g. controlled tightening, lock nuts. Spring lock washers should not be used.

If rails are integrated into the load bearing beams, they shall be fastened with fit bolts, friction grip bolts together with adequate friction surfaces, or by welding. If the connection of the rail to the structure is not shear-resistant, restraints shall be provided to prevent longitudinal movements/creeps of the rail.

5.4.2 Structural equipment

5.4.2.1 General

Cranes that travel at ground level on rails shall be equipped with track cleaners; the clearance between the rail and the track cleaner shall be less than 20 mm.

Where cranes are routinely dismantled, transported and reassembled at a different site, the equipment shall be provided with slinging and attachment points for transport, assembly and maintenance, where the weight, shape or dimensions so require. The slinging and attachment points shall be clearly recognisable and mentioned in the instruction handbook. The equipment and associated slinging and attachment points shall be designed on the basis of the forces to be expected during transportation, assembly, tests, use and maintenance. The number and arrangement of these points shall be provided so that the equipment cannot change its position in any unintended way during handling.

Where there are hazards on persons or crane e.g. due to heat radiation or falling objects, appropriate protective devices shall be provided.

5.4.2.2 Rope-braced structures

Guy ropes or bracing ropes used for outdoor applications shall be protected from corrosion, e.g. by means of galvanised steel wires.

In general, spiral ropes should be used because of their higher rigidity and their smaller surface exposed to corrosion compared with stranded ropes. However, stranded ropes with steel core should be used for cranes intended for frequent changes of location, due to their better resistance to bending.

NOTE For definitions for rope types, see EN 12385-2.

Parallel ropes for bracing a component shall be of the same rope construction, but may be of different directions of rope lay.

Ropes shall be anchored by means of structural devices, e.g. articulated joints, to be bend-free and prevented from rotating. Ropes shall be capable of being tensioned after installation, e.g. using a turnbuckle without the ropes being subjected to any additional twisting stresses.

Ropes shall be terminated in accordance with 5.3.6.6.3.

The minimum radii of rope saddles and minimum diameters of posts shall be in accordance with Table 6.

Table 6 — Rope saddles and posts

Rope construction	Minimum values	
	Rope saddle radius	Post diameter
Fully closed spiral ropes	25 *d*	-
Open spiral ropes	20 *d*	40 *d*
Stranded ropes	15 *d*	30 *d*
NOTE *d* = rope diameter.		

Rope saddles shall, if practicable, have a groove matched to the rope diameter.

5.4.2.3 Counterweights

Counterweights and their components shall be accommodated in housing or secured in such a way that they cannot become loose, and their position in relation to each other and to the crane cannot change unintentionally. Moveable counterweights shall be guided, have protective covering at all accessible points, and their movements outside the designed working range shall be limited by the construction (e.g. by end stops).

Counterweights of cranes that can be removed totally or partially for transporting and using the crane in different configurations shall be designed so that:

- parts shall not become mixed up, and
- assembly and dismantling is possible without additional hazards.

The weight shall be marked on removable parts of counterweights.

Counterweights, their fastening systems and covers shall be such that it is not possible for their mass to change as a result of the effects of weather or losses.

If moveable counterweights are not automatically moved as a function of the jib position, the relevant position of the counterweights shall be indicated by a display that is visible from the driving position. This indicating device is not required if the position of the counterweight is clearly recognisable from the driver's cab.

5.5 Fluid power systems

5.5.1 Controls and control devices of fluid power systems

Controls and control devices shall be in accordance with EN 13557.

Control devices shall be selected so that no pressure and flow disturbances can occur and their level of performance is kept.

Control devices shall be arranged in the control system so that no unwanted functions of the systems (by reaction or similar) can occur. In particular, measures in accordance with EN 1037 shall be taken to prevent unexpected start up.

Control devices in control systems shall be selected and arranged in such a way that in the case of a power failure spring forces return the control into a neutral position.

5.5.2 Protective measures

5.5.2.1 Emergency stop

Where required an emergency stop shall be in accordance with EN ISO 13850.

Operation of the emergency stop shall interrupt the energy supply and stop all motions.

NOTE Pneumatic direct controlled hoist fulfils the requirements of EN ISO 13850, when the actuating elements are positively connected with the energy switching part.

5.5.2.2 Fluid power protection

Disconnecting from the fluid power supply shall be possible without creating hazardous movements. See EN 1037.

In the case of power loss, the zero position of the power valves shall be reached automatically.

5.5.2.3 Mechanical protection

Moving parts (such as cylinders) shall be arranged or covered so that their exposure to the environment and contact with other objects or persons is prevented.

NOTE Cylinders in load lifting attachments (such as clamps and grabs) can be without guards if their protective effect is considered as insignificant in the expected working conditions.

Those adjustable safety and performance related devices that may cause a hazardous situation, if their pre-set values are modified, shall have means to prevent or indicate their readjustment by non-authorised persons. Devices outside of lockable switchgear cabinets shall have irreversible indicators, such as lead-seals, covers, or cup, which shall be destroyed before a readjustment may take place. An irreversible indicator is not necessary if special tools (specified by the manufacturer of the adjustable safety device) are necessary for readjustment.

Each hydraulic circuit shall be provided with means for checking the pressure.

Hydraulic systems shall be such that possible bursting in hoses or expanders do not cause any damage to adjacent components, and are positioned away from access areas. Protective elements, e.g. hoods, covers, oil pans, etc. may be used.

5.5.3 Overload testing

The fluid power systems shall facilitate the required test pressure during the dynamic and static overload tests as specified in the European Standards for the particular crane types.

For hydraulic systems, no measurable unintended leakage shall be permitted other than slight wetting insufficient to form a drop during the overload tests.

5.5.4 Hydraulic equipment

5.5.4.1 General

Hydraulic equipment shall be in accordance with EN ISO 4413 and the following clauses.

Hydraulic systems shall comprise components and auxiliary materials that are compatible and suitable for the given environmental conditions (temperature, humidity).

5.5.4.2 Materials and auxiliary materials

The materials used, (e.g. metals, pressure liquids, grease, coolant), shall be compatible among each other.

Pressure liquids shall be selected so that internal leakage and its effects are kept as low as possible.

The composition of the liquids shall be so that it does not represent any risk for the operating personnel of the machine.

If grease may get into contact with the pressure liquid, it shall be compatible with the pressure liquid.

Elastomeric, polyamide, rubber or equivalent material used for static and dynamic sealing systems, flexible and semi-rigid lines and for coating several components (e.g. reservoirs) shall be compatible with the other materials of components and systems and withstand pressures acting on it. For elastomeric materials, see ISO 6072.

5.5.4.3 Energy converter

5.5.4.3.1 Cylinders

Hydraulic cylinders for any movements that work against gravity shall be equipped with automatic means, e.g. load holding valves, to prevent any uncontrolled movement in the case of hydraulic line failure. Where load holding valves are used, they shall be connected directly to the cylinders exclusively using metallic connecting elements. Hydraulic connections between the load holding valve and the cylinder shall consist of steel tubes; hoses shall not be used. In case more than one cylinder is used for such movement, provisions shall be made to ensure that all load holding valves close at the same moment.

The piston and the piston rod shall be connected to each other so that they shall not detach while operating.

Telescopic cylinders with two or more telescopic sections shall be such that the pistons are prevented from moving out of the cylinders. The extension or the re-entry of the stems of the telescopic cylinders shall be carried out in a defined order.

The seal material(s) shall be selected so that they are compatible with the chemical composition of the fluid used and withstand the temperature, rated pressure and rated speed, without excess leakage or extrusion.

Cylinders shall be fitted in the equipment so that no impermissible load from reaction occurs.

The strokes of cylinders shall be limited by means of mechanical limit stops, provided these are designed in such a way that all forces occurring may be taken up. Otherwise the movements shall be limited by other devices (cushioning in the end positions, limit switches).

5.5.4.3.2 Motors and Brakes

Hydraulic motors for any movements that work against gravity shall be equipped with load holding valves to prevent lowering in the case of a pressure failure. The load holding valves shall be connected directly to the motors exclusively using metallic connecting elements. Hydraulic connections between the load holding valve and the motor shall consist of steel tubes; hoses shall not be used. In case more than one motor is used for such movement, provisions shall be made to ensure that all load holding valves close at the same moment.

The minimum torque of the motor should be 1,4 x M_n.

Loads shall be held securely by use of brakes or self-locking gears.

NOTE Where hydraulic motors are used, internal leakage may cause excessive creep.

It shall be possible to release the brake only if there is sufficient pressure to maintain the load.

5.5.4.4 Connecting elements and accessories

5.5.4.4.1 Tubes

Tubes shall be secured so that impermissible additional load (pressure, bending, temperature) does not occur during operation and wear and corrosion is avoided. This may be done by arranging flexibility by bends and by supports at proper distances.

The calculation of the necessary tube wall thickness shall be done in accordance with EN 13480-3.

5.5.4.4.2 Hose assemblies

Hoses shall be installed so that no torsional strain occurs during fitting. The permissible bend radius shall not be less than the minimum recommended by the hose manufacturer and contact with obstacles or adjacent components shall be avoided.

In order to reduce the risk of fatigue fracture of hoses, the instructions from the manufacturer of the hose shall be followed for the hose installation.

The rated burst pressure of hoses shall be equal or greater than four times the maximum operating pressure.

The marking on the hoses and fittings shall be in accordance with EN ISO 4413.

When assembling fittings to hoses, the hoses shall not be older than four years as hoses lose their properties over time even when stored in good conditions.

When specifying the lifetime of hoses, the usage under high temperatures, bending changes and impulse frequencies shall be taken into account. For guidance, see EN 853.

To enable checking the surface of the hoses and the manufacturing date by inspection, the hoses shall not be painted.

Where damage on the hoses causes a risk of lashing, means shall be installed to prevent the lashing.

When failure of a hose assembly can constitute a whiplash hazard, the hose assembly shall be restrained or shielded by suitable means.

Hoses shall be installed in such a way as to prevent damage from lashing i.e. the violent movement of the hose due to pressure changes in the hydraulic fluid.

Where hose leakages can cause risk of fire, the hoses shall be shielded.

For hydraulic hoses containing fluid with a working pressure of more than 5 MPa (50 bar) and/or having a temperature over 50 °C and which are located within 1,0 m of the crane operator position at a fixed control station, deflecting shields shall be provided to protect the crane operator from hazards arising from sudden hose failure where no other component or structure of the crane performs this function.

Hoses intended to withstand a pressure of more than 15 MPa shall not be fitted with reusable end fittings.

Hydraulic hoses that are used for the connection of interchangeable equipment shall be designed or identified or located to avoid any incorrect connection causing a hazard, e.g. to reverse the direction of movement of a hydraulic cylinder.

5.5.4.4.3 Reservoirs

The reservoir shall be equipped with a fluid level indicator. The reservoir shall contain all the fluid that can flow from the system during normal operation or maintenance in accordance with the intended use. The reservoir size shall be such that a sufficient fluid quantity within the permissible temperature ranges is available at all operating states.

The reservoir shall be located in the installation so that the necessary supply of fluid to the pump is ensured.

Means (e.g. breathing of the reservoir) shall be provided to ensure that impermissible pressure states in the reservoir do not occur.

5.5.4.5 Additional protective measures for hydraulic equipment

5.5.4.5.1 Overpressure and overspeed

Hydraulic systems shall be protected against overpressure of the liquid and overspeed of the load. These protective devices shall act on the hydraulic circuits and elements so that the flow rate and pressure are limited to admissible values.

5.5.4.5.2 Fire

The design of the hydraulic systems shall be such that leaking oil cannot cause a fire. Devices reaching higher temperatures when being operated (also electrical equipment through sparks or short-circuit) shall be thermally separated from devices carrying oil by means of a suitable enclosure, in order to avoid ignition. Under these circumstances, flame-retardant hydraulic liquid should be used (see ISO 7745).

5.5.4.5.3 Inspection and check

Inspection and check of hydraulic systems shall be done according to EN ISO 4413.

5.5.5 Pneumatic equipment

5.5.5.1 General

Pneumatic equipment shall be in accordance with EN ISO 4414 and the following clauses.

All components and materials of equipment shall be compatible and capable of safe functioning in the presumed ambient conditions.

Pneumatic cylinders for any movements that work against gravity shall be equipped with a securing system to prevent creeping.

It shall be possible to release the securing system only if there is sufficient pressure to maintain the load.

5.5.5.2 Air pressure

Sufficient air pressure shall be available for all the operating states at any point of the equipment in order to fulfil all functions. A loss of pressure shall not result in a fall of load or uncontrolled displacement of the load or crane.

5.5.5.3 Maximum speed

Significant differences between lowering and lifting speeds which may exist in hoists with pneumatic drives shall be taken into account in the design.

5.5.5.4 Ambient conditions

Ambient conditions shall be defined and taken into account in selection of the equipment.

5.5.5.5 Energy converter

5.5.5.5.1 Cylinders

Pistons and piston rods shall be connected in such a way that they shall not disconnect. Cylinders shall be arranged in such a way that any hazard due to movements is excluded. If required, covers shall be fitted.

Telescopic cylinders with two or more telescopic sections shall be such that the pistons shall not move out of the cylinders. The extension or the re-entry of the stems of telescopic cylinders shall be carried out in a defined order.

5.5.5.5.2 Motors

Motors shall be such that they do not create hazards either as a result of heating up or icing up.

5.5.5.5.3 Brakes

Hoists using pneumatically released brakes shall be such that unintentional lowering of load is prevented.

NOTE This requirement is fulfilled, for example, if the brake releases only when the motor provides a sufficient moment for holding the load or for controlling the load-movement.

5.5.5.6 Control units/control systems

System-inherent reaction times as a function of control line lengths shall be reduced to a minimum.

Machine movements shall not be triggered by venting control lines.

Control equipment for starting pneumatically operated cranes shall automatically return to the zero position after being released.

Power valves shall have sufficiently dimensioned venting cross sections in their zero position, to prevent malfunction of the brake.

5.6 Fixed load lifting attachments

5.6.1 General

In addition to the requirements specified in this clause, the fixed load lifting attachments shall conform to the requirements of EN 13155 where applicable and not in contradiction with this standard.

In general, the stress history classification (S) of the fixed load lifting attachment shall conform to the usage parameters specified for the crane (C, Q, P) according to EN 13001-1.

Different *S*-classification is permissible, but that shall be clearly marked on the attachment and in the crane documentation.

Hydraulic, pneumatic lines and electric cables for fixed load lifting attachments shall be installed in such a way that no damage is caused during foreseen operating processes.

Fixed load lifting attachments whose capacity may be impaired by wear, corrosion or similar damaging effects shall be designed in such a way that their condition may be checked by inspection. The limits of wear, corrosion and deformations shall be taken into account when designing the fixed load lifting attachments.

Connections and individual parts of fixed load lifting attachments shall be designed so that they are prevented from unintentional loosening.

Bottom blocks shall be provided with additional weights, if necessary, to ensure that lowering with no load from the highest position is possible.

The fixed load lifting attachment shall be tested for fitness for purpose together with the crane by using the test conditions specified for the crane.

Measures shall be taken to prevent unintentional release of the load due to grounding or impact. The backup battery for a load handling magnet shall be able to hold the load for at least 20 min after loss of the power supply.

When selecting the materials, the ambient effects shall be taken into account, e.g. temperatures, thermal radiation when transporting hot molten materials.

5.6.2 Hooks

Hooks for cranes shall be forged, cast or made of rolled steel plate. Cast hooks are not permissible for high risk applications (see 5.9). There shall be no welding on the load bearing parts of hooks.

Means shall be provided to prevent unintentional detachment of the load, unless this is avoided by the application. The requirement can be fulfilled e.g. by providing a safety device such as a safety latch closing the opening of a hook or by shape of the hook.

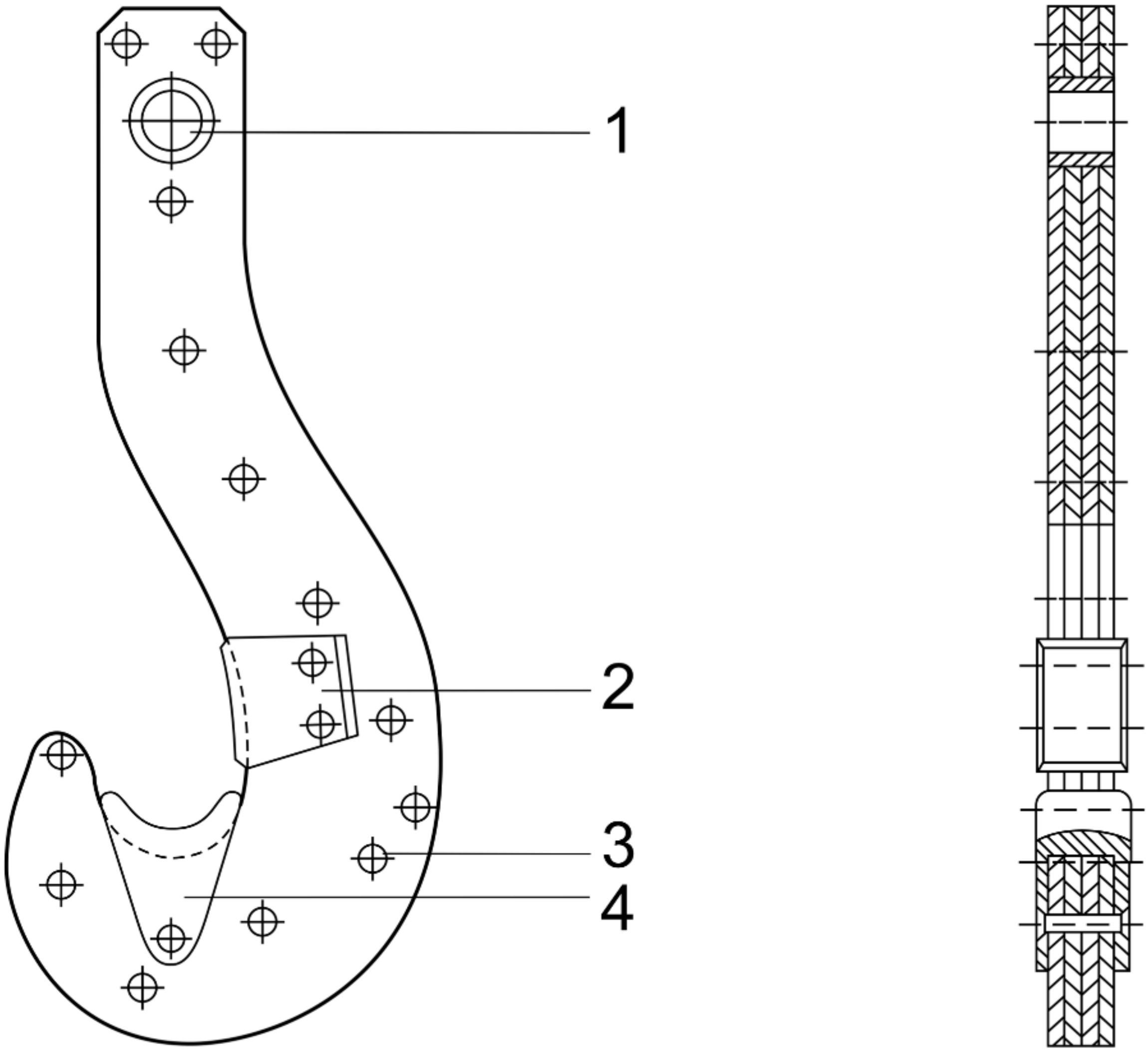
The preferred standard for design of forged hooks is CEN/TS 13001-3-5.

A plate hook can have one or several plate elements. These shall be cut from steel plate so that the rolling direction of the plate is parallel with the loading direction of the hook. The inner edge of plate elements shall be finished smooth after cutting by machining or grinding. Plate elements in a multi-plate hook shall all be of equal thickness and of equal shape and shall be connected by riveting.

Where a plate hook is equipped with a wear or impact protection, these shall be easily removable for inspection of the hook. The hole for a suspension pin should be bushed. For a typical arrangement of wear or impact protection of multi-plate hooks, see Figure 3.

A multi-plate hook with a minimum of four plate elements is considered to be a single failure proof construction.

Load capacity of a plate hook shall be determined in accordance with EN 13001-3-1. Evaluation of stresses shall be done either analytically (by applying curved beam bending theory in accordance with CEN/TS 13001-3-5 or by means of finite element modelling) or experimentally by measurement.



Key

1 bushing

2 impact protection

3 rivets

4 wear protection

Figure 3 — Multi-plate hook

5.7 Equipment for safeguarding

5.7.1 General

Where inherently safe design measures are not practicable, appropriate safeguarding means shall be applied (see EN ISO 12100). Safety related functions shall conform to EN 12077-2 as amended in this standard.

The risk reduction may comprise of one or more safeguards for a specific function; for example limiting of movement may consist of a mechanical restraint (a mechanical end stop/buffer) and a limiting function in the control system. In such a case, the requirements for each subsystem are less stringent than if applying only one safeguard.

5.7.2 Safety related functions of control systems

Safety related functions of control systems shall in general conform to Performance Level c of EN ISO 13849-1, unless another Performance Level is specified by relevant product standards or given by risk analysis. Account should be taken of other risk reduction measures (e.g. mechanical protecting devices such as end stops, buffers etc.).

Unless the hazards are eliminated by other means, at least the following safety related functions shall be addressed:

- overload protection;
- limiting of relevant motions (e.g. hoisting, luffing, slewing, travelling);
- emergency stop;
- over speed control of variable speed hoisting drives, see EN 60204-32:2008, 9.4.4.

It shall be noted that the control system is defined in Annex A of EN ISO 12100:2010 to end at the output of the power control elements. By this definition, e.g. mechanical brakes, load holding valves, gearboxes and other comparable elements are considered to belong to the operating part of the system and not to the safety related control system. Warning and indicating systems are not considered to be safety related control functions.

5.7.3 Measures to decrease the consequences of loss of drive power

Where it can reasonably be foreseen that the loss of drive power is likely to result in a hazardous situation due to a suspended load, means shall be provided to enable the load to be brought to a safe position.

EXAMPLE This can be achieved, for example:

- by a device on the brake for manual release of the brake allowing the loads to be lowered or the crane to be moved in a controlled manner, or
- the rope anchorage being designed in such a way that it can be lowered by an auxiliary hoist, or
- supporting the load with spacing material.

5.7.4 Safety devices to prevent overrunning of movements

All movements with limited operating range shall be interrupted and stopped within the specified slowing-down path by means of limiters, e.g:

- the lifting and lowering movement of hoisting mechanism;
- the luffing movement of a jib;
- the telescoping movement of a jib;
- the slewing movement when limited;
- the travel movement of the trolley;
- the travel movements of the cranes running on rails.

NOTE Suitable means are e.g. buffers, electrical limiting devices, adjustable sliding couplings, and pressure valves.

If the movement is limited by buffers only, these buffers shall absorb the kinetic energy of the moving masses and limit the forces so that the component strength of the crane installation is not exceeded.

Buffer forces shall be calculated from the kinetic energy of 85 % of the nominal travelling speed of the moving crane masses excluding the freely suspended load (free to sway horizontally) and for trolleys from the kinetic energy of 100 % of the nominal travelling speed of the moving masses of the trolley excluding the freely suspended load. For more guidance, see EN 13001-2.

Where braking is actuated by a limiting function before the buffer collision occurs:

— for cranes and trolleys not exposed to wind forces, the buffer forces shall be calculated from the kinetic energy of 70 % of the nominal travelling speed of the moving masses excluding the freely suspended load;

— for cranes and trolleys exposed to wind forces, the buffer forces shall be calculated from the kinetic energy of 85 % of the nominal travelling speed of the moving masses excluding the freely suspended load. Where the wind forces are included in the buffer calculation, 70 % of the nominal travelling speed may be applied.

In both cases, the supporting end stops of the buffers shall however be designed with a specific resistance factor χ_{ss} = 1,8, see EN 13001-3-1.

In the calculation, the resistance to motion due to the frictional contact between wheels and rails may be allowed for by means of a factor f = 0,18.

The driver of the crane shall not be exposed to a deceleration exceeding 4 m/s^2 when the movement is limited.

Where a second limiter (backup limiter) is provided, it shall be installed so that it does not activate if the first limiter stops the motion as intended.

In the case of e.g. luffing jibs, recoil prevention devices shall be provided if there is a risk of tipping over backwards if the load is suddenly removed. An appropriate substitute mass shall be entered in the calculation of the kinetic energy and the buffer forces in lieu of that of the rotating parts or translational moving parts.

5.7.5 Derailment safety device

Means shall be provided to prevent the crane or trolley from leaving the track, falling or overturning in the event of a single wheel failure. This can be achieved by inherent design or the provision of protective devices.

Where the hoisted load or sudden release of a load can cause a wheel of the trolley or crane to rise more than 70 % of the flange height or guiding height of the roller, means of retaining the crane or trolley shall be provided.

Contactless guided cranes (e.g. inductively guided cranes) shall be equipped so that their travel is stopped immediately, when the guiding system is interrupted or a hazardous fault is detected.

The tracks of rail-mounted cranes and of trolleys on cranes shall be fitted with end stops so that the cranes or trolleys are prevented from leaving the track.

Rails, switches and turntables shall be interlocked so that the cranes or trolleys may run over them without derailment.

Means shall be provided to prevent racks, spindles, pistons or telescope sections leaving their guides unintentionally.

5.7.6 Provisions to prevent tipping

Cranes prone to tipping over when coming into contact with travel end stops shall be provided with means of slowing down their travel speed before contact with the end stops is made.

Where dead weight of a crane or trolley does not provide sufficient/adequate stability, they shall be fitted with devices that prevent their tipping over.

5.7.7 Storm-locking

Where a wind speed monitoring system is provided, it shall warn the crane driver when the wind speed level approaches the maximum design level of in-service wind. The warning level shall be set such that the crane driver has enough time to finish the on-going lifting operation, to move the crane to the storm-locking position and to bring the crane out-of-service including all necessary operations specified in the operation manual.

Wind speed at which wind warning is given can be calculated as follows:

$$\boldsymbol{v}_{\boldsymbol{w}} = \sqrt{\boldsymbol{v}(3)^2 - \sqrt{2300 \times \boldsymbol{t}}} \quad (8)$$

where

v_w is the wind speed for wind warning, in m/s;

$v(3)$ is the in-service wind speed regarding the structure of the crane, see EN 13001-2, in m/s;

t is the time needed to shut down the crane from any operating position, in min.

In the shutdown condition, the crane shall be able to withstand the specified out-of-service wind without tilting and drifting. The out-of-service wind force shall be calculated in accordance with EN 13001-2.

For movements held against drifting through friction between braking wheels and a runway, the values of individual wheel loads and the limitation of transmissible torque due to friction shall be taken into account. The friction coefficient shall be taken in accordance with the Table 3 in 5.2.8.2.3.

Where the crane does not have sufficient inherent capacity to avoid its tilting or drifting and such state cannot be achieved by changing its configuration or position, additional means of locking shall be provided, e.g. tie downs or anti-drift devices. Activation of the locking devices while the crane is travelling shall be prevented. Holding action of the locking devices shall not require continuous power. Examples of anti-drift devices are:

- positive locking (pin, bolt, chain, end stop, etc.);
- rail tongs actuated by external force (manually operated or automatic);
- self amplifying friction type clamp;
- rail brake of the friction type dependent on the wheel force on the rail head.

5.7.8 Anti-collision device

Where several cranes are manoeuvred simultaneously in the same place, with risk of collision, it may be necessary to provide buffers or anti-collision devices.

Buffers between the cranes or trolleys shall be seen as sufficient anti-collision devices for risk reduction, if they are able to absorb the kinetic energy resulting from the moving masses in such a way to prevent the following:

- the strength of the components of the crane installation being exceeded;

— the falling or tilting of the cranes or trolleys;

— the dropping of the load;

— the load swaying in a hazardous manner, and

— the driver being exposed to a deceleration exceeding 4 m/s^2.

In other cases, anti-collision systems shall be provided.

Where an anti-collision system is evaluated as being required, all relevant crane motions shall be equipped with the system. The anti-collision system shall have one or both of the following features depending upon the assessment of the risks involved:

— the ability to reduce the speed of the crane parts moving towards a collision;

— the ability to bring the moving crane parts to a stop before a collision occurs.

NOTE Warning of approaching collisions may be required in some cases.

5.8 Environmental effects

5.8.1 Protection against weakening of material

When materials may deteriorate in an unpredictable manner (e.g. non-metallic materials subjected to the effects of wear, corrosion, creep or UV-radiation), the system shall be so designed that an uninterrupted force flow is retained in case of a failure of such materials (e.g. plastic elements in couplings, fastening of the cabin with rubber dampener).

5.8.2 Temperature

5.8.2.1 Selection of materials considering ambient temperature

Materials shall be selected for an ambient temperature range of the crane.

The material used in the equipment of the crane shall be selected so that the equipment maintains its intended properties in the operational and out-of-service temperature specified for the crane. If this is not possible, warming up/cooling down systems and/or standby warming shall be arranged.

5.8.2.2 Protection against hot parts due to operation

Surfaces of parts of the crane shall have their temperature limited in the following three cases:

a) surfaces accessible from the working zone of the crane operator;

b) surfaces accessible by crane operators on their way to the control station;

c) surfaces accessible from the traffic zone.

On access ways and working areas where unintentional touching (0,5 s contact time) of potentially hot surfaces in accordance with EN ISO 13732-1 is likely, these surfaces shall be guarded.

5.8.2.3 Protection against hot parts due to ambient conditions

Parts, which may become hot due to ambient conditions and require intentional touching shall be made from materials of low heat conductivity (such as plastic, wood).

5.9 High risk applications

5.9.1 General

When designing or selecting equipment for cranes, the intended use of which carries an high risk application, the safety requirements or measures of 5.9 shall apply. Although these clauses are focused on the hoisting mechanism, effects of increased severity of possible harm related to other motions of the crane shall also be considered.

In some types of operations, the severity of harm to people or damage to property are considerably higher than in the great majority of cases. Increased severity can be caused by:

a) danger to cause a chain reaction: a failure of the hoisting mechanism may endanger the strength of the whole crane or large parts of it;

b) release of large amount of thermal energy: e.g. hot molten metal;

c) release of dangerous materials, chemicals or gases: the crane is handling dangerous materials or transporting loads over receptacles or pipelines containing such dangerous materials.

5.9.2 Decreasing of the probability of occurrence of harm

5.9.2.1 General

The probability of failure in the load bearing chain shall be decreased by application of one or more of the following methods:

a) apply a risk coefficient in the design of components;

b) duplicate components in the load bearing chain which prevent the load from being dropped in the event of single failure in that component. These additional components are part of the load bearing chain during normal use;

c) specify an enhanced inspection and maintenance program for the crane, e.g. upgrade the criteria for replacing parts, define shorter inspection intervals, provide a condition monitoring system;

d) upgrade the level of quality control in some or all points of the process, e.g. enlarge the scope of non-destructive testing, mark parts for traceability of material.

Measures belonging to the groups a) and b) of the above mentioned methods are specified in 5.9.2.2 to 5.9.2.3 and 5.9.3. Measures in the group c) shall be detailed in the maintenance manual, see 7.4. This standard does not deal with group d).

5.9.2.2 Applying of a risk coefficient

Where this method is used, load bearing components shall be designed with an increased value of design hoist load m_{Hn} obtained by multiplying the gross load m_H , by the risk coefficient γ_n (see EN 13001-2):

$$m_{Hn} = \gamma_n \cdot m_H \quad (9)$$

where

m_{Hn} is the increased value of the design hoist load;

m_H is the gross load of the crane, when lifting the rated load;

γ_n is the risk coefficient, with a value within the range from 1,05 to 2,0. Values of risk coefficients can be found in European product type standards and EN 13001-2.

NOTE 1 The gross load is the total suspended load on the crane (see ISO 4306-1).

NOTE 2 Different values of risk coefficients may be specified for different parts of the crane.

NOTE 3 The risk coefficient γn applies both on static and fatigue design of equipment.

5.9.2.3 Duplicating components

Duplicated components of hoisting mechanism shall be calculated for both of the different conditions as follows:

a) Regular loading condition, where all the components of the mechanism operate as a whole sharing the hoisted load. This shall be assigned to Load Combination A in accordance with EN 13001-2 and used in the proof of fatigue strength of the mechanism.

b) Exceptional loading condition, taking into account a failure of any single component of the mechanism. The loading on the remaining part of the mechanism during the failure incident shall be assigned to Load Combination C (EN 13001-2) and used in the proof of static strength of the remaining part. Dynamic impact due to failure shall be taken into account, either determined by analysis or a dynamic impact factor equal to 1,5 on the total load shall be used for the remaining system. The remaining steel wire rope shall fulfil as a minimum γ_{rb} = 2,05 in accordance with CEN/TS 13001-3-2.

Components, which do not distinguish between fatigue/static design criteria (e.g. brakes, electric motors), shall be designed for a failure condition similarly as for regular loads.

Risk coefficients specified in general for the application in question, need not to be applied for duplicated components.

The design of the duplicated load suspension system shall minimise the sway and tilting of the load if one of the suspensions breaks, so as not to cause a hazard.

In the case of duplicated load suspension systems, the compensating device, e.g. a compensating beam, shall be fitted with damping devices that minimise the impact forces if a suspension breaks. The device shall be equipped with a limiter that will stop the hoisting movement, when the compensation range is exceeded. Clearance to the ceiling and headroom restrictions, as appropriate shall be considered in the design of compensating beam.

Examples of duplications of components in hoisting mechanisms are given in Table 7.

Table 7 — Examples of arrangements of duplication of components

Component	Arrangement 1	Arrangement 2	Arrangement 3	Arrangement 4	Arrangement 5
Backup brake on the drum or sprocket	X	X		X	
Duplicated load suspension system		X	X	X	
Duplication of the gear, the motor and the brake			X		
Two motors and brakes driving through a differential gear. This is used when it is deemed necessary to move the load in case of a motor failure.				X	
Single failure proof or redundant mechanism					X

NOTE 1 Arrangement with backup brake on the primary shaft as the only duplicated component provides only minor decrease in the probability of failure of hoisting mechanism as a whole.

NOTE 2 For backup brake see 5.3.3.5.

NOTE This standard does not deal with non-fixed load lifting attachments, which are also designed in accordance with the arrangement selected for the crane.

5.9.2.4 Control system of the hoisting movement

The safety related control functions defined in 5.7.2 shall conform to Performance level d of EN ISO 13849-1.

Unless the hazard is eliminated by other means, a backup limiter for the upper limit of the hoisting shall be provided.

Where a backup limiter is provided, it shall activate both the service brake and the backup brake where provided. This requirement does not apply to mechanically activated backup brakes.

Devices for safety functions should be provided with equipment necessary for the verification of its function. This equipment should allow the verification to be carried out without a need for a disconnection of conductors or a manual override of terminals. See also 5.2.5 and 7.4.

A display shall be provided for hoisting mechanisms with rated capacity greater than 10 t, showing the crane driver the actual hoisted load or percentage of the rated capacity.

5.9.3 Additional requirements for the transportation of hot molten metal

5.9.3.1 General

Where several bridge cranes can be manoeuvred simultaneously in the same place, with risk of collision, an anti-collision system shall be provided.

Where a duplicated rope system is required, supports shall be provided which prevent drop of the hoist drum in the case of a shaft or gear housing break. The backup brake shall function even with the drum resting on the support. The system shall indicate a drop of the hoist drum.

For hoisting mechanisms with rated capacity greater than 5 t, a load history recorder shall be provided.

Where the lifting operations need more than one hoisting mechanism working simultaneously, the overload protections shall be interconnected, so that if one is stopped the other shall stop also.

Where debris deposits prevent visual inspections of the steel structure, the fatigue strength resistance factor γ_{Mf} = 1,25 shall be used for fatigue design in accordance with EN 13001-3-1.

The most common crane for handling hot molten metals is a bridge crane. The following requirements are valid for bridge cranes handling hot molten metal:

- derailment protection for crane and trolley;
- main girder (box girder) backing is not allowed in the web weld under the wheel; this weld shall be full penetration weld (double sided).

The main girder of box construction without possibility of inside inspection shall be designed with a risk coefficient γ_n = 1,25 in accordance with EN 13001-2.

5.9.3.2 Decreasing the risk dropping load

5.9.3.2.1 General

Cranes whose primary application is handling of hot molten metal may contain equipment or design circumstances where the rules given in 5.9.3.2.2 to 5.9.3.2.5 need not be applied. Such cases are

- an auxiliary hoist intended for maintenance purposes only;
- a loading condition of the main hoisting mechanism, where this is used in a special application to lift heavier loads than those in handling of hot molten metal. Typically, such loads are for maintenance or repair purposes. A switch to change the use mode from handling of hot molten metal to special heavy lift and a visual indication of the selected mode shall be provided. See EN 60204-32:2008, 9.2.4.

5.9.3.2.2 Decreasing the probability of failure of the hoisting mechanism

The minimum requirements for the components of the load bearing chain of hoisting mechanism shall be in accordance with Table 8. The requirements are aimed at decreasing the probability of dropping the load with high thermal energy by measures proportionate to the consequences. Methods to achieve this employ increased safety factors or duplication of components of load bearing chain in the hoisting mechanism and increased reliability of the control system.

These requirements do not take into account the need for hoisting or lowering the load following a failure of a component. The user may specify such requirements and also upgrade the requirements of Table 8 based on risk assessment of local circumstances.

Table 8 — Additional requirements for the load bearing chain of the hoisting mechanism handling hot molten metal

N°	Rated capacity R_C	Requirements
1	$R_C \leq 5$ t	In case of rope suspended load, the whole mechanism, including the fixed load lifting attachment, shall be designed according to the principle of 5.9.2.2 with $\gamma_n = 1,5$. In case of chain suspended load, the risk coefficient for the chain shall be $\gamma_n = 1,7$ and $\gamma_n = 1,5$ for other components of the mechanism.
2	$R_C \leq 40$ t	The rope system and the fixed load lifting attachment shall be designed according to the principle of 5.9.2.2 with $\gamma_n = 1,5$. The rest of the mechanism may be designed without application of a risk coefficient. Hooks for loads greater than 20 t shall be designed in accordance with 5.9.3.2.5. A backup brake shall be provided on the rope drum, Table 7, Arrangement 1.
3	Without limitations	Hooks shall be designed in accordance with 5.9.3.2.5. For other components of the hoisting mechanism, one of the following options shall be selected: a) Duplicated rope system, one or more drums, the backup brake acting on the drum is provided, Table 7, Arrangement 2. b) Duplicated rope system, one or more drums, two parallel systems of gears, brakes and motors are provided, Table 7, Arrangement 3. c) Single failure proof or redundant hoisting mechanism is provided, Table 7, Arrangement 5.
Chain hoists are not be used for rated capacities exceeding 5 t.		

5.9.3.2.3 Duty parameters of hoisting mechanism

The hoisting mechanisms shall be designed to at least:

— load spectrum factor $k_Q = 1,0$;

— number of work cycles C = 32 000.

NOTE For k_Q and C, see EN 13001-1.

5.9.3.2.4 Design of rope systems

For hoisting mechanism with steel wire rope, the following shall apply:

— multilayer spooling on hoist drum shall be prevented;

— mechanical rope guide or device stopping the hoist movement, should the rope climb out of the drum groove, shall be provided;

— rotation resistant steel wire rope is not allowed except in a single fall rope suspension system or two-fall reeving systems where there is a risk of instability of the hook block.

5.9.3.2.5 Design of hooks

The hooks shall be made either as single failure proof hooks (see 5.6.2) or designed with risk coefficient γ_n=1,5 in accordance with 5.9.2.2.

Hooks that directly support the ladle and are subject to possible hot metal spillage should preferably be of multi-plate construction type.

Forged hooks shall be made of a material resistant to ageing.

Bearings shall be designed to withstand prevailing ambient temperatures.

5.9.3.2.6 Design of gear housing of hoisting mechanism

Where the gear housing is equipped with a breather, this shall be equipped with a filter.

Due to their lower ductility, which will induce lower resistance against impact following foreseeable misuse, gear housings made of grey cast iron in accordance with EN 1561 or aluminium alloys are not permissible in hoisting mechanisms carrying hot molten metal for rated capacity above 10 t.

5.9.3.2.7 Decreasing the probability of failure of the control system of the hoisting movement

A backup limiter for the upper limit of the hoisting shall be provided. The backup limiter shall be mechanically activated directly by the hook block or other fixed load lifting attachment. To exclude common cause failures, activation of the backup limiter shall be mechanically and electrically separated from the first upper limiter.

With an exception of chain hoists, operation of the additional safety equipment shall be indicated to the crane operator, e.g. backup brake, equaliser device, backup limiters, backup supports for the rope drum.

High ambient temperature and dust shall be considered in the choice of electrical and other apparatus, or adequate cooling shall be arranged.

5.9.3.3 Protection against thermal radiation and ejection of hot particles

5.9.3.3.1 General

If the control station is exposed to thermal radiation and/or ejection of hot particles, it shall be provided a cabin with proper protection.

To avoid ageing of material due to the exceeding of the maximum permissible equilibrium temperature due to thermal radiation from hot molten masses, either suitable material shall be selected or extra protection shall be provided.

To avoid the sticking and blocking of moveable parts due to the ejection of hot particles, extra protection of these parts shall be provided; e.g. chain curtain and/or thermal protection plates.

All parts subject to hazard from thermal radiation and the ejection of hot particles shall be considered starting with those nearest to the open surface of the hot molten mass, e.g:

— hook block;

— load lifting attachments (with holding slings, straps, bolts, rollers);

— rope on drum;

— trolley.

The thermal protection plates shall be designed and attached to load lifting attachments so that they do not prevent their regular inspection. The thermal protection plates shall be made from material resistant to heat and mechanical damage. There shall be insulation between the protection plate and the protected part (for instance air gap, mineral wool, etc.).

Design of thermal protection plates shall also take into account the clearance to steel wire rope with consideration to load sway.

5.9.3.3.2 Cabins and access

The cabin windows shall be made of double glass for insulation. The outer glasses shall be of safety type (not laminated).

The cabin shall be equipped with air conditioning including filtering and with a fire extinguisher.

Based on a special risk analysis, shields may require fitment above and/or in front of the cabin.

An emergency exit facility separate from the normal exit shall be provided from the cabin.

6 Verification of the safety requirements and/or protective measures

The methods to be used to verify conformity with the requirements given in Clause 5 are detailed in Table 9.

Table 9 — Methods to be used to verify conformity with the safety requirements *(1 of 4)*

Clause number	Requirement	Method of verification
5.1	General	
5.2	Electrical equipment	Testing in accordance with Clause 19 of EN 60204-32 and EN 60204-11.
5.2.1	General	
5.2.2	Physical environment and operating conditions	V, T
5.2.3	Electrical supply	C, T
5.2.4	Protection against electric shock by direct contact	M, V
5.2.5	Control circuits and control functions	V, T
5.2.6	Operator interface and mounted control devices	V
5.2.7	Power driven motions	V, T
5.2.8	Selection of motors	
5.2.8.1	General	C, T
5.2.8.2	Loadings	C, V
5.2.8.3	Multiple motors for a motion	C, T
5.2.8.4	Mechanical strength	C, T
5.2.8.5	Torque requirement for vertical motions	C, T
5.2.8.6	Torque requirement for horizontal motions	C
5.2.8.7	Thermal capacity requirement	C

Table 9 *(2 of 4)*

5.3	Mechanical equipment	
5.3.1	General	C, T, V
5.3.2	Clutches and couplings	C, T, V
5.3.3	Brakes	
5.3.3.1	General	C, T
5.3.3.2	Service brakes	C, T, V
5.3.3.3	Brakes for vertical movements	C, M
5.3.3.4	Brakes for horizontal movements	C
5.3.3.5	Backup brakes for vertical movements	C, T
5.3.4	Gear drives	
5.3.4.1	General	C, T, V
5.3.4.2	Gears	C
5.3.4.3	Gear housing	C, T, M
5.3.4.4	Means preventing load drop during disconnection of drive torque	T, V
5.3.5	Wheels on rails	
5.3.5.1	Travel wheels	C, M, V
5.3.5.2	Guide rollers	C, M
5.3.6	Rope systems	
5.3.6.1	General	V
5.3.6.2	Rope drums	C, T, V
5.3.6.3	Ropes	T, V, C
5.3.6.4	Rope sheaves	M, C, T, V
5.3.6.5	Rope guides and runs	T, V
5.3.6.6	Rope terminations and fittings	T, V
5.3.7	Chain systems	
5.3.7.1	General	V, T
5.3.7.2	Chains	V, T
5.3.7.3	Chain wheels and sprockets	V, T, C
5.3.7.4	Chain guides and runs	C, T, V
5.3.7.5	Chain anchorage and attachments	V, T, C
5.3.8	Belt systems	
5.3.8.1	General	V, T
5.3.8.2	Belt drums	C, T, V, M
5.3.8.3	Belts	C, T, V
5.3.8.4	Belt wheels	C, T, V, M

Table 9 *(3 of 4)*

5.3.8.5	Belt guides and runs	V
5.3.8.6	Belt fastening on drums	V, T, C
5.3.8.7	Belt anchorage and terminations	V, T
5.3.9	Adjustment rods	V
5.3.10	Compensating means	V
5.4	Structures associated with mechanical equipment	
5.4.1	Structures	C, T, V
5.4.2	Structural equipment	
5.4.2.1	General	C, T, V
5.4.2.2	Rope-braced structures	V, M
5.4.2.3	Counterweights	V, M
5.5	Fluid power systems	
5.5.1	Controls and control devices of fluid power systems	T, V
5.5.2	Protective measures	
5.5.2.1	Emergency stop	T, V
5.5.2.2	Fluid power protection	T
5.5.2.3	Mechanical protection	V
5.5.3	Overload testing	T, V
5.5.4	Hydraulic equipment	
5.5.4.1	General	T, C, V
5.5.4.2	Materials and auxiliary materials	T, V
5.5.4.3	Energy converter	T, C, V
5.5.4.4	Connecting elements and accessories	C, T, V, M
5.5.4.5	Additional protective measures for hydraulic equipment	T, V
5.5.5	Pneumatic equipment	
5.5.5.1	General	C, T, V
5.5.5.2	Air pressure	T
5.5.5.3	Maximum speed	C, T
5.5.5.4	Ambient conditions	C, T
5.5.5.5	Energy converter	T, C, V
5.5.5.6	Control units/control systems	T, C
5.6	Fixed load lifting attachments	
5.6.1	General	T, V
5.6.2	Hooks	C, T, V

Table 9 *(4 of 4)*

5.7	Equipment for safeguarding	
5.7.1	General	V
5.7.2	Safety related functions of control systems	C, V
5.7.3	Measures to decrease the consequences of loss of drive power	C, V
5.7.4	Safety device to prevent overrunning of the end positions	C, T, V
5.7.5	Derailment safety device	C, T, V
5.7.6	Provisions to prevent tipping	C, T, V
5.7.7	Storm-locking	C, T, V
5.7.8	Anti-collision device	C, T, V
5.8	Environmental effects	
5.8.1	Protection against weakening of material	C, V
5.8.2	Temperature	
5.8.2.1	Selection of materials considering ambient temperature	T, V
5.8.2.2	Protection against hot parts due to operation	T, V
5.8.2.3	Protection against hot parts due to ambient conditions	T, V
5.9	High risk applications	
5.9.1	General	V
5.9.2	Decreasing of the probability of occurrence of harm	
5.9.2.1	General	V
5.9.2.2	Applying of a risk coefficient	C
5.9.2.3	Duplicating components	C, V, T
5.9.2.4	Control system of the hoisting movement	C, T, V
5.9.3	Additional requirements for the transportation of hot molten metal	
5.9.3.1	General	C, V
5.9.3.2	Decreasing the risk dropping load	C, V, T
5.9.3.3	Protection against thermal radiation and ejection of hot particles	V, T

Key of symbols in the table:

C calculation;

M measurement;

T testing;

V visual inspection or check.

7 Information for use

7.1 General

Information and instructions for the commissioning, use, regular tests, inspections and maintenance of the equipment shall be included in the instructions of the crane.

The provisions of EN ISO 12100:2010, 6.4 and Clause 17 of EN 60204-32:2008 shall apply.

7.2 Instructions for operation in special situations

Operating principles of safety devices and requirements in the event that these devices are triggered, e.g, resetting the emergency stop device, shall be described.

Special features of the crane (e.g. manual release of hoist brakes) shall be described and information on safe use shall be provided within the instruction handbook.

7.3 Instructions for installation and maintenance

All maintenance and repair work required to ensure the safe functioning of the equipment shall be described, e.g:

- lubrication of ropes, chains, gearboxes, bearings, hooks, etc;
- inspection of wearing parts such as ropes, chains, hooks, belts, brake linings and wheels. Specification of test and inspection intervals and wear criteria;
- discard criteria of ropes in accordance with ISO 4309;
- checks and/or adjustment of safety devices;
- instructions for replacement of a hook nut and a hook;
- protection of electrical devices and bearings when arc welding is carried out on the crane;
- prevention of excessive paint from being applied to critical areas, for example limit switch, drain hole, etc.

Special attention shall be given in the inspection instructions to leads with small movement in compensating sheaves.

The manufacturer shall specify the operation time of hoses, based upon ageing of their material. The specified operation time should not be longer than six years. Information provided on the marking of hoses shall be referred to, see also 5.5.4.4.2.

Instructions shall also be given for maintaining the braking capacity of mechanical brakes, which are subject to minimal wear due to the performance of their operational systems.

NOTE This may occur with electrical braking systems or backup brakes.

If during maintenance and repair work, specific hazards to people may occur, precaution of those hazards shall be provided in the maintenance manuals, for example, potentially hot parts.

Position and correct use of slinging points or slinging position for handling of equipment shall be described.

7.4 Maintenance instructions in the case of high risk applications

In cases of high risk application due to failure of a mechanism, the probability of occurrence shall be decreased by ensuring the operational condition of this equipment during crane use. Means of increasing the reliability of the equipment are e.g:

— interval between inspections is shorter than usual;

— scope of inspections is more thorough than usual;

— inspection methods are more accurate than usual;

— discard criteria is more stringent than usual.

The appropriate actions, methods and criteria shall be given in the maintenance instructions.

The manufacturer shall specify tighter discard criteria for ropes in duplicated rope systems in high risk applications. Criteria specifying the number of broken wires shall, in general, reduce the number to 70 % of that given in ISO 4309. Where parallel-closed or rotation resistant steel wire rope is used in the hoist movement, discard criteria of the rope, in addition to what is given in ISO 4309, shall also be expressed in number of hoisting cycles in the maintenance document.

The number of hoisting cycles should be based on the expected displacements of the hoisting motion, type of steel wire rope, the load spectrum, environment and the reeving system (the number of sheaves, orientation of sheaves, reverse bending cycles etc).

As a precaution, in the case of a component failure in a duplicated or single failure proof system, the manufacturer shall instruct the user not only to replace the failed component, but also the equivalent component in the parallel part of the system.

Procedures shall describe how to verify safety systems, e.g. the backup brake and backup limiter. The backup brake can be verified on a lower speed. The backup upper limiter for hoist range shall be tested by disconnecting the first limiter and then the motion driven through at both low and high speed.

Instructions shall be given for monitoring of design life of equipment in accordance with ISO 12482-1.

7.5 Marking

In addition to the provisions contained in EN 12644-2 and EN 60204-32, equipment shall be provided with the following information in a lasting and legible manner, if applicable:

— specifications of the hydraulic connection in the case of an external hydraulic power supply;

— specifications of the pneumatic connection in the case of an external pneumatic power supply;

— specifications of the electrical connection in the case of an external electrical power supply.

Interchangeable accessories, supplied as part of the crane, shall be marked clearly and permanently in order to avoid misuse and/or faulty assembly; e.g. components of supports structures for different configurations shall be marked with the name of the manufacturer or supplier, type number, serial number.

Separate lifting devices (e.g. lifting beams, grabs) shall be marked with their lifting capacity and volume, where relevant.

Annex A
(informative)

Selection of a suitable set of crane standards for a given application

Is there a product standard in the following list that suits the application?	
EN 13000	*Cranes — Mobile cranes*
EN 14439	*Cranes — Tower cranes*
EN 14985	*Cranes — Slewing jib cranes*
EN 15011	Cranes — Bridge and gantry cranes
EN 13852-1	*Cranes — Offshore cranes — Part 1: General purpose offshore cranes*
EN 13852-2	*Cranes — Offshore cranes — Part 2: Floating cranes*
EN 14492-1	*Cranes — Power driven winches and hoists — Part 1: Power driven winches*
EN 14492-2	*Cranes — Power driven winches and hoists — Part 2: Power driven hoists*
EN 12999	*Cranes — Loader cranes*
EN 13157	*Cranes — Safety — Hand powered lifting equipment*
EN 13155	*Cranes — Non-fixed load lifting attachments*
EN 14238	*Cranes — Manually controlled load manipulating devices*
EN 15056	*Cranes — Requirements for container handling spreaders*

YES → Use it directly, plus the standards that are referred to

NO ↓

Use the following:	
EN 13001-1	*Cranes — General design — Part 1: General principles and requirements*
EN 13001-2	*Cranes — General design — Part 2: Load actions*
EN 13001-3-1	*Cranes — General design — Part 3.1: Limit states and proof competence of steel structure*
CEN/TS 13001-3-2	*Cranes — General design — Part 3.2: Limit states and proof of competence of wire ropes in reeving systems*
CEN/TS 13001-3-5	*Cranes — General design — Part 3-5: Limit states and proof of competence of forged hooks*
EN 13135	*Cranes — Safety — Design — Requirements for equipment*
EN 13557	*Cranes — Controls and control stations*
EN 12077-2	*Cranes safety — Requirements for health and safety — Part 2: Limiting and indicating devices*
EN 13586	*Cranes — Access*
EN 14502-1	*Cranes — Equipment for the lifting of persons — Part 1: Suspended baskets*
EN 14502-2	*Cranes — Equipment for the lifting of persons — Part 2: Elevating control stations*
EN 12644-1	*Cranes — Information for use and testing — Part 1: Instructions*
EN 12644-2	*Cranes — Information for use and testing — Part 1: Marking*

Annex B
(informative)

Design of rail wheel flanges

The radial wheel force is typically proportional to the wheel diameter and the width of contact between the wheel and the rail. The lateral force applied to the wheel flange is proportional to the vertical force. To resist the bending and shear stresses due to the acting lateral force on the flange, the thickness should increase with the wheel diameter and width.

The flange height should be proportional to the wheel diameter in such a way that the risk of the flange climbing on the top of the rail is minimised.

According to practiced design principals, wheel flanges are acceptable when the thickness and height of the flanges meet the following conditions.

Flange thickness *t* is calculated by:

$$t \geq 13{,}5\left(\frac{B}{100}\right)^{\frac{2}{3}} + 13{,}5\left(\frac{D}{500}\right)^{\frac{1}{2}} - 0{,}7\left(\frac{D}{500}\right) - 6{,}5 \qquad \text{(B.1)}$$

Flange height *h* is calculated by:

$$h \geq 5{,}5 + 13{,}5\left(\frac{D}{500}\right)^{\frac{1}{2}} \text{ for D} \geq 125 \text{ mm} \qquad \text{(B.2)}$$

$$h \geq 4{,}0 + 13{,}5\left(\frac{D}{500}\right)^{\frac{1}{2}} \text{ for D} < 125 \text{ mm} \qquad \text{(B.3)}$$

where

t is the thickness of the flange in (mm);

h is the height of the flange in (mm);

D is the wheel diameter in (mm);

B is the width of the wheel tread in (mm).

The formula of the flange thickness applies to wheel materials with a nominal value of ultimate strength equal to or greater than 600 N/mm^2.

For other materials, e.g. bronze, stainless steel, hardened flange surface, the wearing properties may allow or require different values of the flange thickness.

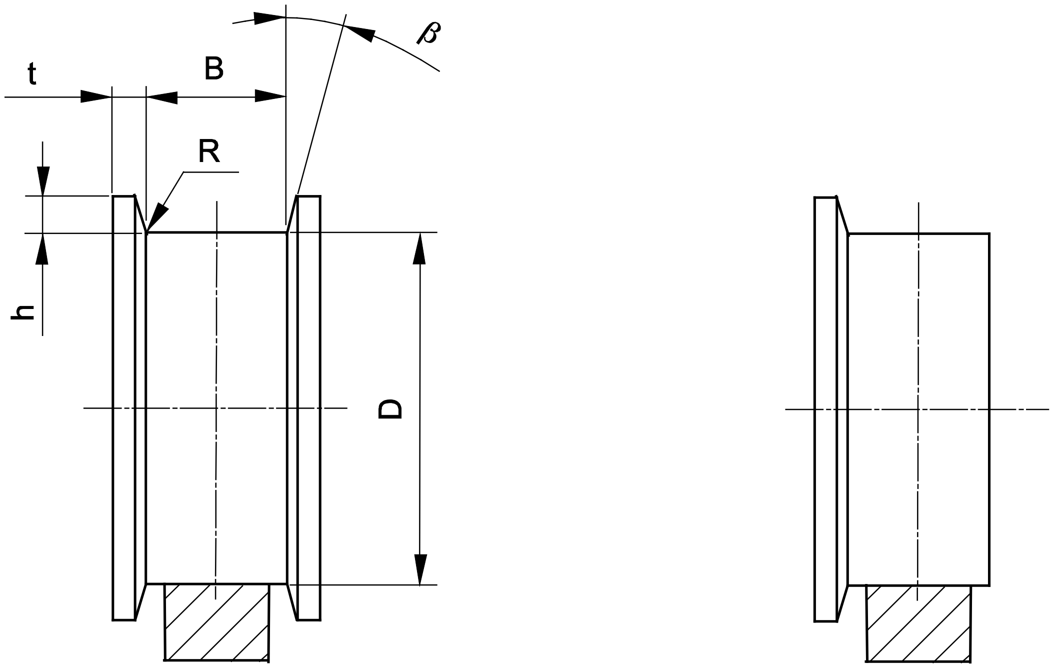


Figure B.1 — Wheel dimensions

The root radius *R* of the wheel flange shall be greater or equal to 1 mm (*R* ≥ 1 mm) and the flange angle *β* shall be greater or equal to 1 degree (*β* ≥ 1°), see Figure B.1.

Values rounded off to 0,5 mm are given in the Table B.1 for a selection of values of B.

Table B.1 — Figures for the thickness and height for some usual values of B

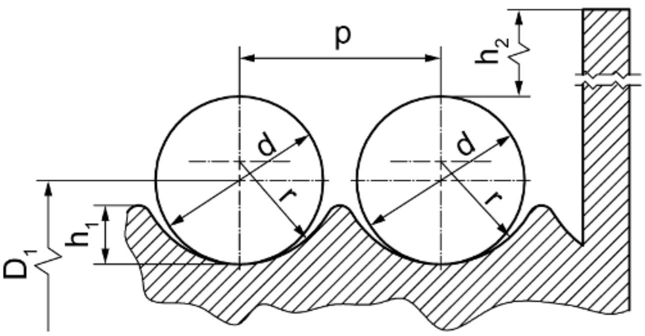
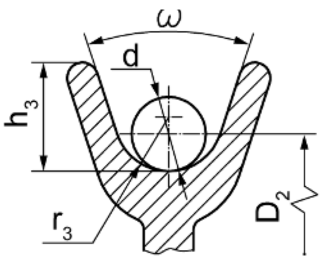
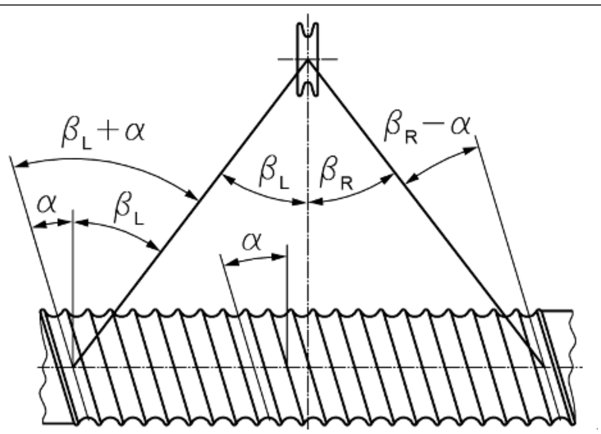
Dimensions in millimetres

D	B = 65	B = 100	B = 150	*h*
	t	*t*	*t*	
80	9,0	12,5	16,5	9,0
100	9,5	13,0	17,0	9,5
112	9,5	13,0	17,0	10,0
125	10,0	13,5	18,0	12,5
160	11,0	14,5	18,5	13,0
200	12,0	15,5	19,5	14,0
250	13,0	16,5	20,5	15,0
320	14,0	17,5	21,5	16,5
400	15,0	18,5	22,5	17,5
500	16,5	20,0	24,0	19,0
630	18,0	21,0	25,5	20,5
710	18,5	22,0	26,5	21,5
800	19,5	23,0	27,0	22,5
900	20,5	24,0	28,0	23,5
1000	21,5	25,0	29,0	25,0

Annex C
(informative)

Guidance on rope systems

Table C.1 — Recommendations for rope system parameters

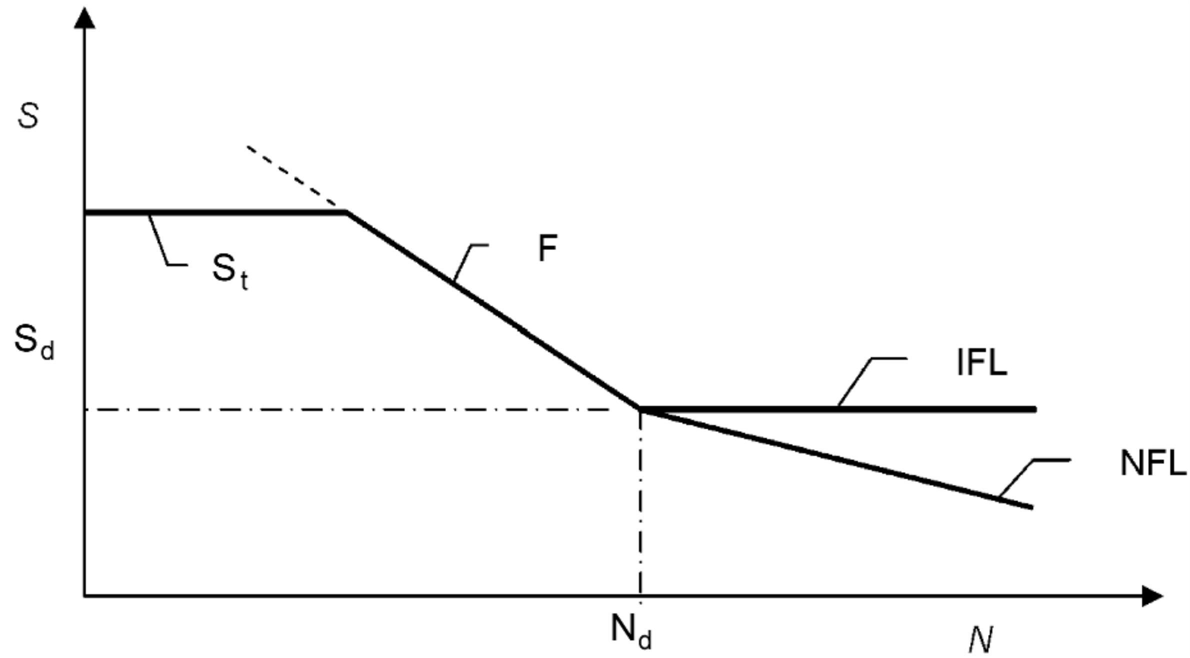
Rope system item	**Parameter values**
 Rope drum detail	$0{,}525 \times d \le r \le 0{,}56 \times d$ $p \ge 1{,}1 \times d$ and $p \ge d + 2$ mm $0{,}33 \times d \le h_1 \le 0{,}45 \times d$; for single layer spooling $0{,}28 \times d \le h_1 \le 0{,}45 \times d$; for multi-layer spooling $h_2 \ge 1{,}5 \times d$ d is the rope diameter r is the radius of the groove bottom D_1 is the pitch circle diameter of the rope drum
 Rope sheave detail	$0{,}52 \times d \le r_3 \le 0{,}56 \times d$ $30° \le \omega \le 60°$ (symmetric) $h_3 \ge 1{,}4 \times d$ D_2 is the pitch circle diameter of the rope sheave Opening angles $\omega < 45°$ should only be used in systems, where rope sheaves do not move in axial direction and fleet angles are less than 1°. Otherwise, rope side contact would cause hazardous twist on the rope.
 Fleet angles	The figure shows four different fleet angles φ: β_L, β_R, $(\beta_L+\alpha)$ and $(\beta_L-\alpha)$. For each of these it should apply that: $\varphi \le 4°$ non-rotation resistant ropes $\varphi \le 2°$ rotation resistant ropes $0{,}5° \le \varphi \le 1{,}5°$ multi-layer drums; to ensure correct spooling For drums without grooves it may be set $\alpha = 0$.

Annex D
(informative)

Specification of endurance of equipment

D.1 Basic approach

The load bearing capacity of a usual mechanically or pressure-loaded component of equipment follows typically the so-called S-N-curve as shown in Figure D.1.



Key

N	is the design life characterised by number of revolutions, by number of cycles or by runtime (in s, h, year) where applicable, and is presented on logarithmic scale;
S	is the load effect characterised by force (in N, kN), or moment (Nm, kNm) or by both of them, or by stress (in MPa) and is presented on logarithmic scale;
S_t	is the maximum load level that the equipment can bear statically in intended use;
F	is the part of the curve that represents the dependence of lifetime *N* on the constantly applied cyclic load due to fatigue (or due to wear, in some cases);
IFL	is the part of the curve that represents a constantly applied cyclic load S_d with which the equipment reaches infinite life that some equipment may have;
NFL	represents an alternate life curve where infinite life is not reached, but the slope of this part of curve may differ from that of curve part F;
S_d, N_d	is a couple of values that represents the load level at which the *IFL*-curve or *NFL*-cu starts at the life point N_d.

Figure D.1 — Typical S-N-curve of equipment

The load characteristics of equipment shall be expressed so that the crane manufacturer using the equipment in a crane is able to form the S_t-*F-IFL*-curve or S_t-*F-NFL*-curve, unless such a curve is not directly given.

The necessary values to form an *S-N*-curve are typically: S_t, S_d, N_d and the fatigue slope exponent *m*. If the NFL-curve applies, a different slope exponent m_2 shall be specified for that part.

Instead of giving exponents *m* the *S-N*-curve can be defined by giving the points of intersection of each straight line.

Physically, the *S-N*-curves shall be determined separately for each component of the equipment. The *S-N*-curve of the equipment is the lowest contour line of all the *S-N*-curves of the components.

In addition to the above-mentioned load-life-values, the scatter of strength or lifetime in terms of standard deviations shall be given so that the crane designer can choose safe margins to the characteristic values. Alternatively, the safety margins, which may be different for different use and conditions, shall be directly given or included in the *S-N*-curve.

D.2 Examples of application

D.2.1 Roller bearing

The parameters used to describe the load vs. life characteristics of the roller bearings and their correspondence with the generic parameters in D.1:

- $S_t = C_0$;
- $S_d = C$;
- N_d =1 000 000;
- $m = c$ (= 10/3 or 3);
- [m_2 = c, in general];
- reliability of values is indicated by the probability of failure = 10 %; L_{10}.

In addition, the load bearing capacity depends on type of loading and conditions of use, e.g. lubrication. These are considered by specific coefficients.

D.2.2 Lifting attachment, fixed or non-fixed

It is supposed that this lifting attachment, e.g. a spreader beam, is made from steel by weldments.

- $S_t = R_{c0}$ = 10 t; maximum rated capacity, permitted up to N_1 =63 000 lifts with the safety margins defined in EN 13001-2;
- $S_d = R_{cd}$ = 3.2 t; rated capacity for constant load lifts *Nd* times;
- N_d =2 000 000;
- $m = 3$ [m_2 = 5, may be given];
- reliability of values is based on design according to EN 13001-series.

Alternatively, the manufacturer may define the rated capacity together with the classification parameters of EN 13001-1.

NOTE The parameters given in this example are beyond the scope of EN 13155.

D.2.3 Turnbuckle

The parameters needed are essentially same as for the lifting attachment in D.2.2.

D.2.4 Electromechanical component

The performance capacity is expressed by nominal current in specified operation conditions, e.g. temperature limits.

— S_t = not relevant;

— S_d = Id = 10 A, 230 V ac;

— N_d =1 000 000 cycles;

— m = not relevant;

— reliability of values is indicated by the probability of failure, e.g. 10 %.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

[1] EN 853, *Rubber hoses and hose assemblies — Wire braid reinforced hydraulic type — Specification*

[2] EN 12385-2+A1:2008, *Steel wire ropes — Safety — Part 2: Definitions, designation and classification*

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

[4] EN 60034-1:1998, *Rotating electrical machines — Part 1: Rating and performance*

[5] EN 60204-1, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

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

[7] ISO 606, *Short-pitch transmission precision roller and bush chains, attachments and associated chain sprockets*

[8] ISO 1940-1, *Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state — Part 1: Specification and verification of balance tolerances*

[9] ISO 2943, *Hydraulic fluid power — Filter elements — Verification of material compatibility with fluids*

[10] ISO 6072, *Rubber — Compatibility between hydraulic fluids and standard elastomeric materials*

[11] ISO 7745, *Hydraulic fluid power — Fire-resistant (FR) fluids — Requirements and guidelines for use*

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK