Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3902 (2020-12)

Design of Lifting Equipment in Nuclear Power Plants

(Auslegung von Hebezeugen in Kernkraftwerken)

Previous versions of this Safety Standard were issued 1975-11, 1978-06, 1983-11, 1992-06, 1999-06 and 2012-11

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

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PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 35-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in the Federal Gazette (Bundesanzeiger) on January 20th, 2021. Copies of the German versions of the KTA safety standards may be mail-ordered through the Wolters Kluwer Deutschland GmbH (info@wolterskluwer.de). Downloads of the English translations are available at the KTA website (http://www.kta-gs.de).

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Comments by the editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of **shall normally** - are specified in the text of the Safety Standard,
shall normally	indicates a requirement to which exceptions are allowed. However, the exceptions used, shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this Safety Standard.

Basic principles

(1) The Safety Standards of the Nuclear Safety Standards Commission (KTA) have the objective to specify safety-related requirements, compliance of which provides the necessary precautions in accordance with the state of the art in science and technology against damage arising from the construction and operation of the facility (Sec. 7 para. 2 subpara. 3 Atomic Energy Act - AtG) in order to achieve the fundamental safety functions specified in the Atomic Energy Act, the Radiation Protection Act (StrlSchG) and the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants (SiAnf) as well as in the Interpretations on the Safety Requirements for Nuclear Power Plants.

(2) Based on the Safety Requirements for Nuclear Power Plants (SiAnf) and the Interpretations of the Safety Requirements for Nuclear Power Plants, this Safety Standard specifies the design criteria for lifting equipment. Additionally, lifting equipment shall be erected and operated in accordance with the valid federal and state safety regulations as well as with the regulations of the official accident insurance institutions.

(3) Regarding the danger potential, the design shall be based on

a) additional requirements or
b) increased requirements

for lifting equipment which exceed the general provisions,

as well as

c) requirements for lifts in reactor containments and
d) requirements for refuelling machines

as specified in this Safety Standard in detail.

(4) General requirements regarding quality assurance are specified in Safety Standard KTA 1401.

(5) The requirements for inspection, testing and operation, including specific requirements for quality assurance, are laid down in KTA 3903.

1 Scope

This Safety Standard applies to the design of lifts, cranes, winches, trolleys, load carrying devices and refueling machines of light water reactors, collectively called lifting equipment in the following, in as far as they are used in nuclear power plants and meet the special provisions of section 4.

2 Definitions

(1) Parts in the load path

In this Safety Standard, parts shall be deemed to be "within the load path" if they

a) can directly lead to an inadmissible impairment of the lifting capacity of lifting equipment in case of their failure,

or

b) are welded on to a part as per a), where only the area of the welded on component, that influences the stress curve within the component according to a), is considered to be within the load path.

(2) Maximum operational load

The maximum operational load is the load which is moved with the lifting equipment during specified normal operation.

(3) Refueling machines for light water reactors

A refueling machine for light water reactors is that equipment which is directly used to charge the reactor core with fuel assemblies or control rods (e.g. shim or shutdown rods), or to discharge these from the core.

(4) Lifting load

The lifting load is the sum of maximum erection load or maximum operational load and the dead weights of the components to take up the load to be handled, e.g. bottom block, lifting beam, and the weight of the supporting means, e.g. of the rope.

(5) Load carrying device

Load carrying devices are supporting means, load suspension devices and lifting accessories. They are defined in DIN 15003.

(6) Load shifting

Load shifting is an event where due to failure of one part within the double drive mechanism chain or due to failure of a redundant part of the rope drive within a drive chain with safety brake an additional load is applied on the lifting equipment.

(7) Machine parts

Machine parts are axles, shafts, bolts, tie rods and similar parts.

(8) Maximum erection load

The maximum erection load is the maximum load which may be moved by the lifting equipment during the erection phase until commencement of licensed nuclear operation.

3 General provisions

(1) Lifting equipment shall be erected in accordance with the valid general safety regulations, especially the federal and state work protection regulations and the regulations of the official accident insurance institutions.

(2) Lifting equipment shall at least comply with the generally accepted engineering standards.

4 Special provisions

4.1 Lifts in reactor containments

Lifts in reactor containments shall, in addition to the general provisions of section 3, comply with the requirements of section 5 if their specified normal use extends to the transportation of persons.

4.2 Cranes, winches, trolleys and load carrying devices with additional requirements

(1) If, in the course of transportation of nuclear fuel, other radioactive substances, radioactive components or other loads, a failure of the lifting equipment is expected to lead

a) to the immediate danger of a release of radioactivity with a subsequent radioactive exposure of persons in the plant subjected to an effective dose by inner exposure exceeding 1 mSv or to an external exposure exceeding 5 mSv

or

b) to a loss of reactor coolant which cannot be isolated, or to a detrimental effect on, and going beyond the redundancy of, the safety equipment which is necessary to shut down the reactor at any time, to maintain the reactor in the shutdown condition or to remove residual heat, and no dangers as per section 4.3 need be expected.

then, in order to provide adequate protection against damage, the cranes, winches, trolleys and load carrying devices shall meet the additional requirements of section 6 exceeding the requirements of the general provisions of section 3.

(2) The classification of lifting equipment with regard to additional requirements shall be specified within the nuclear licensing and supervisory procedure. Examples for this classification and for the procedural steps of classification are given in **Annex A**.

4.3 Cranes, winches, trolleys and load carrying devices with increased requirements

(1) If, in the course of transportation of nuclear fuel, other radioactive substances, radioactive components or other loads, a failure of the lifting equipment is expected to lead

a) to a criticality accident

or

b) to the danger of a release of radioactivity where the maximum allowable discharge into the atmosphere may be exceeded as laid down in the license or the radioactive exposure of individual persons of the population in the nuclear power plant environment may exceed the limit values of the Radiological Protection Ordinance (StrlSchV)

then, in order to provide adequate protection against damage, the cranes, winches, trolleys and load carrying devices shall meet the increased requirements of section 7 exceeding the requirements of the general provisions of section 3.

(2) The classification of lifting equipment with regard to increased requirements shall be specified within the nuclear licensing and supervisory procedure. Examples for this classification and for the procedural steps of classification are given in **Annex A**.

4.4 Refueling machines for light water reactors

Refueling machines for light water reactors shall, in addition to the general provisions of section 3, meet the requirements of section 8.

4.5 External events (EVA)

(1) An analytical proof of the adequate protection of lifting equipment against external events is required provided such requirement also exists for the building.

(2) Exceptions are permitted if it is demonstrated that no effects and damage resulting from the lifting equipment can affect the functional capability of any plant component that is designed against external events.

(3) The adequacy of the protection against external events shall be analytically proven for the lifting equipment without load.

(4) If the lifting equipment is designed for a definite parking position, then the analytical proof is only required for this position.

(5) The general principles of KTA 2201.4 apply to all external events.

4.6 Ambient conditions

(1) Ambient conditions, e.g., pressure, temperature, medium, radiological exposure, shall be considered in the design.

(2) The possibility for decontamination, e.g. of the structures, shall be considered in the structural design.

4.7 Ergonomics requirements

Lifting equipment as per sections 4.2 to 4.4 shall satisfy the design principles of DIN EN 894-1 and DIN EN ISO 12100 leading e.g. to the following requirements:

a) Load carrying devices and their detachable individual items shall be constructed or identified such that confusion of items is excluded.

b) The command, control and monitoring devices as well as identification markings, actuating, connecting and safety elements shall be designed such that

   ba) they are compatible both with the usual expectations and the current practice (conformity of expectation),

   bb) the operating personnel is able to safely perform and monitor the handling processes at any time.

c) Signals and indications shall be handled to comply with their safety-relevant priority.

d) The safe handling as well as safe attachment and detachment of loads shall be supported by technical measures.

Table 4-1 shows typical examples. The technical measures shall be supplemented by administrative measures as regards the organisation of transports as per section 9.2 of KTA 3903.

5 Lifts in reactor containments

5.1 General requirements

Lifts shall meet the requirements of the Directive 2014/33/EU and be provided with a safety level according to DIN EN 81-20.

5.2 Passenger lifts and lifts used for transporting goods and passengers

Passenger lifts and lifts used for transporting goods and passengers shall be

a) connected to a emergency power supply,

b) connected to the alarm system of the nuclear power plant,

c) connected to the intercommunication system such that it is possible to communicate from the cabin with the pertinent permanently manned location,

d) equipped with a specially marked easy-to-open emergency exit.

5.3 Lift shaft

The lift shaft shall be

a) equipped with pressure-equalization openings to all rooms accessible from the lift shaft; the lift cage or the pressure-equalization openings shall be designed against raised external pressure such that they can withstand the dangers in accordance with sub-clause 4.3 (1) b),

b) equipped with devices for an emergency exit from which each lift-shaft door is easily accessible,

c) equipped with lift-shaft doors which can be easily unlocked from the inside,

d) designed such that the escape route can be easily recognized, and

e) equipped with emergency lighting connected to a continuous emergency power supply.

Requirement	Lifting equipment/component	Method (selection)	Items of equipment/auxiliary means (selection)	Design
Specified normal use of lifting equipment	Cranes, refueling machines	Structural design	Lockable control system	
	Lifting beams, hangers, rod assembly (capable of being extended, adapted, assembled), lifting accessories, load attachment points	Visual control	Colour coding of connections	Use clearly discernible colours
			Nameplates, other identification, markings	Plates shall be permanently and easily readable Orientation arrows, KKS [1)], part number
		Structural design	Unmistakable design	e.g. assigned bajonet joints
Load control, ease of running	Cranes, refueling machines	Visual control of load	Load indication on control desk and large display unit	Consistent indication for at least 2 persons
		By control techniques	Additional variably controllable overload protection during operation	Adaptation of overload protection device to the load
		Visual control of travel way	Use of wireless control Under water: camera, searchlight	Non-glare screen easily readable by at least 2 persons form their work position
Load attachment and detachment to meet the requirements	Cranes, refueling machines, lifting beams, hangers, load attachment points	Visual control	Indication of interlocked condition (by colour, mechanical) Under water: camera, searchlight	Recognizable (even under water), component-specific design Unambiguous indication of interlock condition (even in case of an interlock under water) Non-glare screen easily readable by at least 2 persons form their work position.
		Structural design	Interlocking e.g. provided by: - spring-loaded teeth, - bolt with guiding sleeve and connecting member, - spring-loaded safety retainer,	Interlocking under load always effective Consistent design principle (bolts always guided in same direction)
Maintenance of travel areas	Cranes, refueling machines	By control techniques	Travel limits, operational travel interlocks Electrically: travel limiter	Load-dependent travel limiter with indication of state at control points
Exact positioning, avoidance of erroneous positioning, faulty set down/-loading	Cranes	Visual control	Marking/positioning aids (camera, laser measurement)	Easy insight view and unambiguous
			Indication of position	e.g. x-y coordinates
	Refueling machines	Visual control	Visualisation system	Insight view by 2 persons possible
		By control techniques	Automatic operation	Monitoring via inventory management
Precautions against maloperation	Control desk of lifting equipment	Structural design	Simple actuating elements	Anatomically adapted
			Safety against unintentional operation	e.g. shrouded pushbutton
			Actuating elements conforming to expectancy	e.g. lever activated backwards means lifting, lever activated forward means lowering
			Unambiguous assignment of actuating direction and control state	
			Spatial separation/arrangement of operating elements according to function	
			Fault signal	

[1)] Power plant identification system, alternatively also plant identification system (AKZ)

Table 4-1: Examples for ergonomic design of lifting equipment as per sections 4.2 to 4.4 and use of auxiliary means

6 Additional requirements for cranes, winches, trolleys and load carrying devices

6.1 Structures

This section applies to the supporting structures of cranes, trolleys and winches.

6.1.1 Design

(1) For the application of this Safety Standard, two verification methods are permitted:

a) method using a global safety factor (σ_{zul} concept) according to DIN 15018-1

and

b) method using partial safety factors according to the standard series DIN EN 13001.

(2) The simultaneous use of both methods within the entire verification process for a lifting device is allowed only if the parts in question are clearly separated from each other and the transmittal of internal forces within the overall structure can be gathered entirely as well as the load bearing characteristics of the entire structure are ascertained correctly. Where an analytical proof regarding external events is to be carried out, clause 4.5 (5) shall be taken into account.

(3) The following data shall be specified for dimensioning the supporting structures:

a) erection loads including the corresponding working cycles over the intended deployment duration,

b) operational loads including the corresponding working cycles over the intended deployment duration,

c) loads from external events in accordance with section 4.5,

d) ambient conditions in accordance with section 4.6.

6.1.2 Analytic proof

6.1.2.1 Analytic proof using the global safety factor concept according to DIN 15018-1

(1) The stress analysis shall be performed in accordance with **Annex B,** section B 1.1.1.

(2) The supporting structures shall be classified with respect to

a) the maximum erection load: lifting class H1 and loading level group B2 in accordance with DIN 15018-1.

b) the maximum operational load: lifting class H3 and loading level group B3 in accordance with DIN 15018-1.

(3) Where a dynamic factor[1] less than that resulting from (2) is to be used, the maximum dynamic load factor occurring during one working cycle shall be determined by means of calculation or experimentally in each individual case. As regards the determination of the dynamic factor this dynamic load factor shall be multiplied by a safety factor of 1.12.

(4) A verification of service strength need not be carried out if it can be demonstrated that the number of stress cycles is below $2 \cdot 10^4$. The number of stress cycles shall be determined in accordance with **Annex B**, section B 1.2.1.2.

(5) In the case of connections made with preloaded bolts to be re-assembled upon disassembly, the following applies in addition to (4):

a) Where a verification of service strength is to be carried out as per (4), the stress cycles resulting from disassembly and re-assembly operations shall be taken into account in the analysis.

b) Where no verification of service strength is required as per sub-clause (4) and a maximum of 10 disassembly and reassembly operations is carried out, a verification of service strength may be waived.

c) Where more than 10 disassembly and re-assembly operations are carried out, a verification of service strength shall be carried out independently of the requirements of subcl. (4). In this case, both the stress cycles from operational loadings and from disassembly and re-assembly operations shall be taken into account.

6.1.2.2 Analytical proof using the partial safety factors concept according to the standard series DIN EN 13001

(1) The stress analysis shall be performed in accordance with **Annex B,** section B 1.1.2.

(2) The supporting structures shall be classified with respect to

a) the maximum erection load: stress history class S1 according to DIN EN 13001-3-1,

b) the maximum operational load: stress history class S3 according to DIN EN 13001-3-1.

(3) The fatigue analysis need not be carried out if the conditions according to section 6.3.3 of DIN EN 13001-3-1 so permit. The number of stress cycles shall be determined in accordance with **Annex B**, section B 1.2.1.2.

(4) In the case of connections made with preloaded bolts to be re-assembled upon disassembly, the following applies in addition to (3):

a) Where a fatigue analysis is to be carried out as per (3), the stress cycles resulting from disassembly and re-assembly operations shall be taken into account in the analysis.

b) Where no fatigue analysis is required as per subcl. (3) and a maximum of 10 disassembly and re-assembly operations is carried out, a fatigue analysis may be waived.

c) Where more than 10 disassembly and re-assembly operations are carried out, an analysis for cyclic operation shall be carried out independently of the conditions according to section 6.3.3 of DIN EN 13001-3-1. In this case, both the stress cycles from operational loadings and from disassembly and re-assembly operations shall be taken into account.

6.1.3 Design and structural requirements

Notes:

(1) Requirements for the design of supporting structures and structural requirements are also contained in DIN EN 1090-2.

(2) Requirements for the structural design of rails, rail connections, track bedding and rail fasteners are also contained in VDI 3576.

(1) When using the global safety factor concept together with an analytical proof according to DIN 15018-1, the design shall be based on DIN 15018-2.

(2) When using the partial safety factor concept together with an analytical proof according to the standard series DIN EN 13001, the design shall be based on the relevant stipulations of this standard series.

(3) Dynamically loaded weld seams shall meet the requirements of quality level B according to DIN EN ISO 5817 or DIN EN ISO 13919-1. Weld seams primarily subject to static loadings shall satisfy the requirements of quality level C of DIN EN ISO 5817 or DIN EN ISO 13919-1.

[1] *In DIN 15018-1 the term "nominal load spectrum factor" is used instead of "dynamic factor".*

(4) Hollow spaces in supporting structures of lifting equipment inside the containment shall be equipped with pressure equalization openings for the case of raised external pressure or shall be dimensioned to withstand these pressure conditions.

(5) The preloading of preloaded bolted connections shall be carried out according to the guideline DASt 024 of the German Committee for Steel Construction. The calculated preloading force shall be limited to the nominal minimum preloading force $F_{p,C}^* = 0{,}7 \cdot f_{yb} \cdot A_s$.

6.2 Hoists

This section applies to drive mechanisms and rope drives.

6.2.1 Drive mechanisms

This section applies to gear boxes, series gear boxes, series electric hoists, couplings and brakes.

6.2.1.1 Design

(1) The following data shall be specified for the design of drive mechanisms:

a) erection loads including the pertinent working cycles over the intended deployment duration,

b) operational loads including the pertinent working cycles over the intended deployment duration,

c) dead load of the load suspension devices and supporting means,

d) special loads, e.g. loads from the acceptance test, from in-service inspections, from test runs of the gear box, from actuation of the brakes, including the corresponding working cycles over the intended deployment duration,

   Note:

   When using systems to ascertain the braking effect without test load for in-service inspection, see also KTA 3903, Annex D, section D 3.1.

e) duty cycle of the hoist under erection load, operational load and dead load as well as pertinent average hoisting speed and average travel path,

f) ambient conditions in accordance with section 4.6.

(2) The dimensioning of series-produced parts like brakes, brake discs, couplings, shall be based on the design data to be determined in accordance with the corresponding forms of KTA 3903, Annex C.

(3) The roller bearings shall be dimensioned on the basis of the calculation principles of the roller bearing manufacturer. Dynamic loads may be subjected to cubic averaging methods which shall be based on a probability of failure of 3 % to be taken with $a_1 = 0.44$. The maximum test load shall be considered to be the static (continuous) load.

6.2.1.2 Analytic proofs

The analytic proofs shall be performed in accordance with **Annex B**, section B 1.2.

6.2.1.3 Design and structural requirements

6.2.1.3.1 General

(1) Hoists shall be equipped with an overload protection device which shall be adjusted to no more than 1.1 times the maximum operational load. The tolerance of the overload protection response level relating to the maximum operational load shall not exceed ± 5 %.

(2) Hoists shall be equipped with a meter for counting the running hours or the load collectives. A meter for monitoring the load collectives is required if the analytic proofs are based on a load collective.

   Note:

   It is presumed that the parameters counted with the load collective meter are adjusted to or transferrable to the assumptions of the design by analysis.

When using a meter that only counts the running time during which the drive mechanism is in motion, 50 % of the indicated time shall be considered full-load hours. When using a meter for load collectives, all loads greater than 10 % of the maximum operational load shall be recorded.

(3) If the weight of the supporting means amounts to more than 30 % of the maximum operational load, then the entire running time of the drive mechanism shall be recorded.

(4) Grey-cast iron bearing housings are not permitted.

6.2.1.3.2 Gear boxes

(1) Shaft-hub linkages with flat, hollow, sunk, tangent and gib-head keys are not allowed.

(2) Shaft hub connections with press fit assembly are permitted for series-production hoist gear boxes and series-production electric hoists with rope if they are designed and constructed according to the state-of-the-art.

(3) The offset between two fitting keys shall be at least 120°. The value of the bearing length of the key used in the analysis shall not exceed 1.2 times the shaft diameter.

(4) The design and construction of transmission gears shall meet the following requirements:

a) When calculating the load bearing capacity in accordance with DIN 3990-11, the limits of application and requirements of this DIN standard shall be taken into account.

b) When calculating the load bearing capacity according to the method of Niemann [2] in accordance with **Annex B** the following requirements ba) to bg) shall be taken into account.

   ba) The ratio of useable face width to pitch circle diameter, b/d_{w1} shall be smaller than or equal to 1.2 for the case of a rigid pinion shaft supported at both ends.

   bb) Longitudinal crowning and profile reduction are permitted provided they stay within the size of tooth deformation.

   bc) In case of a floating support of the transmission gears or if the bearings of the gear transmission are located on the supporting structure or if the requirement under ba) cannot be met, the width factor shall be determined by measurement or by a correspondingly accurate numerical analysis.

   This numerical analysis shall take into account any deformation and relocation that are essential with regard to load distribution over the gear width. Furthermore, the numerical analysis shall consider any fabrication deviations and corrections with their true sign.

   bd) The normal modulus m_n for transmission gears shall normally be equal to or greater than 1/25 of the useable face width, b. If the bearings of the gear transmission are located on the supporting structure or in the case of a floating support of the pinions, the normal modulus m_n shall be larger than b/25.

   be) No grinding recess is allowed on the side of the tooth.

   bf) In the case of ground teeth, protuberance profiles shall be used or the grinding shall be carried out down to the bottom of the tooth with a rounded-off tool head.

   bg) Sufficient lubrication shall be ensured. It shall be ensured that the lubrication has an adequate viscosity at the operating temperature.

(5) Grey-cast iron gear box housings are not allowed except for series-produced electric hoists. The weld seams of welded gear box housings shall satisfy the requirements of quality level C of DIN EN ISO 5817 or DIN EN ISO 13919-1.

(6) The gear box quality shall be chosen such that at zero load the tooth bearing

a) in the case of non-crowned teeth, is at least 60 % of the useable face width in counter direction to the deformation tendency under load

and

b) in the case of longitudinally crowned teeth, is at least 40 % of the useable face width beginning about at the centre of the tooth face and running in counter direction to the deformation tendency under load.

6.2.1.3.3 Brakes

(1) Two brakes (service brake and auxiliary brake) shall be located on the drive side upstream of the output transmission which shall act independently of each other.

(2) The brakes shall satisfy the requirements of DIN 15434-1. The required braking torque of each brake shall be designed for the maximum operational load.

(3) It shall be ensured that upon standstill of the drive mechanisms, the maximum operational load is held alone by the service or the auxiliary brake and that the maximum erection load is held by the service and the auxiliary brake, and in both cases with a 2-fold safety. The brakes shall be capable of withstanding the thermal and dynamic operational conditions.

(4) If the service brake fails, the auxiliary brake shall be capable of safely absorbing the increased energy of the system resulting from the failure condition.

(5) Where the drive is of the non-converter type, the auxiliary brake shall engage during any operational braking after a certain time delay with respect to the service brake. The delay time shall be fixed such that during operational braking at full lowering speed and maximum operational load the auxiliary brake engages at the latest when the lowering speed has reached a residual value of 5 %.

6.2.2 Rope drives

The section applies to ropes, rope sheaves, rope drums, rope end terminations and rope drum hinge connections.

6.2.2.1 Design

(1) The rope drives shall be classified in accordance with DIN 15020-1, in which case the larger of the resulting rope diameters shall be used:

a) for the maximum erection load at least drive mechanism group $1B_m$ according to DIN 15020-1. If the ratio of rope minimum breaking strength to static rope traction force is at least 3.5, and if ropes are used whose individual strands have a nominal strength up to 1960 N/mm^2, the design may be based on drive mechanism group $1E_m$.

b) for the maximum operational load at least drive mechanism group 2_m for dangerous transports.

(2) The dimensioning of rope sheaves and wedge sockets shall be based on the design data to be determined in accordance with the corresponding forms of KTA 3903, Annex C.

(3) The diameter of the rope drums, rope sheaves and compensating pulleys shall be dimensioned at least in accordance with drive mechanism group 2_m according to DIN 15020-1.

(4) The rope end terminations shall be dimensioned in accordance with DIN 15020-1.

(5) The rope drum wall thickness shall be calculated using the maximum prevalent dynamic force S_{max} from the load collective of operational conditions in accordance with **Annex B**, sub-clauses B 1.2.1.1 (2) a) to c). Stress peaks which occur rarely and for only very short periods of time need not be considered since they affect only a fraction of one rope wrap.

(6) Rope drum hinge connections shall be dimensioned on the basis of the load collective of operational conditions in accordance with **Annex B,** sub-clauses B 1.2.1.1 (2) a) to c) and shall be analyzed in accordance with the design principles of the manufacturer.

(7) The rope clips shall be dimensioned in accordance with SEB 666211 Suppl. Sheet 1, taking the structural circumstances into account.

6.2.2.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B,** section B 1.2.4.

6.2.2.3 Design and structural requirements

(1) Grey-cast iron rope sheaves and rope compensating pulleys are only allowed if they are series-produced and are protected against mechanical damage.

(2) The wire rope ends may be fastened as follows:

a) metal socketing in accordance with DIN EN 13411-4.

b) ferrules according to DIN EN 13411-3 provided the ropes have steel cores,

c) asymmetrical wedge sockets with a clamping angle of about 14°, a clamping length equal to 5 times the rope diameter and a bending radius at the rope key equal to 1.5 times the rope diameter. The rope key shall be marked with the rope diameter. The wedge socket shall have a breaking strength of at least 85 % of the minimum breaking strength of the rope.

d) clamping plates for fastening rope ends on the drum in accordance with section 6.4 of DIN 15020-1.

(3) The number of wraps assumed during design, but at least two safety windings of rope shall remain on the drum when the load hook is in its lowest position.

(4) Rope drums shall be of the single-layer winding type only. The orderly winding of the rope shall be monitored or be ensured by structural design measures (e.g. rope guide rings).

(5) The weld seams of welded rope drums shall satisfy the requirements of quality level B of DIN EN ISO 5817 or DIN EN ISO 13919-1.

6.3 Lateral transport drives

This section applies to the wheel bearings and wheels, wheel axles and shafts.

6.3.1 Design

The following data shall be specified for the dimensioning of lateral transport drives:

a) running time classification in accordance with Table 5 of the DIN calculation principles for drive mechanisms in lifting equipment [7],

b) standard load collective in accordance with Table 6 of the DIN calculation principles for drive mechanisms in lifting equipment [7],

c) running time of the drive motor (in terms of 1 h) in accordance with Table 4 of DIN 15070,

d) ambient conditions corresponding to section 4.6.

6.3.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B**, section B 1.3.

6.3.3 Design and structural requirements

(1) Lateral transport drives shall be equipped with wheel-fracture supports.

(2) DIN 15085 applies to the wheels.

6.4 Load carrying devices

This section applies to supporting means, load suspension devices and lifting accessories.

6.4.1 Supporting means

This section applies to jigs and fixtures permanently connected to the lifting equipment for the purpose of attaching load suspension devices, lifting accessories, or loads (e.g. load hooks, load hook mountings, grabs, lifting beams, hangers) as well as top and bottom blocks and the mountings for compensation pulleys and rope end terminations.

6.4.1.1 Design

(1) The load hooks shall be classified in accordance with DIN 15400 as follows:

a) for the maximum erection load at least classified in drive mechanism group $1B_m$,

b) for the maximum operational load at least classified in drive mechanism group 2_m.

(2) Stainless steel load hooks shall be classified with additional consideration given to the material characteristics.

(3) The design of supporting means as supporting structures shall be in accordance with the requirements of section 6.1.1 and the design of supporting means as machine parts in accordance with section 6.2.1.1.

(4) If bolted connections according to DIN EN ISO 898-1 and DIN EN ISO 898-2 or DIN EN ISO 3506-1 and DIN EN ISO 3506-2 subject to additional tensional loading are used, then the determined bolt load shall be increased by a factor of 1.12 both in the stress analysis and the fatigue analysis. These requirements need not be met if bolts acc. to KTA 3903, Annex A, materials test sheet WPB 3.17 are used.

6.4.1.2 Analytical proofs

(1) The analytical proofs shall be performed in accordance with **Annex B,** section B 1.4.

(2) A fatigue analysis is not required

a) for structural steel components

 aa) which are designed according to DIN 15018-1, provided a number of stress cycles $N_\sigma = 2 \cdot 10^4$ will not be exceeded,

 ab) which are designed according to the standard series DIN EN 13001, provided a fatigue analysis may be omitted for the respective case of application in compliance with this standard series,

b) for non-rotating mechanical parts and other parts, provided a number of 6,000 stress cycles will not be exceeded.

 Notes:

 (1) Structural steel components for the purposes of this Safety Standard are load-bearing elements made of welded or screwed together steel plates or rolled steel sections.

 (2) Other parts refer, inter alia, to parts where a stress evaluation on the basis of nominal stresses is not purposeful.

This requirement shall likewise apply if austenitic steels are used.

(3) In addition to (2) the requirements of clause 6.1.2.1 (5) apply in case of joints with preloaded bolts which, after disassembly, have to be re-assembled again.

6.4.1.3 Design and structural requirements

(1) The load shall be attached in a positive-locking way only. Structural safeguarding measures shall be taken against unintentional detachment of the load. The connections and individual items shall be designed such that they cannot be detached unintentionally. The safeguarding devices shall be designed and arranged so that such unintentional changes of their positions are excluded where their safety functions are ensured only to a limited extent or are completely cancelled.

(2) For the protection against damage the following requirements shall be met:

a) Hydraulic, pneumatic and electric lines shall be laid such that damage due to operational equipment movement is avoided.

b) where the lifting capacity can be adversely affected by wear, corrosion or other damaging influences it shall be ensured that the respective condition can be checked.

c) Firmly sheathed individual parts shall be protected against corrosion.

d) Movable sheathing shall be designed or arranged such that it is possible to uncover parts requiring an examination.

6.4.2 Load suspension devices

This section applies to jigs and fixtures not belonging to the lifting equipment, which can be connected to the supporting means of the lifting equipment for the purpose of attaching the load, e.g. load hooks, load hook mountings, lifting beams, hangers and grabs.

6.4.2.1 Design

(1) The design of load suspension devices as supporting structures shall be in accordance with the requirements of section 6.1.1 and the design of load suspension devices as machine parts in accordance with section 6.2.1.1.

(2) Section 6.4.1.1 applies to load hooks.

(3) The working load limit of

a) rope slings acc. to DIN EN 13414-1 and DIN EN 13414-2,

b) chain slings according to DIN EN 818-4,

c) components for lifting accessories according to DIN EN 1677-1, DIN EN 1677-2, DIN EN 1677-3, and DIN EN 1677-4,

d) shackles according to DIN EN 13889

respectively, as a fixed component part of load suspension devices may be utilized to reach not more than 50 % of the values specified in these standards. A dynamic factor need not be taken into account.

(4) If bolted connections according to DIN EN ISO 898-1 and DIN EN ISO 898-2 or DIN EN ISO 3506-1 and DIN EN ISO 3506-2 subject to additional tensional loading are used, then the determined bolt load shall be increased by a factor of 1.12 both in the stress analysis and the fatigue analysis. These requirements need not be met, if bolts acc. to KTA 3903, Annex A, materials test sheet WPB 3.17 are used.

6.4.2.2 Analytical proofs

The requirements of section 6.4.1.2 shall be met.

6.4.2.3 Design and structural requirements

(1) The requirements of section 6.4.1.3 shall be met.

(2) The use of rope slings and chain slings as fixed component parts of load suspension devices is permitted provided they meet the requirements of DIN EN 13414-1 and DIN EN 13414-2 as well as DIN EN 818-4, respectively, and if both are designed without sheaving and with defined load transmission points.

(3) Fibre ropes and woven bands are not permitted.

(4) Only chains according to DIN EN 818-2 and with an inside width $b_1 = 1.3 \cdot d$ are permitted.

(5) DIN EN 1677-1, DIN EN 1677-2, DIN EN 1677-3, and DIN EN 1677-4 shall apply to the components of lifting accessories.

(6) Chain attachment elements and connection parts shall be designed to be irremovable from the hanger and end links.

(7) The elements connecting the rope slings and chain slings to the load attachment points shall be designed to be unambiguously identifiable, where confusion of elements may lead to an unacceptable condition.

(8) Any surface treatment procedure used on chain slings shall be such that no damage occurs to the base material (e.g. hydrogen inclusion).

6.4.3 Lifting accessories

6.4.3.1 General

(1) This section applies to rope slings and chain slings.

(2) Lifting accessories shall be clearly assigned to fixed transport operations and shall only be used for operations they are assigned to.

6.4.3.2 Design

The working load limit of

a) rope slings acc. to DIN EN 13414-1 and DIN EN 13414-2,
b) chain slings according to DIN EN 818-4,
c) components for lifting accessories according to DIN EN 1677-1, DIN EN 1677-2, DIN EN 1677-3, and DIN EN 1677-4,
d) shackles according to DIN EN 13889

may be utilized to reach not more than 50 % of the values specified in these standards. A dynamic factor need not be taken into account.

6.4.3.3 Design and structural requirements

(1) Only rope slings according to DIN EN 13414-1 and DIN EN 13414-2 and chain slings that meet the requirements of DIN EN 818-4 as well as components for lifting accessories according to DIN EN 1677-1, DIN EN 1677-2, DIN EN 1677-3, and DIN EN 1677-4 are permitted.

(2) Rope slings and chain slings are permitted only if both are designed without sheaving and with defined load transmission points.

(3) The requirements specified in section 6.4.1.3 shall be met.

(4) The requirements specified in para 6.4.2.3 (3) through (8) shall be taken into account.

6.5 Electrical equipment

6.5.1 General

(1) Safety functions shall be provided which, in case of inadmissible operating conditions or inadmissible excess of limitations (travel, speed and loads, or a combination thereof), shall effect shutdown of the pertinent drives and prevent drives from starting up. The shutdown of a drive shall include the release of the required brakes.

(2) The control system shall be subdivided into an operational control system and a safety-related control system. The latter shall be independent of the operational control such that in case of specified normal operation, malfunction or failure of the operational control system, the function of the safety-related control system remains effective. In such case, the following shall be satisfied:

a) Functions required for lifting equipment operation, which do not monitor the occurrence of inadmissible operating conditions or inadmissible excess of limitations e.g. travelling control command shall be part of the operational control system.
b) The safety-related control system shall monitor the observance of all safety-relevant limit values of lifting equipment and, in the case of inadmissible operating conditions or inadmissible excess of limitations, shall transfer the lifting equipment to safe condition. Functions classified into Performance Levels c, d and e according to **Annex E**, shall be part of the safety-related control system.
c) Whenever software-based safety-related control systems are employed, only software shall be used, that has been developed and established satisfying the requirements for the software of class 2 I&C systems acc. to DIN EN IEC 62138, section 6.

(3) When realizing the functions required for safe operation of lifting equipment the requirements of DIN EN ISO 13849-1 shall basically be met, in which case the Performance Levels shall be determined to **Annex E,** section E 2. **Table E-1** assigns Performance Levels to the respective typical functions. Deviations from the Performance Level laid down in **Table E-1** shall be justified in each individual case.

Note:

The requirements of DIN EN ISO 13849-1 include that the failure behavior of mechanical components used for connection and actuation of sensors involved in the execution of safety functions shall be taken into account.

In lieu of the Performance Levels laid down in **Table E-1** according to DIN EN ISO 13849-1, the Safety Integrity Levels (SIL) defined in the standard series DIN EN 61508 may be used, in which case the requirements as per SIL 2 according to DIN EN 61508 are deemed to be equivalent to the requirements as per Performance Level “d“ according to DIN EN ISO 13849-1 and the requirements as per SIL 3 are deemed to be equivalent to the requirements as per Performance Level “e“.

(4) Safety-related functions of Performance Level “c“ to “e“ according to DIN EN ISO 13849-1 shall be effective independently of the operational control functions. Faults in operational control functions shall not render these safety-related functions ineffective. Safety-related functions of Performance Level “d“ shall be effective at least in category 3 and safety-related functions of Performance Level “e“ in category 4 according to DIN EN ISO 13849-1. The reaction times of all safety-related functions shall be sufficiently short to fulfil the respective safety task.

(5) When planning, designing and executing the safety-related functions of Performance Levels “c” to “e” according to DIN EN ISO 13849-1 the requirements contained in DIN IEC 61513 for functions of category B shall be met.

(6) For all limiting and interlocking functions required by this Safety Standard positively opening control switches operating to the closed-circuit current principle or another technique shall be used to obtain equivalent safety like in the case of positively opening control switches.

(7) Closed working cabins and operating cabins in cranes inside the controlled area shall be connected to the alarm system and the safety illumination system of the nuclear power plant such that alarms are perceived and escape routes are discernible.

(8) Measures shall be taken to make possible the unambiguous identification of the current version of hardware and software utilized for functions classified into Performance Levels c, d and e according to **Annex E**.

(9) Measures shall be taken to ensure that the in-service functional tests in accordance with KTA 3903 can be performed without manipulation of the electrical equipment (e.g. loosening of wire connections, removal of equipment parts). In this case, it shall be ensured that the entire signal path can be covered by the in-service functional tests.

Testing equipment shall be provided with an access-enable program so that it can be activated by authorized personnel only.

Where testing equipment not provided with automatic return is used, its activation shall be annunciated by a signal. Deactivated testing equipment shall not have any influence on the safety-related functions of Performance Levels “c” through “e” according to DIN EN ISO 13849-1 even in the case of fault.

For the in-service tests of safety travel limiters of hoists and lateral transport drives a release device shall be provided which, when activated, makes it possible for the crane operator, upon release of the travel limiter, to leave the travel way in opposite direction of movement at creep speed. The release device for leaving the safety travel limiter shall be of the locking-type and be provided with automatic return (e.g. key-operated pushbutton) and be positioned such that a second person (within the sense of the 4-eyes principle) can be employed to operate the release device.

6.5.2 Requirements for the electrical equipment

(1) It shall be possible to activate the crane switch only if it has been released by means of a key-operated switch or a similarly safeguarded switching device.

(2) The three-phase current supply shall be equipped with a phase-sequence relays and a phase conductor monitor. Where these monitoring devices respond, it shall not be possible to switch in the crane switch, and where the lifting equipment is operating, the crane switch shall switch off. The response of these monitoring devices shall initiate an alarm signal at the control points.

(3) The response of overcurrent protective devices shall switch off only the pertinent motor branch circuit, unless several motors are available for the same function which must be switched off simultaneously. The coils of hoist motors shall be equipped with sensors for monitoring the temperature. The response of overcurrent protective devices shall trigger an alarm signal at the control points.

(4) The actuation of the overload protection shall interrupt the hoist movement and trigger an alarm signal at the control points. Upon acknowledgement of the alarm signal lowering shall be possible.

The overload protection shall be set at no more than 1.1 times the maximum operational load.

The response tolerance of the overload protection relating to the maximum operational load shall not exceed ± 5 %.

For the putting of lifting equipment into operation the switching threshold shall be adapted to the swinging behaviour when lifting the load.

(5) The hoists shall be equipped with a meter for monitoring the running time or the load collective in accordance with section 6.2.1.3.1. Measures shall be taken to prevent data loss (e.g. by redundant data storage, storage on fail-safe medium or regular data saving).

(6) It must be possible to actuate the hoist brakes individually and independently of each other; the brakes shall be connected to all phases. In the case of non-converter operated drives, the auxiliary brake in accordance with para. 6.2.1.3.3 (5) shall engage after a certain time delay after the service brake.

A warning shall be triggered at the control points if the brake lining thickness of the service brake is less than the minimum thickness and if the service or the auxiliary brake do not open or close (activity of the brake bleeding device). In case of electromagnetic compact brakes it is permitted to derive the indication that the brake does not open or close from one switch only. Sliding rotor motors with integrated brakes are exempted from the requirement regarding a non-opening or non-closing alarm.

Note:
When using systems to ascertain the braking effect without test load for in-service inspection, see also KTA 3903, Annex D, section D 3.1.

(7) If non-converter drives are used, the lateral transport drives and hoists shall have at least one creep speed aside from the nominal speed. Accelerations and decelerations shall be kept low when changing speed.

(8) In the case of converter drives, monitoring shall be required such that the lifting equipment is stopped at zero position of the control system and maintained at standstill and that, at activation of the control system, movement is in the right direction.

(9) In the case of electrically driven load suspension devices respective position indications shall be provided at the control points (e.g. grab opened, grab closed).

(10) It shall be ensured by means of electrical interlock that the control command for detachment of an attached load (e.g. control signal “Open grab“ cannot be released unintentionally or at positions which are not permitted as regards safety.

(11) Where the orderly winding up of the rope on the drum cannot be ensured by structural measures, monitoring is required. Where monitoring shows an inadmissible deviation, a standstill shall be effected and an alarm signal be released at the control points.

6.5.3 Limiting functions

(1) To limit the crane and trolley movement as well as the lifting and lowering movement, operational travel limiters in accordance with **Table E-1** shall be provided. Additional safety travel limiters shall be provided in accordance with **Table E-1**.

a) for lateral transport drives where no mechanical travel way end limiters are provided,
b) for hoists at the top and bottom end of hoist travel way.

(2) Where electronic travel way measuring systems are used for safety-related functions of Performance Levels “c” through “e” according to DIN EN ISO 13849-1,

a) the adjustment function (preset) of these systems shall be released by technical measures (e.g. key-operated switches),
b) redundant travel way measuring systems shall basically be designed and arranged such that a simultaneous mechanically caused failure of the transmitters is excluded,
c) a monitoring device for the detection of a sensor failure due to mechanical reasons is required in the case of redundant travel way measuring systems that cannot meet the requirement according to b) and in the case of non-redundant travel way measuring systems,
d) a slip-free drive is required if absolute value encoders are used.

(3) Where the operational travel limiter responds, its slowing-down path shall be dimensioned such that drive standstill is effected prior to reaching the safety travel limiter position. Upon response of the operational travel limiter, movement in the respective opposite direction shall be possible.

(4) As long as the safety travel limiter is actuated, no movement of the lateral transport drive or hoist shall be possible. For in-service inspections measures shall be taken to make movement in opposite direction possible upon running into the safety travel limiter. The response of the safety travel limiter shall trigger an alarm signal at the control points.

(5) It shall be ensured by technical measures that mechanical travel limiters and safety travel limiters can only be approached with the allowable speed. Measures to limit and monitor the allowable speed at the lateral transport drive and hoist end positions are not required if

a) for lateral transport drives

   aa) the mechanical travel way end limiter is designed for the nominal speed

   or

   ab) the slowing-down path provided for at response of the safety travel limiter is dimensioned such that the mechanical travel limiter is not approached or only at the allowable speed,

b) for hoists the slowing-down path provided for at response of the safety travel limiter is adequately dimensioned.

(6) If, for safety reasons, the lifting and lateral movements need be partially or entirely restricted (e.g. movements above the fuel pool), this shall be ensured by a respective interlock function. The activation of the interlock shall trigger an alarm at the control points.

6.5.4 Control and alarm systems

6.5.4.1 Control system

(1) An interlock shall be provided to ensure that no drives are started up when activating lifting equipment (even in the case of an activated control device).

(2) In the case of drives with specific speed levels, the speed controls for the hoists and lateral transport drives shall be designed such that the maximum speed can only be set by passing through the individual speed levels starting at zero. The individual speed levels shall be displayed at the controls.

(3) The controls shall be designed not to be self-locking. Mechanical controls shall be designed to self-reset into normal position. This is not required if a release switch in the control mechanism initiates the resetting procedure electronically.

(4) At the controls, the direction of movement shall be clearly discernible and identical to the markings on the lifting equipment or building.

(5) All control points shall be equipped with an "emergency-off" switch for all-pole disconnection which turns off all drives. This switch shall remain operative even at inactivated control points. The emergency-off function shall be designed according to DIN EN 60204-32 in stop category “0“ or stop category “1“. Where stop category “1” is used, the delayed safe shut-off (less than 0.5 seconds) shall be initiated independently of the drive standstill reached.

(6) For transport operations according to KTA 3903, subclause 9.2 (10) a switch-off device, e.g. an additional “emergency-off switch” shall be provided for all-pole disconnection of drives by the supervising person. The position of this switch-off device shall make a sufficient overview on the respective work area possible.

(7) Where several control points are available, they shall be interlocked such that the lifting equipment is controllable from only one point.

(8) Wireless controls shall meet the requirements of DIN EN 60204-32, section 9.2.7.

6.5.4.2 Signalling systems

(1) The signalling systems shall differentiate between report signals, e.g. operational conditions or interlocks, warning signals, e.g. changes or imminent changes of operational conditions, and alarm signals effecting switching off.

(2) The report signals shall be optically displayed, warning and alarm signals both as optical and as acoustic signals.

(3) It shall be possible to test the optical displays and sound generators by actuating a test button.

(4) Optical displays shall remain actuated until the corresponding condition has been eliminated. When warning signals and alarm signals have been acknowledged, the optical displays shall change from blinking to continuous light and the acoustic signal shall be muted. Any subsequent warning or alarm signal shall reactivate the acoustic signal.

7 Increased requirements for cranes, winches, trolleys and load carrying devices

7.1 Structures

This section applies to the supporting structures of cranes, trolleys and winches.

7.1.1 Design

(1) For the application of this Safety Standard, two verification methods are permitted:

a) method using a global safety factor (σ_{zul} concept) according to DIN 15018-1

and

b) method using partial safety factors according to the standard series DIN EN 13001.

(2) The simultaneous use of both methods within the entire verification process for a lifting device is allowed only if the parts in question are clearly separated from each other and the transmittal of internal forces within the overall structure can be gathered entirely as well as the load bearing characteristics of the entire structure are ascertained correctly. Where an analytical proof regarding external events is to be carried out, clause 4.5 (5) shall be taken into account.

(3) The following data shall be specified for dimensioning the supporting structures:

a) erection loads including the corresponding working cycles over the intended deployment duration,

b) operational loads including the corresponding working cycles over the intended deployment duration,

c) loads from external events in accordance with section 4.5,

d) ambient conditions in accordance with section 4.6.

7.1.2 Analytical proof

7.1.2.1 Analytical proof using the global safety factor concept according to DIN 15018-1

(1) The analytical proof shall be performed in accordance with **Annex B**, section B 2.1.1.

(2) The supporting structures shall be classified with respect to

a) the maximum erection load: lifting class H1 and loading level group B2 according to DIN 15018-1.

b) the maximum operational load: lifting class H4 and loading level group B4 according to DIN 15018-1.

(3) Where a dynamic factor less than that resulting from (2) is to be used, the maximum dynamic load factor occurring during one working cycle shall be determined by means of calculation or experimentally in each individual case. As regards the determination of the dynamic factor this dynamic load factor shall be multiplied by a safety factor of 1.25.

(4) The loading resulting from shifting load shall be considered a special load case in accordance with DIN 15018-1 for the supporting structure.

(5) A verification of service strength need not be carried out if it can be demonstrated that the number of stress cycles is below $2 \cdot 10^4$. The number of stress cycles shall be determined in accordance with **Annex B**, section B 1.2.1.2.

(6) In the case of connections made with preloaded bolts to be re-assembled upon disassembly the following applies in addition to (5):

a) Where a verification of service strength is to be carried out as per (5), the stress cycles resulting from disassembly and re-assembly operations shall be taken into account in the analysis.

b) Where no verification of service strength is required as per subclause (5) and a maximum of 10 disassembly and re-assembly operations is carried out, a verification of service strength may be waived.

c) Where more than 10 disassembly and re-assembly operations are carried out, a verification of service strength shall be carried out independently of the requirements of subclause (5). In this case, both the stress cycles from operational loadings and from disassembly and re-assembly operations shall be taken into account.

7.1.2.2 Analytical proof using the partial safety factors concept according to the standard series DIN EN 13001

(1) The stress analysis shall be performed in accordance with **Annex B**, section B 2.1.2.

(2) The supporting structures shall be classified with respect to

a) the maximum erection load: stress history class S1 according to DIN EN 13001-3-1,

b) the maximum operational load: stress history class S4 according to DIN EN 13001-3-1.

(3) The fatigue analysis need not be carried out if the conditions according to section 6.3.3 of DIN EN 13001-3-1 so permit. The number of stress cycles shall be determined in accordance with **Annex B**, section B 1.2.1.2.

(4) In the case of connections made with preloaded bolts to be re-assembled upon disassembly, the following applies in addition to (3):

a) Where a fatigue analysis is to be carried out as per (3), the stress cycles resulting from disassembly and re-assembly operations shall be taken into account in the analysis.

b) Where no fatigue analysis is required as per subcl. (3) and a maximum of 10 disassembly and re-assembly operations is carried out, the fatigue analysis may be waived.

c) Where more than 10 disassembly and re-assembly operations are carried out, an analysis for cyclic operation shall be carried out independently of the conditions according to section 6.3.3 of DIN EN 13001-3-1. In this case, both the stress cycles from operational loadings and from disassembly and re-assembly operations shall be taken into account.

7.1.3 Design and structural requirements

The requirements of section 6.1.3 shall be met.

7.2 Hoists

This section applies to drive mechanisms and rope drives.

7.2.1 Drive mechanisms

This section applies to gear boxes, series gear boxes, series electric hoists, couplings and brakes.

7.2.1.1 Design

(1) The following data shall be specified for the design of drive mechanisms:

a) erection loads including the pertinent working cycles over the intended deployment duration,

b) operational loads including the pertinent working cycles over the intended deployment duration,

c) dead load of the load suspension devices and supporting means,

d) special loads, e.g. loads from the acceptance test, from in-service inspections, from test runs of the gear box, from actuation of the brakes, including the corresponding working cycles over the intended deployment duration,

Note:

When using systems to ascertain the braking effect without test load for in-service inspection, see also KTA 3903, Annex D, section D 3.1.

e) duty cycle of the hoist under erection load, operational load and dead load as well as pertinent average hoisting speed and average travel path,

f) duty cycle for which a lifting equipment with double drive mechanism chain shall be designed to manipulate the load after failure of one drive mechanism chain.

g) ambient conditions in accordance with section 4.6.

(2) When dimensioning the hoists with a double drive mechanism chain, both drive mechanism chains shall be considered as mutually carrying the load under consideration of para 1 f). This does not apply to the brakes.

(3) The safety brake shall be designed for the maximum operational load with due consideration of the maximum possible failure load in the drive mechanism chain. The design moment shall be at least 1.4 times the static load moment. The braking distance of the safety brake for maximum possible failure load shall, basically, not exceed three times the braking distance of the service brake.

The following assumptions are permitted as basis for the analytical demonstration that the braking distance of the safety brake does not exceed three times the braking distance of the operational brake:

a) The braking distance of the service brake may be calculated using the theoretical minimum braking torque (two times the static load moment) and the delay times of the brake and the control system to be expected.

b) The braking distance of the safety brake may be calculated using the nominal values of delay times and braking torques.

The acceptability of larger braking distances shall be demonstrated for each individual case, where in the case of slow lowering speeds the acceptability - upon agreement with the authorized inspector - may be demonstrated by complying with a maximum allowable absolute value of the braking distance.

Note:

The braking distance of the service brake is understood to be the entire distance travelled from the moment of actuating the brakes by an "emergency-off" to total arrest of motion. The braking distance of the safety brake is understood to be the entire distance travelled from the moment of failure to total arrest of motion.

(4) The dimensioning of series-produced parts like brakes, brake discs, couplings, shall be based on the design data to be determined in accordance with the corresponding forms of KTA 3903, Annex C.

(5) The roller bearings shall be dimensioned on the basis of the calculation principles of the roller bearing manufacturer. Dynamic loads may be subjected to cubic averaging methods which shall be based on a probability of failure of 1 % to be taken with a_1 = 0.21. The maximum test load shall be considered to be the static (continuous) load.

7.2.1.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B**, section B 2.2.

7.2.1.3 Design and structural requirements

7.2.1.3.1 General

(1) Section 6.2.1.3.1 applies to hoists.

(2) In addition, hoists shall be equipped with a double drive mechanism chain or with a single drive mechanism chain with a safety brake.

(3) In the case of hoists with a double drive mechanism chain, redundancy is required for all mechanical parts in the load path according to sub-clause 2 (1) a), as well as for the brakes. This requirement does not apply to load hooks and the supporting structures of the top and bottom blocks.

(4) It shall be possible even during non-stationary operation to define the static condition of both drive mechanism chains.

(5) In the case of a single drive mechanism chain with safety brake, redundancy is required for the ropes and rope sheaves.

(6) The failure of a part within a double drive mechanism chain or within a single drive mechanism chain with safety brake shall initiate shutdown of the drive mechanism.

(7) If systems and auxiliary media (liquids, gases) are installed to take up or dampen a load shifting pulse, this system shall be monitored (e.g. pressure, filling level). Any impermissible deviation shall initiate shutdown of the drive mechanisms.

(8) In case of hoists for handling

a) fuel elements, rod cluster control elements and core instrumentation lances in pressurised water reactors,
b) fuel elements, control rods and fuel channels in boiling water reactors,
c) enclosures of core components

the loads arising at the load attachment points of these core components due to load shifting shall be limited.

The design shall ensure that the loads arising from load shifting do not lead to more unfavourable loadings at the load attachment points than those arising from the dead weight of the core component, multiplied by a load intensification factor of 4.

7.2.1.3.2 Gear boxes

Section 6.2.1.3.2 applies to the gear boxes.

7.2.1.3.3 Brakes

(1) Section 6.2.1.3.3 applies to brakes.

(2) In case of a break of the shaft or gear box, the safety brake shall engage on the rope drum or at the end of the drive mechanism chain. It shall be possible to safely set down the load by means of devices or operational measures.

7.2.2 Rope drives

This section applies to ropes, rope sheaves, rope drums, rope end terminations and the rope drum hinge connection.

7.2.2.1 Design

(1) Section 6.2.2.1 applies to the design of rope drives.

(2) In addition, the following applies: If the maximum operational load is applied in consideration of the dynamic loading upon failure of a part in a rope drive, then the rope diameter shall be such that after failure of a part in one rope drive a minimum safety against failure of 2.5 with respect to the rope minimum breaking strength is demonstrated in the other load-carrying rope drive.

(3) The design forces and moments for the rope drum hinge connections shall be increased by 20 %.

7.2.2.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B**, section B 2.2.4.

7.2.2.3 Design and structural requirements

(1) Section 6.2.2.3 applies to rope drives.

(2) In addition, in case of a single drive mechanism chain with a safety brake each rope drum shall be equipped with a support bearing that is designed such that the safety brake remains effective in the case of a break in the shaft or gear box and that the load can be safely set down in the case of a failure of a drum bearing or break of the drum trunnion.

7.3 Lateral transport drives

This section applies to the wheel bearings and wheels, wheel axles and shafts.

7.3.1 Design

Section 6.3.1 applies to the design of lateral transport drives.

7.3.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B**, section B 1.3.

7.3.3 Design and structural requirements

Section 6.3.3 applies to the design and structural requirements of lateral support drives.

7.4 Load carrying devices

This section applies to supporting means, load suspension devices and lifting accessories.

7.4.1 Supporting means

This section applies to jigs and fixtures permanently connected to the lifting equipment for the purpose of attaching load suspension devices, lifting accessories, or loads (e.g. load hooks, load hook mountings, grabs, lifting beams, hangers as well as top and bottom blocks and the mountings for compensation pulleys and rope end terminations.

7.4.1.1 Design

(1) The load hooks shall be classified with respect to the drive mechanism groups in accordance with sub-clauses

6.4.1.1 (1) and (2), however, with respect to the operational load at least in drive mechanism group 3_m.

(2) The design of supporting means as supporting structures shall be in accordance with the requirements of section 7.1.1 and the design of supporting means as machine parts in accordance with section 7.2.1.1.

(3) In the case of non-redundant supporting means 1.25 times the dynamic factor shall be used in the analysis. Para. 1 applies to the load hook.

(4) If bolted connections according to DIN EN ISO 898-1 and DIN EN ISO 898-2 or DIN EN ISO 3506-1 and DIN EN ISO 3506-2 subject to additional tensional loading are used, then the required number of bolts shall be doubled or the determined bolt load shall be increased by a factor of 1.5 both in the stress analysis and the fatigue analysis. These requirements need not be met if bolts according to KTA 3903, Annex A, materials test sheet WPB 3.17 are used.

7.4.1.2 Analytical proofs

(1) The analytical proofs shall be performed in accordance with **Annex B**, section B 2.4.

(2) The stipulations of clauses 6.4.1.2 (2) and 6.4.1.2 (3) apply.

7.4.1.3 Design and structural requirements

The requirements of section 6.4.1.3 apply.

7.4.2 Load suspension devices

This section applies to jigs and fixtures not belonging to the lifting equipment, which can be connected to the supporting means of the lifting equipment for the purpose of attaching the load, e.g. load hooks, load hook mountings, lifting beams, hangers and grabs.

7.4.2.1 Design

(1) The design of load suspension devices as supporting structures shall be in accordance with the requirements of section 7.1.1 and the design of load suspension devices as machine parts in accordance with section 7.2.1.1.

(2) Section 7.4.1.1 applies to load hooks.

(3) In the case of non-redundant load suspension devices 1.25 times the dynamic factor shall be used in the analysis.

(4) The requirements of sub-clauses 6.4.2.1 (3) and of 7.4.1.1 (4) apply.

7.4.2.2 Analytical proofs

The requirements of section 7.4.1.2 apply.

7.4.2.3 Design and structural requirements

The requirements of section 6.4.2.3 apply.

7.4.3 Lifting accessories

The requirements of section 6.4.3 apply.

7.5 Electrical equipment

The requirements of section 6.5 shall be met. In addition to section 6.5, the following applies:

a) The loss of one outer conductor of the hoist motor or drive converter power supply shall automatically lead to an all-phase switch-off of the hoist motor. The loss of one outer conductor shall trigger an alarm signal at the control points.

b) In the case of hoists with a single drive mechanism chain a monitoring device shall be provided to engage the safety brake in case of damage caused by break of the shaft or gear box. Where, in case of failure of this function, an event beyond the accident planning reference levels of § 104 of the Radiation Protection Ordinance is to be assumed and where the function is provided by means of software-based systems, monitoring of hoists with a maximum operational load greater than 5 t shall be ensured by two independent and varying devices (for examples see **Figures E-2** and **E-4**). In this case, one of the monitoring devices shall detect the break of the shaft or gear box by continuous comparison of rotational movement of the drive motor and the rope drum. The engagement of the safety brake at hoist movement shall be recorded by a meter. The non-disengaging of the safety brake shall be monitored.

c) The reinstatement to operation after failure of a part in one drive mechanism chain shall only be possible by means of a key switch in the electrical operation room.

d) Where, in case of failure of the safety travel limiter at the hoist gear travel end, an event beyond the accident planning reference levels of § 104 of the Radiation Protection Ordinance is to be assumed and where the function is to be provided by means of software-based systems, switching-off in case of excess of the allowable speed and of the safety travel limiter shall be effected by two independent and varying devices (for examples see **Figures E-1**, **E-3** and **E-4**).

e) The failure of a part in a double drive mechanism chain or in a drive mechanism chain with safety brake shall lead to a shutdown of the drive mechanism and shall trigger an alarm signal at the control points.

f) If systems and auxiliary media (liquids, gases) are provided to take up or dampen a load shifting pulse, this system shall be monitored (e.g. pressure, filling level). Any impermissible deviation shall initiate arrest of motion and shall trigger an alarm signal at the control points.

g) A continuous load indicator shall be provided at the control points.

h) If for certain transports a limitation of the load in the part-load area of the maximum operational load is required, it shall be ensured in addition to the overload protection as per 6.5.2 (4) that further limit values for overload can be adjusted.

8 Requirements for refueling machines for light water reactors

8.1 Structures

This section applies to the supporting structures of cranes and trolleys.

8.1.1 Design

(1) For the application of this Safety Standard, two verification methods are permitted:

a) method using a global safety factor (σ_{zul} concept) according to DIN 15018-1

and

b) method using partial safety factors according to the standard series DIN EN 13001.

(2) The simultaneous use of both methods within the entire verification process for a lifting device is allowed only if the

parts in question are clearly separated from each other and the transmittal of internal forces within the overall structure can be gathered entirely as well as the load bearing characteristics of the entire structure are ascertained correctly. Where an analytical proof regarding external events is to be carried out, clause 4.5 (5) shall be taken into account.

(3) The following data shall be specified for dimensioning the supporting structures:

a) operational loads including the pertinent working cycles over the intended deployment duration,
b) loads from external events in accordance with section 4.5,
c) ambient conditions in accordance with section 4.6.

8.1.2 Analytical proof

8.1.2.1 Analytical proof using the global safety factor concept according to DIN 15018-1

(1) The analytical proof shall be performed in accordance with **Annex B**, section B 2.1.1.

(2) The supporting structures shall be classified with respect to the maximum operational load in lifting class H4 and loading level group B4 in accordance with DIN 15018-1.

(3) Where a dynamic factor less than that resulting from (2) is to be used, the maximum dynamic load factor occurring during one working cycle shall be determined by means of calculation or experimentally in each individual case. As regards the determination of the dynamic factor this dynamic load factor shall be multiplied by a safety factor of 1.25.

(4) The loadings resulting from load shifting shall be considered a special load case in accordance with DIN 15018-1 for the supporting structure.

(5) A verification of service strength need not be carried out if it can be demonstrated that the number of stress cycles is below $2 \cdot 10^4$. The number of stress cycles shall be determined in accordance with **Annex B**, section B 1.2.1.2.

(6) In the case of connections made with preloaded bolts to be re-assembled upon disassembly the following applies in addition to (5):

a) Where a verification of service strength is to be carried out as per (5), the stress cycles resulting from disassembly and re-assembly operations shall be taken into account in the analysis.
b) Where no verification of service strength is required as per subclause (5) and a maximum of 10 disassembly and re-assembly operations is carried out, a verification of service strength may be waived.
c) Where more than 10 disassembly and re-assembly operations are carried out, a verification of service strength shall be carried out independently of the requirements of subclause (5). In this case, both the stress cycles from operational loadings and from disassembly and re-assembly operations shall be taken into account.

8.1.2.2 Analytical proof using the partial safety factors concept according to the standard series DIN EN 13001

(1) The stress analysis shall be performed in accordance with **Annex B,** section B 2.1.2.

(2) The supporting structures shall be classified with respect to the maximum operational load: stress history class S4 according to DIN EN 13001-3-1.

(3) The fatigue analysis need not be carried out if the conditions according to section 6.3.3 of DIN EN 13001-3-1 so permit. The number of stress cycles shall be determined in accordance with **Annex B**, section B 1.2.1.2.

(4) In the case of connections made with preloaded bolts to be re-assembled upon disassembly, the following applies in addition to (3):

a) Where a fatigue analysis is to be carried out as per (3), the stress cycles resulting from disassembly and re-assembly operations shall be taken into account in the analysis.
b) Where no fatigue analysis is required as per subcl. (3) and a maximum of 10 disassembly and re-assembly operations is carried out, the fatigue analysis may be waived.
c) Where more than 10 disassembly and re-assembly operations are carried out, an analysis for cyclic operation shall be carried out independently of the conditions according to section 6.3.3 of DIN EN 13001-3-1. In this case, both the stress cycles from operational loadings and from disassembly and re-assembly operations shall be taken into account.

8.1.3 Design and structural requirements

(1) The requirements of section 6.1.3 apply.

(2) The refueling machines shall be constructed such that corresponding compensation measures counteract the deflection of the bridge girders in order to make vertical lifting possible during insertion and removal of fuel assemblies.

8.2 Hoists

This section applies to drive mechanisms and rope drives.

8.2.1 Drive mechanisms

This section applies to gear boxes, series gear boxes, couplings and brakes.

8.2.1.1 Design

(1) The following data shall be specified for the design of drive mechanisms:

a) operational loads including the pertinent working cycles over the intended deployment duration,
b) dead load of the load carrying device,
c) special loads, e.g. loads from the acceptance test, from in-service inspections, from test runs of the transmission, from actuation of the brakes, including the corresponding working cycles over the intended deployment duration,

   Note:
   When using systems to ascertain the braking effect without test load for in-service inspection, see also KTA 3903, Annex D, section D 3.1.

d) duty cycle of the hoist under operational load and dead load as well as pertinent average hoisting speed and average travel paths,
e) duty cycle for which a lifting equipment with double drive mechanism chain shall be designed to manipulate the load after failure of one drive mechanism chains.
f) ambient conditions in accordance with section 4.6.

(2) When dimensioning the hoists with a double drive mechanism chain, both drive mechanism chains shall be considered as mutually carrying the load under consideration of para. (1) e). This does not apply to the brakes.

(3) The safety brake shall be designed for the maximum operational load with due consideration of the maximum possible failure load in the drive mechanism chain. The design moment shall be at least 1.4 times the static load moment. The braking distance of the safety brake for maximum possi-

ble failure load shall basically not exceed three times the braking distance of the service brake.

The following assumptions are permitted as basis for the analytical demonstration that the braking distance of the safety brake does not exceed three times the braking distance of the service brake:

a) The braking distance of the service brake may be calculated using the theoretical minimum braking torque (two times the static load moment) and the delay times of the brake and the control system to be expected.

b) The braking distance of the safety brake may be calculated using the nominal values of delay times and braking torques.

The acceptability of larger braking distances shall be demonstrated for each individual case, where in the case of slow lowering speeds the acceptability - upon agreement with the authorized inspector - may be demonstrated by complying with a maximum allowable absolute value of the braking distance.

Note:
The braking distance of the service brake is understood to be the entire distance travelled from the moment of actuating the brakes by an "emergency-off" to total arrest of motion. The braking distance of the safety brake is understood to be the entire distance travelled from the moment of failure to total arrest of motion.

(4) The dimensioning of series-produced parts like brakes, brake discs, couplings, shall be based on the design data to be determined in accordance with the corresponding forms of KTA 3903, Annex C.

(5) The roller bearings shall be dimensioned on the basis of the calculation principles of the roller bearing manufacturer. Dynamic loads may be subjected to cubic averaging methods which shall be based on a probability of failure of 1 % to be taken with a_1 = 0.21. The maximum test load shall be considered to be the static (continuous) load.

8.2.1.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B**, section B 2.2.

8.2.1.3 Design and structural requirements

8.2.1.3.1 General

(1) Section 6.2.1.3 applies to hoists.

(2) In addition, hoists shall be equipped with a double drive mechanism chain or with a single drive mechanism chain with a safety brake.

(3) In the case of hoists with a double drive mechanism chain, redundancy is required for all mechanical parts in the load path according to sub-clause 2 (1) a), as well as for the brakes. This requirement does not apply to grabs and their load guides.

(4) It shall be possible even during non-stationary operation to define the static condition of both drive mechanism chains.

(5) In the case of a single drive mechanism chain with safety brake, redundancy is required for the ropes and rope sheaves.

(6) The failure of a part within a double drive mechanism chain or within a single drive mechanism chain with safety brake shall initiate shutdown of the drive mechanism.

(7) Slack rope monitoring shall be carried out and equipment for a continuous measurement of the load be provided.

(8) It must be possible to set down the fuel assembly in a safe position, even in the case of power failure or failure of a part in the drive mechanism.

(9) The movements of all manually operated parts, with the exception of the emergency drives, shall be limited in a reliable way.

(10) If systems and auxiliary media (liquids, gases) are installed to take up or dampen a load shifting pulse, this system shall be monitored (e.g. pressure, filling level). Any impermissible deviation shall initiate arrest of motion.

(11) In case of hoists for handling

a) fuel elements, rod cluster control elements and core instrumentation lances in pressurised water reactors,

b) fuel elements, control rods and fuel channels in boiling water reactors,

c) enclosures of core components

the loads arising at the load attachment points of these core components due to load shifting shall be limited.

The design shall ensure that the loads arising from load shifting do not lead to more unfavourable loadings at the load attachment points than those arising from the dead weight of the core component, multiplied by a load intensification factor of 4.

8.2.1.3.2 Gear boxes

Section 6.2.1.3.2 applies to the gear boxes.

8.2.1.3.3 Brakes

(1) Section 6.2.1.3.3 applies to brakes.

(2) In the case of a break of the shaft or gear box, the safety brake shall engage on the rope drum or at the end of the drive mechanism chain. It shall be possible to safely set down the load by means of devices or operational measures.

8.2.2 Rope drives

This section applies to ropes, rope sheaves, rope drums, rope end terminations and the rope drum hinge connection.

8.2.2.1 Design

(1) Section 6.2.2.1 applies to the design of rope drives.

(2) In addition to section 6.2.2.1, if the maximum operational load is applied in consideration of the dynamic loading upon failure of a part in a rope drive, then the rope diameter shall be such that after failure of a part in one rope drive a minimum safety against failure of 2.5 with respect to the rope minimum breaking strength is demonstrated in the other load-carrying rope drive.

(3) The design forces and moments for the rope drum hinge connections shall be increased by 20 %.

8.2.2.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B**, section B 2.2.4.

8.2.2.3 Design and structural requirements

(1) Section 6.2.2.3 applies to rope drives.

(2) In addition, each rope drum shall be equipped with a support bearing that is designed such that the safety brake remains effective in the case of a break in the shaft or gear box or that the load can be safely set down in the case of a failure of a drum bearing or break of the drum trunnion.

8.3 Lateral transport drives

This section applies to the wheel bearings and wheels, wheel axles and shafts.

8.3.1 Design

Section 6.3.1 applies to the design of lateral transport drives.

8.3.2 Analytical proofs

The analytical proofs shall be performed in accordance with **Annex B**, section B 1.3.

8.3.3 Design and structural requirements

Section 6.3.3 applies to the design and structural requirements of lateral support drives.

8.4 Load carrying devices

This section applies to grabs and load guides of refueling machines, e.g. telescoping mast and guide tube.

8.4.1 Design

(1) The design of load guides as supporting structures shall be in accordance with the requirements of section 8.1 and the design of grabs in accordance with section 8.2.

(2) For non-redundant parts 1.25 times the dynamic factor shall used in the analysis.

(3) If bolted connections according to DIN EN ISO 898-1 and DIN EN ISO 898-2 or DIN EN ISO 3506-1 and DIN EN ISO 3506-2 subject to additional tensional loading are used, then the required number of bolts shall be doubled or the determined bolt load shall be increased by a factor of 1.5 both in the stress analysis and the fatigue analysis. These requirements need not be met if bolts according to KTA 3903, Annex A, materials test sheet WPB 3.17 are used.

8.4.2 Analytical proofs

(1) The analytical proofs shall be performed in accordance with **Annex B**, section B 2.4.

(2) The stipulations of clauses 6.4.1.2 (2) apply.

8.4.3 Design and structural requirements

(1) The load shall be attached in a positive-locking way only.

(2) The grabs shall be interlocked in two independent ways against unintentional opening and opening in locations that are non-permissible for safety reasons. This also applies in the case of complete or partial power failure (electricity, hydraulics, pneumatics).

(3) It must be possible to set down the fuel assembly in a safe position, even in the case of a power failure.

8.5 Electrical equipment

The requirements of sections 6.5 and 7.5 shall be met, however, the realization of the safety functions as per sub-clause 7.5 b) or 7.5 d) is not required by means of two different systems. In addition to the requirements of sections 6.5 and 7.5, the following applies:

a) The end positions "open" and "closed" of the grabs and all related interlocks shall be optically displayed at the control points. No movement of the hoist shall be possible before any of the two end positions is reached.

b) It shall not be possible to actuate the switch for the power supply to the refueling machine unless this actuation has been released, either by means of a key-operated switch or similarly safe switching means from the reactor control room or from a location comparable from a safety point of view. Communication shall be possible between this location and all control points, either directly or through an intercommunication system connected to a continuous power supply. The action of taking back the clearance may not trigger turning-off of the power supply switch; it shall, however, prevent a reactivation of the power supply switch after it has been turned off.

c) The position of the fuel assembly grabs shall be displayed with all coordinates.

d) The continuous load measurement device on the control console shall be equipped with a display of the actual load attached to the rope. For certain assigned loads, e.g. fuel assemblies or control rods, specifically assigned limit values depending on the type of operation shall automatically be activated in the case of overload or underload and switch off the hoist.

e) The response of any limit load monitor and the response of the slack-rope monitor shall trigger an alarm signal at the control points.

f) Lateral movements shall be interlocked such that they are only possible if the grab has reached the allowable altitude permitted for the respective operation.

g) In order to limit the lateral movements to the travel area permitted with regard to safety which is defined by the contour of the reactor and fuel pool areas as well as by fixed internals, an independent safety travel limiter shall be provided in addition to the operational travel limiter according to clause 6.5.3 (1).

h) If parts of the refueling machine can be moved both manually and by motors, turning on of the motor drive is not allowed and shall be made impossible as long as a manual movement can be performed.

i) In the case of hoists with telescope mast the correct sequence of mast sections during extension and retraction of the telescope mast shall be monitored. In the case of hoists with double grab the correct sequence during extension and retraction of the movable parts (centring bell, fuel assembly grabs, control rod grabs) shall be monitored.

   In case of failure the hoist shall be switched off.

j) The setting down of a transported load (e.g. fuel element) on an already occupied position in the fuel pool or reactor core shall be prevented by an interlock.

k) The electrical interlock according to clause 6.5.2 (10) shall be designed such that the control command for the detachment of the load can only be executed at simultaneous release of two independent criteria (e.g. hoisting height and load).

l) It shall be ensured by interlocking that, when passing over the BWR flooding compensator or the PWR reactor vessel cavity seal, no lifting or lowering movement of the main hoist is possible.

Annex A

Examples for classification of lifting equipment

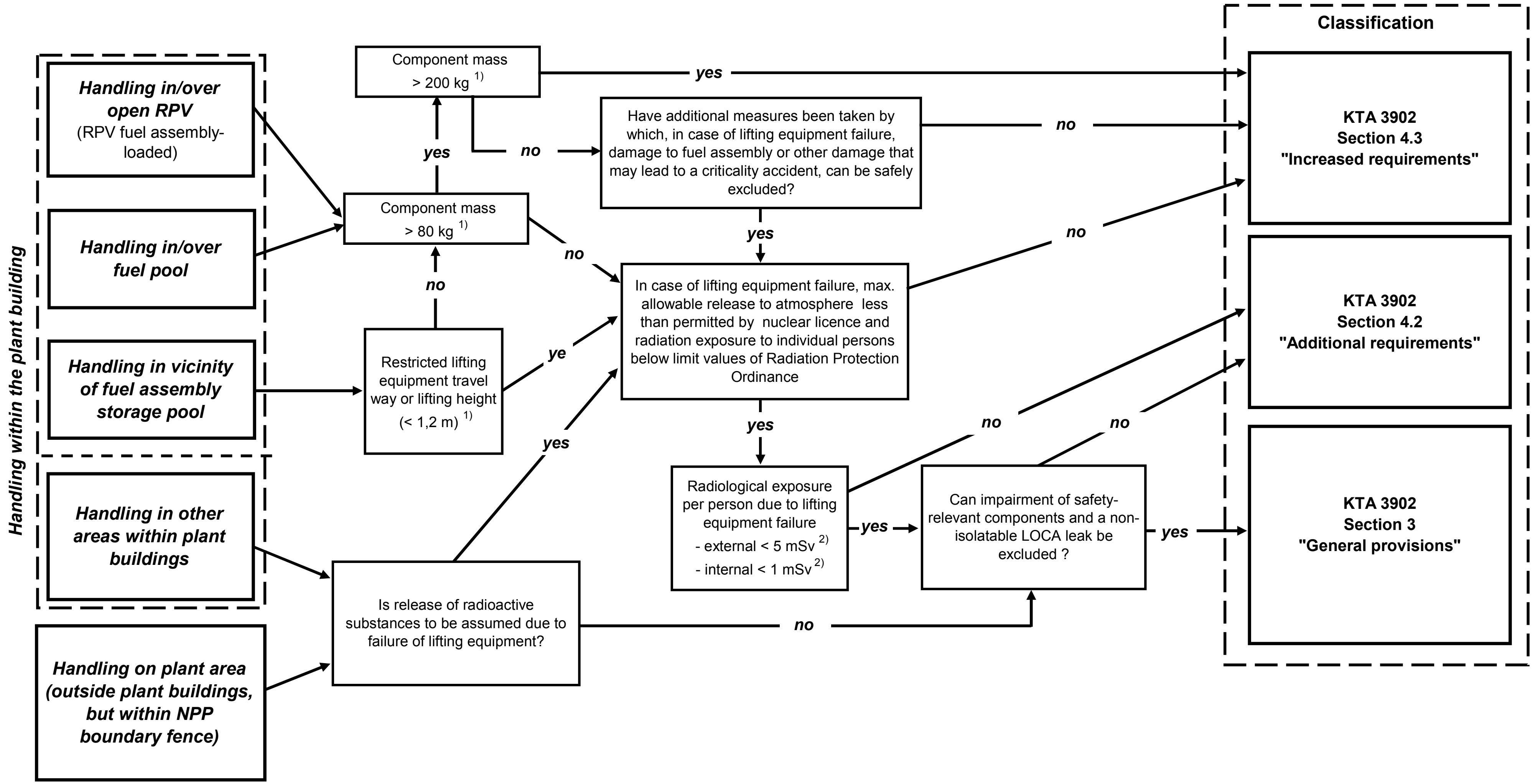
A 1 Examples for classification of lifting equipment in Pressurized Water Reactor plants

Serial number	Lifting equipment	Additional requirements in accordance with section 4.2	Increased requirements in accordance with section 4.3
1	Reactor building crane except for maintenance hoist		X
2	Semi-gantry crane		X
3	Walking crane inside the reactor building	X	
4	Crane in new fuel storage	X	
5	Auxiliary hoist on the refueling machine		X
6	Lifting beam for radiation protection slabs above the reactor pool and set-down pool		X
7	Lifting beam for the cover of the reactor pressure vessel		X
8	Lifting beam for the irradiated fuel shipping cask		X
9	Lifting beam for the shipping cask for fresh UO_2 fuel assemblies	X	
10	Lifting beam for the metallic contamination protection shroud	X	
11	Lifting beam for reactor pressure vessel internals:		
	- upper core structure		X
	- lower core structure	X	
12	Lifting beam for refueling slot gates		X
13	Lifting beam for the stud tensioner of the reactor pressure vessel cover	X	

A2 Examples for classification of lifting equipment in Boiling Water Reactor plants

Serial number	Lifting equipment	Additional requirements in accordance with section 4.2	Increased requirements in accordance with section 4.3
1	Reactor building crane except for maintenance hoist		X
2	Crane in new fuel storage	X	
3	Auxiliary hoist on the refueling machine		X
4	Winch for handling irradiated fuel assemblies in the storage pool		X
5	Lifting beam for the cover of the reactor pressure vessel and containment and for the flooding compensator		X
6	Lifting beam for radiation protection slabs of the reactor pool and set-down pool		X
7	Lifting beam for refueling slot gates		X
8	Lifting beam for steam separator and steam dryer		X
9	Lifting beam for the irradiated fuel shipping cask inside the reactor building		X
10	Lifting beam for the shipping cask for fresh UO_2 fuel assemblies inside the reactor building	X	
11	Lifting beam for the metallic contamination protection shroud	X	
12	Lifting beam for the stud tensioner of the reactor pressure vessel cover	X	

A 3 Examples for procedural steps of classifying lifting equipment in accordance with KTA 3902



1) The numerical values are based on experience and are guide values only. Lifting equipment shall be classified in due consideration of the actual conditions (inter alia location of use, component geometry) within the nuclear licensing and supervisory procedure.

2) Lifting equipment shall be classified in due consideration of the actual conditions (inter alia location of use, frequency and duration of transport operations) within the nuclear licensing and supervisory procedure.

Annex B

Load cases and analytical proofs for lifting equipment

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B 1 Load cases and analytical proofs for cranes, winches, trolleys as well as load carrying devices under section 6

B 1.1 Structures

B 1.1.1 Analytical proof using the global safety factor concept according to DIN 15018-1

(1) The erection and operational load cases shall be calculated in accordance with DIN 15018-1. For structural members made of the austenitic steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3 the allowable stresses shall be taken from section D 1.

(2) The verification procedure according to section 4.3 of KTA 3205.1 shall be used for all external events.

(3) Where the operating conditions are exactly known, e.g. the actually occurring loadings and stress cycles, the verification of service strength may be performed for a single-step or multi-step load collective on the basis of a stress-number diagram according to **Annex C** for the steels S235 and S355, or on the basis of a stress-number diagram according to section D 2 for the austenitic steels 1.4541, 1.4306 and 1.4571.

Note:
The relationship between number of stress cycles and number of working cycles can be derived from section B 1.2.1.2.

The analytical proof based on a multi-step stress-number diagram shall be performed in due consideration of a damage-equivalent stress to the linear damage rule (Miner rule) according to formula (B 1-14).

The following safety factor as regards the allowable maximum stress shall be observed:

$$\overline{\nu} = \sigma_D / \overline{\sigma} \geq 1.12. \qquad \text{(B 1-1)}$$

B 1.1.2 Analytical proof using the partial safety factors concept

(1) The erection and operational load cases shall be calculated in accordance with DIN EN 13001-3-1 in conjunction with DIN EN 13001-1 and DIN EN 13001-2 using the specifications given in (2).

A design of structural members using austenitic steels within the partial safety factors concept is permitted only in those cases where the fatigue analysis may be waived according to section 6.3.3 of DIN EN 13001-3-1, in which case the number of stress cycles shall be determined according to section B 1.2.1.2.

(2) The procedure of proof according to DIN EN 13001-3-1 in conjunction with DIN EN 13001-1 and DIN EN 13001-2 shall be conducted in compliance with the following requirements:

a) Regardless of the specific conditions of crane design and operation, the dynamic factor Φ_2 used in the proof according to DIN 13001-2 shall be calculated by applying the following formulae:

   aa) for operational loads: $\Phi_2 = 1.3 + 0.396 \cdot v_{h,max}$

   ab) for erection loads: $\Phi_2 = 1.1 + 0.132 \cdot v_{h,max}$

   For $v_{h,max}$ the maximum hoisting speed relevant for the load case in question shall be inserted.

b) Where a dynamic factor less than that resulting from a) is to be used, the maximum dynamic load factor occurring during one working cycle shall be determined by means of calculation or experimentally in each individual case. For the determination of the dynamic factor this dynamic load factor shall be multiplied by a safety factor of 1.12.

c) When calculating the loads due to skewed running, the coefficient of friction for cleaned rails shall be used:

   $\mu_0 = 0.3.$

d) Where a verification of loads due to wind during crane operation is required, the wind loads shall be calculated using the wind state "normal".

e) It shall be ensured that during a buffer impact no negative wheel loads can occur due to a presumed load resulting from 1.1 times the buffer force, the forces due to driven masses of dead loads and the lifting load, if any.

f) The specific resistance factor for material γ_{sm} shall be used as specified in section 5.2.2 of DIN EN 13001-3-1, however, a value of at least 1.0 shall be applied.

g) When determining the limit design stresses of bolted connections loaded in tension, a load introduction factor of α_L = 1 shall be used. The specific resistance factor of slip-resistance connections γ_{ss} shall be selected as specified in Table 6 of DIN EN 13001-3-1 assuming that a hazard is created in the case of connection slippage.

h) The test loads shall be as follows:

 ha) for cranes, winches, trolleys, load suspending devices and refueling machines as specified in KTA 3903 Table 8-1 ser. no. 1.4,

 hb) for load suspension devices and lifting accessories as specified in KTA 3903 Table 8-1 ser. no. 2.4.

 The proof shall be performed in accordance with the requirements in section 4.2.4.3 of DIN EN 13001-2 using the test loads as specified under ha) and hb) and the dynamic factor as specified under a).

i) The fatigue strength specific resistance factor γ_{mf} in the fatigue analysis according to DIN EN 13001-3-1 shall be taken as γ_{mf} = 1.25 for parts and welded connections as well as for bolted connections which are not hot dip galvanised, and as γ_{mf} = 1.5 for hot dip galvanised bolted connections.

j) Based on the specifications as per a) through i), the risk coefficient γ_n according to DIN EN 13001-2 may be taken as 1.0.

(3) The following procedures shall be used to demonstrate the safety against all external events:

a) either the procedure according to DIN EN 13001-3-1 using the following resistance and partial safety factors

 γ_m = 1.0

 γ_P = 1.0

 where in the case of parts and welded connections made of austenitic steels the $R_{p1.0}$ proof stress may be used as f_y instead of the $R_{p0.2}$ proof stress,

or

b) the procedure according to section 4.2 of KTA 3205.1.

(4) Where the operating conditions are exactly known, e.g. the actually occurring loadings and stress cycles, the fatigue analysis may be performed for a single-step or multi-step load collective in accordance with the requirements of DIN EN 13001-3-1 and the specifications in (2).

 Note:

 The relationship between the number of stress cycles and the number of working cycles can be derived from section B 1.2.1.2.

The analytical proof based on a multi-step stress-number diagram shall be performed in due consideration of a damage-equivalent stress to the linear damage rule (Miner rule) according to formula (B 1-14).

The following safety factor as regards the allowable stress range shall be observed:

$$\nu = \frac{\Delta\sigma_{Rd}}{\Delta\sigma_{Sd}} \geq 1.12\,. \tag{B 1-2}$$

B 1.1.3 Alternative ways of analytical proof

(1) Analytical proofs may be performed either by calculation or experimentally or as a combination of calculation and experiments.

(2) The stress analysis or fatigue analysis may be performed by calculation using the Finite Element Method in compliance with the requirements specified in section B 3, e.g. because the complexity of a structural member so requires.

(3) If types of analytical proof are used, which differ from the approach according to DIN 15018-1 and the standard series DIN EN 13001, it shall be ensured that the safety level is not lower than required by these standards.

B 1.2 Hoists

B 1.2.1 Design parameters

B 1.2.1.1 Determination of moments and forces

(1) The moments specified in **Table B 1-1** shall be determined for the design of parts of the drive mechanism chain, starting with the service brake and ending with the rope drum.

 Note:

 When using systems to ascertain the braking effect without test load for in-service inspection, see also KTA 3903, Annex D, section D 3.1.

(2) The calculation of the moments $\hat{T}_M$, $\hat{T}_B$, $\hat{T}_0$ and $\hat{T}_{SO}$ shall be based on the following operational conditions and shall be performed for the individual intersection:

a) Acceleration during lifting:

$$\hat{T}_{BS} = T_L - T_R + \varphi_s \cdot \left[2 \cdot T_R + \left(T_{Mot} - T_L - T_R\right) \cdot \frac{J_{ab}}{J_{ab} + J_{an}}\right] \tag{B 1-3}$$

 where T_{Mot} is the largest motor moment created during the stepwise switching-up of the motor for drives with three-phase current slip-ring rotor motors. If this is not exactly known, then, in case of automatic switching-up with time or frequency relays, a value of 2/3 of the motor breakdown torque, and in case of manual switching-up the full motor breakdown torque shall be used. In the case of drives with squirrel-cage rotor motors, the start-up moment upon turning on the motor shall be used. In the case of converter drives, the motor moment at the upper current limit shall be used.

b) Deceleration during lowering:

$$\hat{T}_{BR} = T_L + T_R + \varphi_s \cdot \left(T_{Bre} - T_L - T_R\right) \cdot \frac{J_{ab}}{J_{ab} + J_{an}}\,, \tag{B 1-4}$$

 with φ_s = 2

c) Lifting of a set-down load:

$$\hat{T}_{AN} = \left(T_L + T_R\right) \cdot \psi \tag{B 1-5}$$

 Note:

 The dynamic factor ψ is chosen in accordance with the classification of the supporting structure.

The following rule shall apply to the directional sense:

All torques shall be given a positive sign if, on the input side of the drive shaft analysed, they act in the direction of motion and, on the output side in the direction of motion of the drive shaft counter to the direction of motion.

(3) The design forces for the non-rotating mechanical parts between rope drum and load shall be determined from the above moments.

Load case no.	Moments	Nomenclature	Type of proof
1	T_M	Static moment for the maximum erection load	Fatigue analysis and static stress analysis for the first step of the load collective
	$\hat{T}_M$	Dynamic moment for the maximum erection load T_M (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
2	T_B	Static moment for the maximum operational load	
	$\hat{T}_B$	Dynamic moment for the maximum operational load T_B (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
3	T_0	Static moment for idling runs if the dead weight of half the supporting means plus load suspension device plus lifting accessory is larger than 30 % of the maximum load	
	$\hat{T}_0$	Dynamic moment for dead weight T_O (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
4	T_{SO}	Maximum moment for the special load case, e.g. acceptance test, in-service inspection, gear box test run, simultaneous engagement of the service and auxiliary brake	
	$\hat{T}_{SO}$	Dynamic moment for the special load case T_{SO}	

Table B 1-1: Moments

B 1.2.1.2 Determination of stress cycles

(1) The stress cycles required for the fatigue analysis shall be determined as follows:

a) rotating parts:

$$h_i = \frac{U_i}{3600 \cdot \bar{v}_i} \cdot \bar{s}_i \qquad \text{(B 1-6)}$$

$$\hat{N}_{i\sigma} = U_i \cdot \frac{n_i}{60} \cdot \hat{t}_i \qquad \text{(B 1-7)}$$

$$\hat{N}_{i\tau} = U_i \cdot Z_{Sch_i} \cdot \varepsilon \qquad \text{(B 1-8)}$$

$$N_{i\sigma} = 60 \cdot n_i \cdot h_i - \hat{N}_{i\sigma} \qquad \text{(B 1-9)}$$

$N_{i\tau}$ = 0, because only static stresses occur. (B 1-10)

b) non-rotating parts:

$$\hat{N}_{i\sigma} = U_i \cdot Z_{Sch_i} \cdot k_a \qquad \text{(B 1-11)}$$

$N_{i\sigma}$ = 0, because only static stresses occur. (B 1-10)

The following values shall be inserted:

ε = 10

k_a = 3

$\hat{t}_i$ = 30 s however, at a maximum only 50 % of the integral running time if no additional proof is rendered,

Z_{Sch_i} = 10 in the case of precision hoists and of converter drives,

Z_{Sch_i} = 20 in the case of other drives.

(2) If the actual stresses within one working cycle are known through experimental investigations or through an applicable estimation of the loading with adequate mathematical models (e.g. taking into account the inner-friction loss of the oscillatory energy impressed upon the system by the coupling impulse), the fatigue analysis may be based on these values.

B 1.2.1.3 Determination of the (general) load collective

(1) From the determined moments in accordance with **Table B 1-1** and the resulting forces, the stresses in the part shall be calculated and sorted according to size. With the corresponding stress cycles, the load collective shall be established. This load collective shall be compared to the part's stress-number diagram (cf. **Figure B 1-1**).

Examples for determining load collectives are presented in [12].

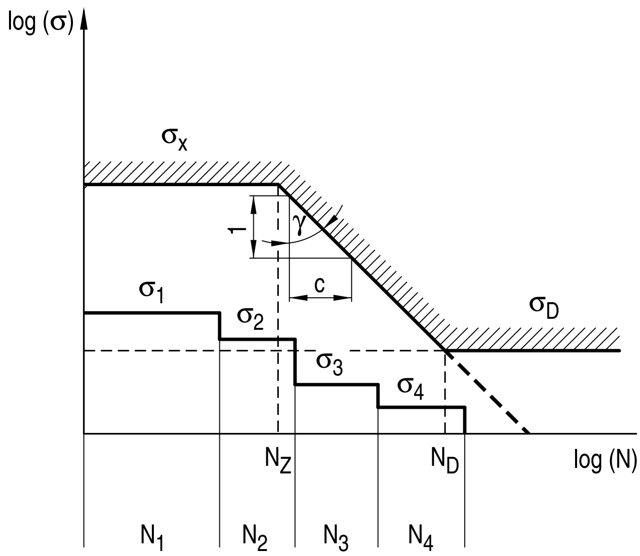


Figure B 1-1: Stress collectives

(2) The location of the part's S/N diagram within the finite-life fatigue range shall be determined from the values for N_Z and σ_X as well as N_D and σ_D; in a logarithmic diagram, the S/N diagram is represented by a straight line with a gradient that shall be determined by the following equation:

$$c = \tan\gamma = \frac{\log N_D - \log N_Z}{\log\sigma_X - \log\sigma_D} \qquad \text{(B 1-13)}$$

(3) The fatigue analysis shall be based on cases A, B or C shown in **Figures B 1-2** through **B 1-4**:

a) Case A: $\sigma_1 \geq \sigma_D$

If no step in the load collective does touch or exceed the extended finite-life fatigue line, then $\bar{\sigma}$ shall be calculated from all steps in the load collective.

b) Case B: $\sigma_1 < \sigma_D$
$N_1 < N_D$

None of the stress cycle values larger than N_D shall be considered. $\bar{\sigma}$ shall be calculated from the load collective steps up to N_D.

c) Case C: $\sigma_1 < \sigma_D$
$N_1 \geq N_D$

The endurance limit shall be calculated on the basis of σ_1.

(4) In Case A and Case B, a damaging equivalent stress (e.g. $\bar{\sigma}$, $\bar{k}$, $\bar{\tau}$) shall be calculated in accordance with the linear damage rule (Miner's rule) as follows:

$$\bar{\sigma} = \sigma_1 \cdot \left[\frac{\sum_i N_i (\sigma_i / \sigma_1)^c}{N_D} \right]^{1/c} \qquad \text{(B 1-14)}$$

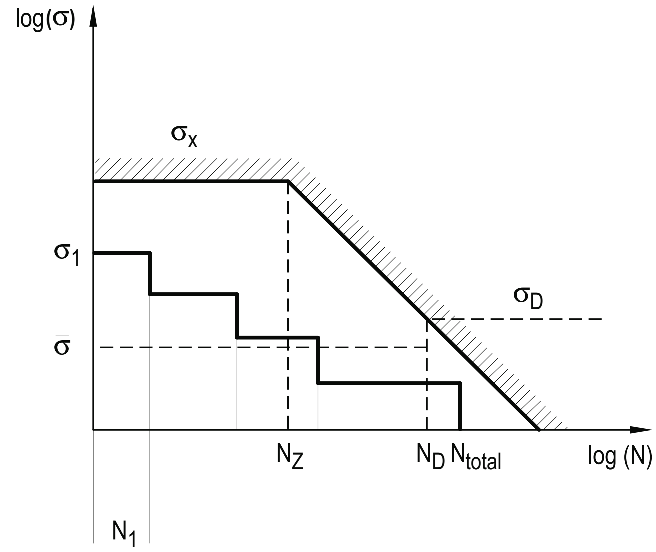


Figure B 1-2: Stress-number diagram for Case A

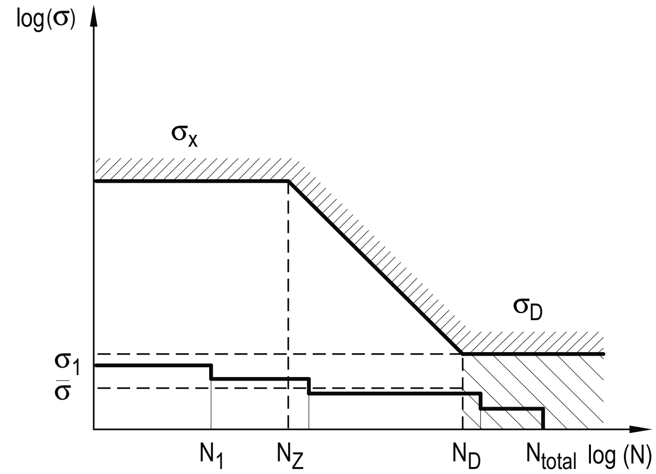


Figure B 1-3: Stress-number diagram for Case B

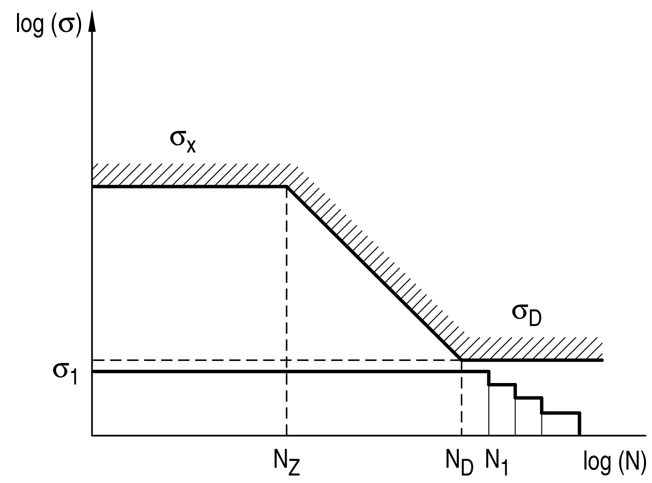


Figure B 1-4: Stress-number diagram for Case C

B 1.2.2 Shafts, axles and similar parts

B 1.2.2.1 Determination of stress-number diagram

(1) In the case of shafts, axles and similar parts, the location of the S/N diagram in the finite-life fatigue range is given by the endurance limit dependent on the loading stress σ_D (tension, compression, bending, torsion) for $5 \cdot 10^6$ stress cycles (N_D), and σ_X shall be the yield strength dependent on the loading condition for $1 \cdot 10^4$ stress cycles (N_Z). The endurance limit is set for a survival probability of 50 %. Decisive for the specification of the value of the yield point is the elastic ratio (ratio of yield strength R_{eH} or $R_{p0.2}$ to tensile strength R_m) of the material used. Here, the following applies:

a) if the elastic ratio is less than 0.7, the value of the yield strength R_{eH} or proof stress $R_{p0.2}$ shall be taken,

b) if the elastic ratio is equal to or greater than 0.7, the tensile strength value limited to $0.7 \cdot R_m$ shall be taken.

Where an analytical proof acc. to [7] is performed, the location of the S/N diagram in the finite-life fatigue range for shafts, axles and similar parts in load carrying devices may be determined in accordance with [7] with the points of support σ_D (endurance limit depending on loading) at $5 \cdot 10^6$ stress cycles (N_D) and $\sigma_X = R_m$ at $5 \cdot 10^3$ stress cycles (N_Z). The limit values under a) and b) for σ_X need not be considered here.

Where the steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3 are used, the stress-number diagram for the fatigue analysis shall be determined by means of the parameters of **Table B 1-2**.

Ser. no.	Loading ratio R	Parameters of stress-number diagram in double-logarithmic coordinate system: Stress coordinate at salient point S_D (σ_D) in N/mm2	Life cycle coordinate at salient point N_D	Slope k
1	0	263.6	$5.0 \cdot 10^6$	8.77
2	-1	180.0	$5.0 \cdot 10^6$	10.8
These parameters apply in the range $5.0 \cdot 10^3 < N \le 5.0 \cdot 10^6$.				

Table B 1-2: Parameters for the stress-number diagrams of the steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3

(2) The endurance strengths σ_D and τ_D shall be determined as follows:

$$\sigma_D = \frac{\sigma_n}{K_n}, \; \tau_D = \frac{\tau_t}{K_t}, \quad \text{where } \tau_t = \frac{\sigma_n}{\sqrt{3}} \qquad \text{(B 1-15)}$$

(if applicable, the shear stress from transverse forces shall be considered.)

(3) Values for material properties, fatigue strength reduction factor, roughness factor, stress concentration factor and size factor shall be taken from the referenced literature [1], [3], [4], [5], [6], [7] or from the standards DIN 743-2 and DIN 743-3. Other materials may be used if the necessary data are guaranteed and demonstrated.

(4) When applying DIN 743-2 and DIN 743-3 for determining the factors influencing the design strength values, the following shall be used as regards the determination of the stress-number diagram

a) as endurance limit σ_D the value of the endurance limit of the part according to DIN 743-1 and

b) as yield strength σ_X the value of the yield limit of the part according to DIN 743-1 at the considered cross-section of the respective part in dependence of the actually occurring loading (tension/pressure, bending or torsion) and the stress history (cyclic loading, pulsating loading) to meet the requirements of DIN 743-1, DIN 743-2 and DIN 743-3. In this case, the ratio of mean stress to stress amplitude due to the individually acting external load can be presumed to be constant for all steps of the load collective. The limit values fixed under (1) (a) and (1) (b) for the yield strength of the respective material in dependence of the elastic ratio shall be considered.

B 1.2.2.2 Safety factors for shafts, axles and similar parts

(1) The safety factors specified in **Table B 1-3** shall apply.

(2) When applying the Finite Element Method the requirements of section B3 shall be met.

Proof of	Loading type	Equation for proof of safety	Required safety factor for additional requirements under sec. 6
Static strength [1)]	First step of the collective	$\nu_{\sigma 1} = \sigma_x / \left(\sigma_1 \cdot \alpha_{k_n}\right)$	≥ 1.25
		$\nu_{\tau 1} = \tau_{S_t} / \left(\tau_1 \cdot \alpha_{k_t}\right)$	≥ 1.25
Cyclic strength	Collective Case A or B	$\overline{\nu}_\sigma = \sigma_D / \overline{\sigma}$	≥ 2.0
		$\overline{\nu}_\tau = \tau_D / \overline{\tau}$	≥ 2.0
		$\left(\frac{\overline{\sigma}_n}{\sigma_D}\right)^2 + \left(\frac{\overline{\tau}_t}{\tau_D}\right)^2 \le \left(\frac{1.0}{\nu}\right)^2$	≥ 2.0
Endurance strength	First collective step Case A	$\nu_\sigma = \sigma_D / \sigma_1$	≥ 2.0
		$\nu_\tau = \tau_D / \tau_1$	≥ 2.0
		$\left(\frac{\sigma_1}{\sigma_D}\right)^2 + \left(\frac{\tau_1}{\tau_D}\right)^2 \le \left(\frac{1.0}{\nu}\right)^2$	≥ 2.0

1) Applies only to hoists; in the case of non-rotating parts no stress concentration factors are required and the required safety factor is greater than or equal to 1.5, where R_{eH} or $R_{p0.2}$ shall be taken for σ_x.

Table B 1-3: Safety factors for shafts, axles and similar parts

B 1.2.2.3 Proofs regarding fitting keys

(1) The allowable contact Hertzian stress in the case of one parallel key for the linkage with shaft or hub may be

$$p_{zul} = 0.4 \cdot R_{p0.2}\,(R_{eH}) \qquad \text{(B 1-16)}$$

and, with two parallel keys,

$$p_{zul} = 0.3 \cdot R_{p0.2}\,(R_{eH}) \qquad \text{(B 1-17)}$$

(2) The allowable contact Hertzian stress in the case of a hardened parallel key linkage may be

$$p_{zul} = 0.5 \cdot R_{p0.2}\,(R_{eH}) \qquad \text{(B 1-18)}$$

and, with two parallel keys,

$$p_{zul} = 0.4 \cdot R_{p0.2}\,(R_{eH}) \qquad \text{(B 1-19)}$$

(3) The allowable contact Hertzian stresses apply to loadings from operational or erection loads with static moment. For the special loading case, these values may be increased by 50 %.

(4) Proofs for splined shafts and pinion shaft linkages shall be performed in accordance with Decker [4], where the allowable contact Hertzian stress of $p_{zul} = 0.4 \cdot R_{p0.2}\,(R_{eH})$ shall not be exceeded.

B 1.2.3 Pinions

B 1.2.3.1 Determination of the effective stresses and of the load capacity

(1) The pinions' strength shall be determined in accordance with the following requirements according to DIN 3990-11 or the analysis procedure of Niemann [2].

(2) For both calculation procedures the stress levels for the pinions (tooth foot stress and tooth flank compression) shall be determined from the torque levels and be correlated with the corresponding load cycle values.

(3) According to the calculation procedure of DIN 3990-11 the effective tooth foot stress σ_F and the flank compression σ_H shall be determined for each stress level if they are required for the fatigue analysis with regard to the cases mentioned in B 1.2.1.3.

(4) If the analysis procedure of Niemann [2] is used for determining the strength of pinions, the following shall apply:

For each stress level the effective tooth foot stress σ_W and the effective tooth flank compression k_W shall be determined in accordance with Niemann [2] for the pinions, taking into consideration the following additional requirements for the tooth bearing error coefficient C_T provided, this is necessary with regard to the fatigue analysis of the case differentiation mentioned in B 1.2.1.3.

a) For tempered and gas-nitrided pinions, a tooth bearing error factor C_T = 1.7 shall be used and for flame and case hardened pinions, a value of C_T = 1.5. If the calculation is based on other C_T values, this assumption shall be validated either analytically or experimentally.

b) The analytical proof may be based on Table 117/1, Niemann [2]. The effective tooth flank direction error f_{RW} to be used in this context may be determined, e.g., using the equation presented therein on page 114, with a flank direction error f_R for the pinion equal to 1.4 times the value of the flank line deviation $f_{Hß}$ in accordance with DIN 3962-2. The factor 1.4 takes the probable flank line deviation from the $f_{Hß}$ values for pinion and wheel into account. The assumed pinion quality shall be demonstrated. The load distribution considered shall be parabolic for tempered pinions and linear for surface hardened pinions. The analysis shall be carried out, e.g., in accordance with Dudley/Winter [10] or in accordance with FVA [11]. This also applies to overhanging pinions or wheels.

c) If the bearings of the gear transmission are located on the supporting structure, then it shall in all cases be demonstrated that the load bearing pattern coincides with that on which the analysis is based and which determines the C_T value.

(5) For both calculation procedures the maximum load line (maximum loading level) shall be correlated to the specified stress levels of the pinions.

(6) If the calculation procedure according to DIN 3990-11 is used for determining the strength of the pinions, the following shall apply:

a) The maximum loading limits for the creep and endurance limit ranges shall be determined in accordance with DIN 3990-11. The maximum load line according to DIN 3990-11 for a consideration of certain "pitting" shall not be used.

b) The material properties shall be taken from **Table B 1-4** in consideration of the material quality MQ according to DIN 3990-5. Other materials and material properties may be used if it is proved that these values meet the same quality requirements as for quality level MQ.

(7) If the analysis procedure of Niemann [2] is used for determining the strength of pinions, the following shall apply:

a) The maximum load line required in determining the tooth foot load capacity or tooth flank load capacity (pitting) shall be derived as follows:

aa) The tooth foot endurance limit σ_D or the flank compression endurance limit k_D runs as a horizontal line from the stress cycle value N_D into the endurance limit range. The equation for σ_D is obtained from Niemann [2] Table 121/2 and the equation for k_D from Niemann [2] Table 121/1, where in addition, the influence of the surface condition shall be taken into account by applying a roughness factor y_R.

$$k_D = y_G \cdot y_H \cdot y_S \cdot y_V \cdot y_R \cdot k_0 \qquad \text{(B 1-20)}$$

ab) The finite-life fatigue line is defined by the stress cycle value N_Z and, in the case of σ_X, by the corresponding maximum finite-life fatigue strength value max σ_Z, or by max k_Z. For the range N smaller than or equal to N_Z, the maximum load line runs as a horizontal line with the values max σ_Z or max k_Z. The value of max σ_Z is obtained from

$$\max \sigma_Z = y_\sigma \cdot \sigma_D \qquad \text{(B 1-21)}$$

ac) The value of max k_Z shall be determined from

$$\max k_Z = y_K \cdot y_G \cdot y_H \cdot k_0 \qquad \text{(B 1-22)}$$

ad) Depending on the type of loading, the material and the heat treatment, the values specified in **Table B 1-5** for the determination of the maximum load line shall be adhered to, where y_σ and y_K are life cycle factors.

ae) The material property values σ_0 of the tooth foot endurance limit and k_0 of the flank compression endurance limit shall be taken from **Table B 1-6**. Other materials may be used if the required material property data are demonstrated and guaranteed.

b) The roughness factor y_R shall be calculated from the equation

$$y_R = Z_R^2 \qquad \text{(B 1-23)}$$

In **Figure B 1-5**, the curves of the factor Z_R are shown as a function of R_{z100}. The diagram applies to paired pinions with an axial displacement of a = 100 mm and an equivalent curvature radius at the pitch point of ρ_{red} = 10 mm.

The average roughness R_z shall be determined from equation (B 1-24). The average roughness of the pinion R_{z1} and of the wheel R_{z2} are average values of the roughness depth R_1 measured at several tooth flanks.

$$R_z = \frac{R_{z1} + R_{z2}}{2} \qquad \text{(B 1-24)}$$

Note:

The average roughness depths are determined for the values R_{z1} and R_{z2} for pinion and wheel, for the condition subsequent to the manufacture including special running-in treatment or a running-in process (as part of the fabrication program), if this leads to a smoothening of the surface, and also including a running-in under operating conditions, if this can be assumed to be safe (as based on the load collective for a number of cranes and lifting equipment).

If the roughness is specified as a R_a-value, the following approximation may be used:

$$R_a \approx \frac{R_z}{6} \qquad \text{(B 1-25)}$$

The average relative roughness (based on an axial distance of a = 100 mm) shall be determined as follows:

$$R_{z100} = \frac{R_{z1} + R_{z2}}{2} \cdot \left(\frac{100}{a}\right)^{1/3} \qquad \text{(B 1-26)}$$

Note:

Results are available for ρ_{red} from 7 to 10 mm. Since ρ_{red} is a linear function of a, equation (B 1-26) may be applied, based on the technical knowledge available today.

B 1.2.3.2 Safety factors for pinions

(1) Where the calculation is performed according to DIN 3990-11, the safety factors of **Table B 1-7** shall be taken.

(2) Where the calculation is performed according to Niemann [2], the safety factors of **Table B 1-8** shall be taken.

B 1.2.4 Rope drives

(1) Rope drives shall be designed in accordance with DIN 15020-1. To determine the required rope diameter a corrected factor as per [13] may be used instead of the factor c according to DIN 15020-1 Table 2

$$c_{corrected} = c \cdot \sqrt{\frac{0.825 \cdot 0.455}{k \cdot f}} \qquad \text{(B 1-27)}$$

where

c : factor as per DIN 15020-1, Table 2

k : stranding factor of the rope selected

f : fill factor of the rope selected

(2) The rope drum wall thickness shall satisfy the following condition with respect to the loading from rope wrapping:

$$\frac{S_{max}}{h \cdot s} < \frac{R_{p0.2}}{\nu} \qquad \text{(B 1-28)}$$

with the safety factor $\nu \geq 1.5$.

(3) An exact analysis in accordance with the procedure described in [8] and [9] is permitted.

B 1.3 Lateral transport drives

B 1.3.1 Design analysis of drive wheels

(1) The design analysis of the steel drive wheels shall be performed in accordance with DIN 15070 on the basis of the wheel forces present in the most frequent operational positions and under operational loads.

(2) In the case of erection and special loads, the contact Hertzian stress (cylinder / plane) may be demonstrated for the maximum wheel forces in accordance with equation (B 1-29):

$$p_{max\,H} = 0.418 \cdot \sqrt{\frac{R_{max} \cdot 2.1 \cdot 10^5}{\frac{d}{2} \cdot (k - 2 \cdot r_1)}} \leq 1.85 \cdot R_m \qquad \text{(B 1-29)}$$

where the number of wheeling load cycles shall not be larger than 5,000, and d equals the wheel diameter in mm.

B 1.3.2 Design analysis of wheel axles and wheel shafts

(1) The design analysis of the wheel axles and wheel shafts shall be performed in accordance with DIN calculation principles for drive mechanisms in lifting equipment [7] on the basis of the wheel forces present in the most frequent operational positions and under the operational load for the load cases H and HZ.

(2) In the case of erection and special loads, the design analysis of the wheel axles and wheel shafts shall be performed in accordance with DIN calculation principles for drive mechanisms in lifting equipment [7] on the basis of the load case HS.

(3) The material properties, fatigue strength reduction factor, roughness factor, stress concentration factor and size factor may also be taken from DIN 743-2 and DIN 743-3.

B 1.3.3 Design analysis of roller bearings

The design principles of the roller bearing manufacturers shall be used for the design analysis of the roller bearings. The loading shall be determined in accordance with DIN 15071.

Type of material and treatment	Short designation and heat treatment diameter d, mm		Tensile strength R_m , N/mm^2 (to be indicated in the drawing)	Hardness (HRC or HV)	Minimum hardness HV	Endurance strength σ_{FE} N/mm^2	$\sigma_{H\,lim}$ N/mm^2
Quenched and tempered steel	C 45 E+QT (W.-Nr. 1.119[1)])	$16 < d \le 40$	$650 \le R_m \le 800$	—	215	460	590
		$40 < d \le 100$	$630 \le R_m \le 780$		205	445	575
		$100 < d \le 250$	$590 \le R_m \le 740$		190	415	535
	42 CrMo 4 +QT (W.-Nr. 1.7225)	$16 < d \le 40$	$1000 \le R_m \le 1200$		300	570	600
		$40 < d \le 100$	$900 \le R_m \le 1100$		270	510	540
		$100 < d \le 160$	$800 \le R_m \le 950$		240	455	480
		$160 < d \le 250$	$750 \le R_m \le 900$		225	425	450
	30 CrNiMo 8 +QT (W.-Nr. 1.6580)	$16 < d \le 40$	$1250 \le R_m \le 1450$		350	690	715
		$40 < d \le 100$	$1100 \le R_m \le 1300$		310	605	630
		$100 < d \le 160$	$1000 \le R_m \le 1200$		280	550	570
		$160 < d \le 250$	$900 \le R_m \le 1100$		250	495	515
		$250 < d \le 500$	$850 \le R_m \le 1000$		235	470	485
Case hardened steel	16 MnCr 5 HH BG (W.-Nr. 1.7131)		$650 \le R_m \le 950$ [3)]	HRC 58 ± 2	720	860	1470
	20 MnCr 5 HH BG (W.-Nr. 1.7147)		$800 \le R_m \le 1100$ [3)]		720	860	1470
	18CrNiMo7-6+HH+FP (W.-Nr. 1.6587)		$950 \le R_m \le 1250$ [3)]		740	1000	1500
	18 CrNi 8 HH BG (W.-Nr. 1.5920)		$1080 \le R_m \le 1330$ [3)]		740	1000	1500
Flame hardened steel	C 45 E+N (W.-Nr. 1.1191)	$d \le 16$	$R_m \ge 620$	HRC 53 ± 2	530	500	1035
		$16 < d \le 100$	$R_m \ge 580$				
		$100 < d \le 250$	$R_m \ge 560$				
	42 CrMo 4 +QT (W.-Nr. 1.7225)	$16 < d \le 40$	$1000 \le R_m \le 1200$		530	600	1120
		$40 < d \le 100$	$900 \le R_m \le 1100$				
		$100 < d \le 160$	$800 \le R_m \le 950$				
		$160 < d \le 250$	$750 \le R_m \le 900$				
Induction hardened steel	C 45 E+N (W.-Nr. 1.1191) 42 CrMo 4 +QT (W.-Nr. 1.7225)	$d \le 16$	$R_m \ge 620$	HRC 53 ± 2	560	460 [1)] 285 [2)]	1035
		$16 < d \le 100$	$R_m \ge 580$				
		$100 < d \le 250$	$R_m \ge 560$				
		$16 < d \le 40$	$1000 \le R_m \le 1200$		610	605 [1)] 375 [2)]	1120
		$40 < d \le 100$	$900 \le R_m \le 1100$				
		$100 < d \le 160$	$800 \le R_m \le 950$				
		$160 < d \le 250$	$750 \le R_m \le 900$				
Gas-nitrided steel (long term nitriding)	42 CrMo 4 +QT (W.-Nr. 1.7225)	$16 < d \le 40$	$1000 \le R_m \le 1200$	$560 \le HV \le 620$	560	625	1070
		$40 < d \le 100$	$900 \le R_m \le 1100$				
		$100 < d \le 160$	$800 \le R_m \le 950$				
		$160 < d \le 250$	$750 \le R_m \le 900$				

1) Base of tooth hardened
2) Base of tooth not hardened
3) Tensile test on blank hardened test bar with a 63 mm diameter

Table B 1-4: Material properties for the calculation of pinions, material quality MQ according to DIN 3990-5

Type of material and treatment	Load capacity of the tooth foot			Load capacity of the tooth flank		
	N_D	N_Z	y_σ	N_D	N_Z	y_K
Tempered steel	$3 \cdot 10^6$	10^4	2.5	$5 \cdot 10^7$	10^5	2.56
Case hardened, induction hardened or recirculation hardened steel	$3 \cdot 10^6$	10^3	2.5	$5 \cdot 10^7$	10^5	2.56
Gas-nitrided steel	$3 \cdot 10^6$	10^3	1.6	$2 \cdot 10^6$	10^5	1.69

Table B 1-5: Parameters for the determination of the maximum load line

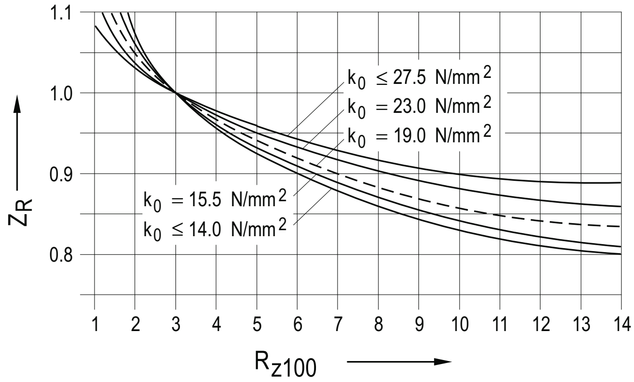


Figure B 1-5: Dependence of the factor Z_R on the average relative roughness R_{z100}

Type of material and treatment	Short designation and heat treatment diameter d, mm		Tensile strength R_m, N/mm² (to be indicated in the drawing)	Hardness (HRC or HV)	Minimum hardness HV	Endurance strength σ_{FE} N/mm²	Endurance strength $\sigma_{H\,lim}$ N/mm²
Quenched and tempered steel	C 45 E+QT (W.-Nr. 1.1191)	$16 < d \leq 40$	$650 \leq R_m \leq 800$	—	215	4.2	235
		$40 < d \leq 100$	$630 \leq R_m \leq 780$		205	4.0	230
		$100 < d \leq 250$	$590 \leq R_m \leq 740$		190	3.5	220
	42 CrMo 4+QT (W.-Nr. 1.7225)	$16 < d \leq 40$	$1000 \leq R_m \leq 1200$		300	9.0	320
		$40 < d \leq 100$	$900 \leq R_m \leq 1100$		270	8.5	310
		$100 < d \leq 160$	$800 \leq R_m \leq 950$		240	7.8	300
		$160 < d \leq 250$	$750 \leq R_m \leq 900$		225	7.3	290
	30 CrNiMo 8+QT (W.-Nr. 1.6580)	$16 < d \leq 40$	$1250 \leq R_m \leq 1450$		350	13.0	390
		$40 < d \leq 100$	$1100 \leq R_m \leq 1300$		310	12.0	370
		$100 < d \leq 160$	$1000 \leq R_m \leq 1200$		280	11.1	350
		$160 < d \leq 250$	$900 \leq R_m \leq 1100$		250	10.0	340
		$250 < d \leq 500$	$850 \leq R_m \leq 1000$		235	9.5	320
Case hardened steel	16 MnCr 5 HH BG (W.-Nr. 1.7131)		$650 \leq R_m \leq 950$ 3)	HRC 58 ± 2	720	50	420
	20 MnCr 5 HH BG (W.-Nr. 1.7147)		$800 \leq R_m \leq 1100$ 3)		720	50	420
	18CrNiMo7-6+HH+FP (W.-Nr. 1.6587)		$950 \leq R_m \leq 1250$ 3)		740	50	470
	18 CrNi 8 HH BG (W.-Nr. 1.5920)		$1080 \leq R_m \leq 1330$ 3)		740	50	470
Flame hardened steel	C 45 E+N (W.-Nr. 1.1191)	$d \leq 16$	$R_m \geq 620$	HRC 53 ± 2	530	23	284
		$16 < d \leq 100$	$R_m \geq 580$				
		$100 < d \leq 250$	$R_m \geq 560$				
	42 CrMo 4 +QT (W.-Nr. 1.7225)	$16 < d \leq 40$	$1000 \leq R_m \leq 1200$		560	27	340
		$40 < d \leq 100$	$900 \leq R_m \leq 1100$				
		$100 < d \leq 160$	$800 \leq R_m \leq 950$				
		$160 < d \leq 250$	$750 \leq R_m \leq 900$				
Induction hardened steel	C 45 E+N (W.-Nr. 1.1191)	$d \leq 16$	$R_m \geq 620$	HRC 53 ± 2	560	23	260 1) 160 2)
		$16 < d \leq 100$	$R_m \geq 580$				
		$100 < d \leq 250$	$R_m \geq 560$				
	42 CrMo 4 +QT (W.-Nr. 1.7225)	$16 < d \leq 40$	$1000 \leq R_m \leq 1200$		610	27	340 1) 210 2)
		$40 < d \leq 100$	$900 \leq R_m \leq 1100$				
		$100 < d \leq 160$	$800 \leq R_m \leq 950$				
		$160 < d \leq 250$	$750 \leq R_m \leq 900$				
Gas-nitrided steel (long term nitriding)	42 CrMo 4 +QT (W.-Nr. 1.7225)	$16 < d \leq 40$	$1000 \leq R_m \leq 1200$	$560 \leq HV \leq 620$	560	27	350
		$40 < d \leq 100$	$900 \leq R_m \leq 1100$				
		$100 < d \leq 160$	$800 \leq R_m \leq 950$				
		$160 < d \leq 250$	$750 \leq R_m \leq 900$				

1) Base of tooth hardened
2) Base of tooth not hardened
3) Tensile test on blank hardened test bar with a 63 mm diameter

Table B 1-6: Material properties for the calculation of pinions according to Niemann [2]

Analytical proof	Loading type	Equation for proof of safety	Required safety factor for additional requirements according to section 6
Static strength	First step of collective	$\sigma_{F_{min}} = \max \frac{\sigma_{FG}}{\sigma_{F_1}}$	≥ 1.40
		$S_{H_{min_1}} = \max \frac{\sigma_{HG}}{\sigma_{H_1}}$	≥ 1.12
		Proof only required if $N_{ges} < N_Z$	
Cyclic strength	Load collective Case A or B	$\overline{S}_{F_{min}} = \frac{\sigma_{FG}}{\sigma_F}$	≥ 1.57
		$\overline{S}_{H_{min}} = \frac{\sigma_{HG}}{\sigma_H}$	≥ 1.12
Endurance strength	First step of collective Case C	$\overline{S}_{F_{min}} = \frac{\sigma_{FG}}{\sigma_{F_1}}$	≥ 1.57
		$\overline{S}_{H_{min}} = \frac{\sigma_{HG}}{\sigma_{H_1}}$	≥ 1.12

Table B 1-7: Safety factors for pinions according to DIN 3990-11

Proof of	Loading type	Equation for proof of safety	Required safety factor for additional requirements according to section 6
Static strength	First step of collective	$\nu_{\sigma_1} = \max \frac{\sigma_Z}{\sigma_1}$	≥ 1.35
		$\nu_{k_1} = \max \frac{k_Z}{k_1}$	≥ 1.25
		Proof only required if N_{ges} < NZ	
Cyclic strength	Load collective Case A or B	$\overline{\nu}_\sigma = \frac{\sigma_D}{\overline{\sigma}}$	≥ 2.0
		$\overline{\nu}_k = \frac{k_D}{\overline{k}}$	≥ 1.3
Endurance strength	First step of collective Case C	$\overline{\nu}_\sigma = \frac{\sigma_D}{\sigma_1}$	≥ 2.0
		$\overline{\nu}_k = \frac{k_D}{k_1}$	≥ 1.3

Table B 1-8: Safety factors for pinions according to Niemann [2]

B 1.4 Load carrying devices

B 1.4.1 Supporting means

B 1.4.1.1 Load hooks

Unless load hooks according to DIN 15401-1 and DIN 15401-2 or DIN 15402-1 and DIN 15402-2 are used, a design analysis following DIN 15400 is required.

B 1.4.1.2 Load hook mountings

(1) The design analysis of the load hook cross-bar shall be performed in accordance with section B 1.2.

(2) Unless a load hook nut according to DIN 15413 is used, a design analysis following DIN 15400 is required.

(3) In the case of statically loaded roller bearings (only slight rotary motion), the design principles of the roller bearing manufacturers shall be used with static loads for the design analysis of the roller bearings.

B 1.4.1.3 Grabs, lifting beams and hangers

The design analysis for supporting structures shall be performed in accordance with section B 1.1 and for machine elements in accordance with section B 1.2.

B 1.4.1.4 Top and bottom blocks

(1) The design forces for the rope sheaves required for the demonstration of suitability under KTA 3903 shall be determined in accordance with section B 1.2.

(2) In the case of statically loaded roller bearings with only slight rotary motion, the design principles of the roller bearing manufacturers shall be applied with static loads for the design analysis of the roller bearings.

(3) The design analysis for supporting structures shall be performed in accordance with section B 1.1 and for machine elements in accordance with section B 1.2.

B 1.4.1.5 Bolted connections

(1) The stress analysis shall be performed according to VDI 2230 Sheet 1 for bolted connections with additional tensile loading, in which case the following requirements shall be met:

a) the usage factor of the yield stress during tightening shall be limited to 0.7,

b) the usage factor of the yield stress due to additional forces from operating conditions shall be limited to 0.1.

(2) The fatigue analysis shall be performed according to VDI 2230 Sheet 1, in which case a safety factor of 2.0 against the stress amplitude of the endurance or of the finite-life fatigue strength shall be satisfied.

(3) In case of a multi-step load collective (e.g. due to assembly and disassembly activities), the loading history covered by the stress analysis as per (1) shall be modelled as damage-equivalent single-step stress collective. The damage-equivalent stress pertinent to the number of stress cycles N_D shall be determined as follows in the analysis of finally quenched and tempered bolts:

$$\bar{\sigma} = \sigma_1 \cdot \left[\frac{\sum_i N_i \cdot \left(\frac{\sigma_i}{\sigma_1} \right)^c}{N_D} \right]^{\frac{1}{c}} \qquad \text{(B 1-30)}$$

where the following is to be used:

$N_D = 2 \cdot 10^6$

$c = 3$

with:

σ_1 actual stress amplitude of 1st step of load collective step (maximum stress)

σ_i actual stress amplitude of the respective step of load collective

N_i actual number of stress cycles of the respective step of load collective

The following shall be verified:

$$\nu = \frac{\sigma_{ASV}}{\bar{\sigma}} \geq 2.0 \qquad \text{(B 1-31)}$$

with:

σ_{ASV} stress amplitude of endurance limit of finally quenched and tempered bolts according to VDI 2230 Sheet 1

Note:

Where in the analysis of final-rolled bolts, the stress amplitude of the endurance limit is determined in a suitable manner in due consideration of its dependence on the mean stress, the damaging-equivalent stress may be determined analogously by using σ_{ASG} (stress amplitude of endurance limit of final-rolled bolts in accordance with VDI 2230 Sheet 1) in lieu of σ_{ASV} and c=6.

B 1.4.2 Load suspension devices

The requirements of section B 1.4.1 apply to load suspension devices.

B 2 Load cases and analytical proofs for cranes, winches, trolleys as well as load carrying devices under section 7 and for refueling machines under section 8

B 2.1 Structures

B 2.1.1 Performance of proof using the global safety factor concept

B 2.1.1.1 Erection and operational loads

(1) The calculation shall be performed in accordance with DIN 15018-1. For structural members made of the austenitic steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3 the allowable stresses shall be taken from section D 1.

(2) The verification procedure according to section 4.3 of KTA 3205.1 shall be used for all external events.

(3) Where the operating conditions are exactly known, e.g. the actually occurring loadings and stress cycles, the verification of service strength may be performed for a single-step or multi-step load collective on the basis of a stress-number diagram according to **Annex C** for the steels S235 and S355, or on the basis of a stress-number diagram according to section D 2 for the austenitic steels 1.4541, 1.4306 and 1.4571.

In this respect, the requirements of clause B 1.1.1 (3) apply, in which case the following safety factor as regards the allowable maximum stress shall be observed:

$$\bar{\nu} = \sigma_D / \bar{\sigma} \geq 1.25. \qquad \text{(B 2-1)}$$

B 2.1.1.2 Special load case - load shifting

The effects of stresses resulting from load shifting shall be analysed as special load case (special load case HS) in accordance with DIN 15018-1. The stresses required as input to this calculation shall be taken from the analytical proof in accordance with section B 2.2.

B 2.1.2 Performance of proof using the partial safety factors concept

B 2.1.2.1 Erection and operational loads

(1) The calculation shall be performed in accordance with DIN EN 13001-3-1 in conjunction with DIN EN 13001-1 and DIN EN 13001-2 using the specifications given in (2).

A design of structural members using austenitic steels within the partial safety factors concept is permitted only in those cases where the fatigue analysis may be waived according to section 6.3.3 of DIN EN 13001-3-1, in which case the number of stress cycles shall be determined according to section B 1.2.1.2.

(2) The procedure of proof according to DIN EN 13001-3-1 in conjunction with DIN EN 13001-1 and DIN EN 13001-2 shall be conducted in compliance with the following requirements:

a) Regardless of the specific conditions of crane design and operation, the dynamic factor Φ_2 used in the proof according to DIN 13001-2 shall be calculated by applying the following formulae:

aa) for operational loads: $\Phi_2 = 1.4 + 0.528 \cdot v_{h,max}$

ab) for erection loads: $\Phi_2 = 1.1 + 0.132 \cdot v_{h,max}$

For $v_{h,max}$ the maximum hoisting speed relevant for the load case in question shall be inserted.

b) Where a dynamic factor less than that resulting from a) is to be used, the maximum dynamic load factor occurring during one working cycle shall be determined by means of calculation or experimentally in each individual case. As regards the determination of the dynamic factor this dynamic load factor shall be multiplied by a safety factor of 1.25.

c) The requirements of clauses B 1.1.2 (2) c) to g) apply.

d) The test loads shall be as follows:

da) for cranes, winches, trolleys, load suspending devices and refueling machines as specified in KTA 3903 Table 8-1 ser. no. 1.4,

db) for load suspension devices and lifting accessories as specified in KTA 3903 Table 8-1 ser. no. 2.4.

The proof shall be performed in accordance with the requirements in section 4.2.4.3 of DIN EN 13001-2 using the test loads as specified under da) and db) and the dynamic factor as specified under a).

e) The fatigue strength specific resistance factor γ_{mf} in the fatigue analysis according to DIN EN 13001-3-1 shall be taken as γ_{mf} = 1.5 for parts and welded connections as well as for bolted connections which are not hot dip galvanised, and as γ_{mf} = 1.8 for hot dip galvanised bolted connections.

f) Based on the specifications as per a) through e), the risk coefficient γ_n according to DIN EN 13001-2 may be taken as 1.0.

(3) The following procedures shall be used to demonstrate the safety against all external events:

a) either the procedure according to DIN EN 13001-3-1 using the following resistance and partial safety factors

$\gamma_m = 1.0$

$\gamma_P = 1.0$

where in the case of parts and welded connections made of austenitic steels the $R_{p1.0}$ proof stress may be used as f_y instead of the $R_{p0.2}$ proof stress,

or

b) the procedure according to section 4.2 of KTA 3205.1.

(4) Where the operating conditions are exactly known, e.g. the actually occurring loadings and stress cycles, the fatigue analysis may be performed for a single-step or multi-step load collective in accordance with the requirements of DIN EN 13001-3-1 and the specifications in (2).

Note:
The relationship between number of stress cycles and number of working cycles can be derived from section B 1.2.1.2.

The analytical proof based on a multi-step stress-number diagram shall be performed in due consideration of a damage-equivalent stress to the linear damage rule (Miner rule) according to formula (B 1-14).

The following safety factor as regards the allowable stress range shall be observed:

$$\nu = \frac{\Delta\sigma_{Rd}}{\Delta\sigma_{Sd}} \geq 1.25 \,. \qquad \text{(B 2-2)}$$

B 2.1.2.2 Special load case - load shifting

The effects of stresses resulting from load shifting shall be analysed as load combination C in accordance with DIN EN 13001-2. The stresses required as input to this calculation shall be taken from the analytical proof in accordance with section B 2.2.

B 2.1.3 Alternative ways of analytical proof

The stipulations of section B 1.1.3 apply.

B 2.2 Hoists

B 2.2.1 Design data

B 2.2.1.1 Determination of moments and forces

(1) The moments specified in **Tables B 2-1** and **B 2-2** shall be determined for the design of parts of the drive mechanism chain, starting with the service brake and ending with the rope drum.

Note:
When using systems to ascertain the braking effect without test load for in-service inspection, see also KTA 3903, Annex D, section D 3.1.

Load case no.	Moments	Nomenclature	Type of proof
1	T_M	Static moment for the maximum erection load	Fatigue analysis and static stress analysis for the first step of the load collective
	$\hat{T}_M$	Dynamic moment for the maximum erection load T_M (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
2	T_B	Static moment for the maximum operational load	
	$\hat{T}_B$	Dynamic moment for the maximum operational load T_B (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
3	T_0	Static moment for idling runs if the dead weight of half the supporting means plus load suspension devices plus lifting accessory is larger than 30 % of the maximum load	
	$\hat{T}_0$	Dynamic moment for the dead weight T_0 (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
4	T_{SO}	Maximum moment for the special load case, e.g. acceptance test, in-service inspection, gear box test run, simultaneous engagement of the service and auxiliary brake	
	$\hat{T}_{SO}$	Dynamic moment for the special load T_{SO}	
5	T_{BS_1}	Static moment for the entire operational load carried by one drive mechanism chain (second drive mechanism chain does not carry)	
	$\hat{T}_{BS_1}$	Dynamic moment for the entire operational load carried by one drive mechanism chain (second drive mechanism chain does not carry) (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
6	$\hat{T}_{BAS_1}$	Dynamic moment for load shifting under operational load in one drive mechanism chain	Static stress analysis

Table B 2-1: Moments for a double drive mechanism chain

Load case no.	Moments	Nomenclature	Type of proof
1	T_M	Static moment for the maximum erection load	Fatigue analysis and static tress analysis for the first step of the load collective
	$\hat{T}_M$	Dynamic moment for the maximum erection load T_M (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
2	T_B	Static moment for the maximum operational load	
	$\hat{T}_B$	Dynamic moment for the maximum operational load T_B (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
3	T_0	Static moment for idling runs if the dead weight of half the supporting means plus load suspension devices plus lifting accessory is larger than 30 % of the maximum load	
	$\hat{T}_0$	Dynamic moment for the dead weight T_0 (largest value of $\hat{T}_{BS}$, $\hat{T}_{BR}$, $\hat{T}_{AN}$)	
4	T_{SO}	Maximum moment for the special load case, e.g. acceptance test, in-service inspection, gear box test run, simultaneous engagement of the service and auxiliary brake	
	$\hat{T}_{SO}$	Dynamic moment for the special load T_{SO}	
5	$\hat{T}_{BAS_2}$	Dynamic moment for the vibration effect of the safety brake under the governing operational load case	
6	$\hat{T}_{BAS_1}$	Dynamic moment for load shifting under operational load in one drive mechanism chain	Static stress analysis

Table B 2-2: Moments for drive mechanism chain with safety brake

(2) The calculation of the moments $\hat{T}_M$, $\hat{T}_B$, $\hat{T}_O$, $\hat{T}_{SO}$ and $\hat{T}_{BS1}$ shall be based on the operating conditions in accordance with clause B 1.2.1.1 (2). The moments shall be calculated for those intersections that are to be analysed individually. The moment $\hat{T}_{BAS1}$ shall be determined from the load shifting analysis under maximum operational load.

For the determination of $\hat{T}_{BAS2}$ the drive mechanism shall be modelled by a suitable model, and its dynamic behaviour shall be proved to be verifiable by the method of Stenkamp [12] or by using a numerical simulation procedure. A damping factor D = 0.05 may be used if no analytical proof is performed for the individual case.

The flexibility C_i of a spring is given by $C_i = \frac{1}{NG}$, with C_i in Nm/rad and the torsional pliability NG in rad/Nm. The equations for determining the torsional pliability are specified in **Table B 2-3** for typical gear box parts.

(3) The design forces of non-rotating machine elements between rope drum and load shall be determined from the moments specified above.

(4) In the case of a non-redundancy of parts between rope drum and load, 1.25 times the dynamic factor shall be used in the calculation of these parts.

B 2.2.1.2 Determination of the number of stress cycles

The number of stress cycles required for the fatigue analysis shall be determined in accordance with section B 1.2.1.2.

B 2.2.1.3 Determination of the (general) load collective

From the determined moments in accordance with **Table B 2-1** or **B 2-2** and the resulting forces, the stresses in the part shall be calculated and sorted according to size. With the corresponding stress cycles, the load collective shall be established. This load collective shall be compared to the part's stress-number diagram in accordance with section B 1.2.1.3.

B 2.2.2 Shafts, axles and similar parts

B 2.2.2.1 Determination of the stress-number diagram

The requirements under section B 1.2.2.1 shall apply.

B 2.2.2.2 Safety factors for shafts, axles and similar parts

(1) The safety factors specified in **Table B 2-4** shall apply.

(2) When using the finite element method, the requirements of section B3 shall be met.

B 2.2.2.3 Analytical proofs for parallel keys

(1) The requirements under section B 1.2.2.3 shall apply.

(2) For stresses resulting from the load cases “Load shifting“ and “Engagement of safety brake“ the allowable contact stresses can be taken as

$$p_{zul} = 0.9 \cdot R_{p0.2}\,(R_{eH}) \qquad \text{(B 2-3)}$$

B 2.2.3 Pinions

B 2.2.3.1 Determination of the effective stresses and of the load capacity

The requirements under section B 1.2.3.1 shall apply.

B 2.2.3.2 Safety factors for pinions

(1) If the calculation procedure according to DIN 3990-11 is used the safety factors specified in **Table B 2-5** shall apply.

(2) If the analysis procedure of Niemann [2] is used for determining the strength of pinions, the safety factors specified in **Table B 2-6** shall apply.

B 2.2.4 Rope drives

(1) The rope drive shall be calculated in accordance with section B 1.2.4.

(2) With regard to the analytical proof of the rope drum wall thickness and the rope fasteners on the drum, it is allowed to neglect those stress peaks from $\hat{T}_{BAS1}$ and $\hat{T}_{BAS2}$ that very rarely occur and then for only very short time periods, since they affect only a fraction of a rope wrap.

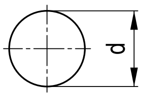
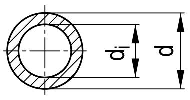
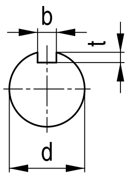
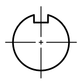
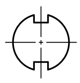
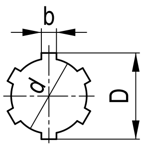
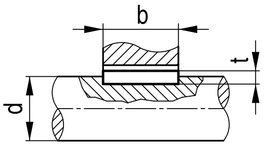
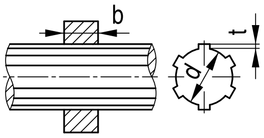
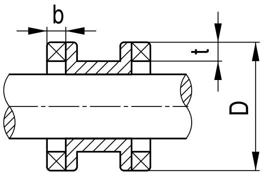
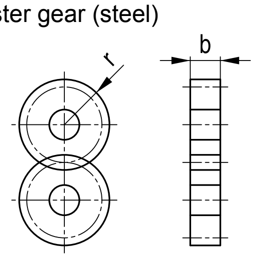
Sketch	Equation
1. Shaft 	$NG = \frac{32 \cdot l}{G \cdot \pi \cdot d^4}$ G : Modulus of rigidity l : Shaft length
2. Sleeve 	$NG = \frac{32 \cdot l}{G \cdot \pi \cdot d^4 \cdot \left[1 - \left(d_1 / d\right)^4\right]}$
3. Shaft with groove for parallel key   	$NG = \frac{32 \cdot l}{G \cdot \pi \cdot d^4} \cdot \alpha$ $\alpha = \frac{32 \cdot \pi^3}{\left(\pi - 4 \cdot \sigma \cdot \psi\right)^4} \left[\frac{\pi}{32} - \frac{\sigma^4 \cdot \psi \cdot \left(1+\psi\right)^2}{12} - \frac{\pi \cdot \sigma^2 \cdot \psi \cdot \left(1 - \psi \cdot \sigma\right)^2}{4 \cdot \left(\pi - 4 \cdot \sigma^2 \cdot \psi\right)}\right]$ $\alpha = \frac{32 \cdot \pi^3}{\left(\pi - 8 \cdot \sigma^2 \cdot \psi\right)^4} \left[\frac{\pi}{32} - \frac{\sigma^4 \cdot \psi \cdot \left(1+\psi\right)^2}{6} - \frac{\sigma^2 \cdot \psi \cdot \left(1 - \psi \cdot \sigma\right)^2}{2}\right]$ σ = t/b ψ = b/d
4. Splinted shaft 	$NG = \frac{32 \cdot l}{G \cdot \pi \cdot d^4} \cdot \alpha$ $\alpha = 1 / \left[1 - \left(z / \pi\right) \cdot \beta \cdot \left(1 - \delta^4\right)\right]^2$ β = b/d δ = D/d l : Shaft length z : Number of splines
5. Parallel key connection 	$NG = \frac{6.4}{d^2 \cdot b \cdot t}$ d, b, t in mm
6. Splined-shaft connection 	$NG = \frac{4}{d^2 \cdot b \cdot t \cdot z}$ d, b, t in mm
7. Gear coupling 	$NG = \frac{4}{D^2 \cdot b \cdot t \cdot \beta} \cdot \alpha$ α = (3 to 4) β = (4 to 5) for z = (6 to 8) d, b, t in mm z : Number of teeth
8. Cluster gear (steel) 	$NG = \frac{1}{b \cdot r^2 \cdot \cos^2 \cdot \alpha} \cdot K$ $K = 6 \cdot 10^{-2}$ Straight tooth gearing $K = 3.6 \cdot 10^{-2}$ Spiral tooth gearing $K = 4.4 \cdot 10^{-2}$ Internal tooth gearing α : Pressure angle b, r in mm

Table B 2-3: Equations for the determination of the torsional pliability NG [rad/Nm] of typical gear box parts

Analytical proof	Loading type	Equation for proof of safety	Required safety factor for increased requirements according to section 7 and for refueling machines
Static strength	First step of the collective 1)	$\nu_{\sigma 1} = \sigma_x / \left(\sigma_1 \cdot \alpha_{k_n}\right)$	≥ 1.35
		$\nu_{\tau 1} = \tau_{S_t} / \left(\tau_1 \cdot \alpha_{k_t}\right)$	
	Failure of a part for a double drive mechanism chain 2)	$\nu_{BAS1_\sigma} = \sigma_x / \left(\hat{\sigma}_{BAS1} \cdot \alpha_{k_n}\right)$	
		$\nu_{BAS1_\tau} = \tau_{S_t} / \left(\hat{\tau}_{BAS1} \cdot \alpha_{k_t}\right)$	
		$\nu_{BAS1_{\sigma V}} = \sigma_x / \hat{\sigma}_{VBAS1}$	
	Failure of a part for a single drive mechanism chain with safety brake 2)	$\nu_{BAS1_\sigma} = \sigma_x / \left(\hat{\sigma}_{BAS1} \cdot \alpha_{k_n}\right)$	
		$\nu_{BAS1_\tau} = \tau_{S_t} / \left(\hat{\tau}_{BAS1} \cdot \alpha_{k_t}\right)$	
		$\nu_{BAS1_{\sigma V}} = \sigma_x / \hat{\sigma}_{VBAS1}$	
		$\nu_{BAS2_\sigma} = \sigma_x / \left(\hat{\sigma}_{BAS2} \cdot \alpha_{k_n}\right)$	
		$\nu_{BAS2_\tau} = \tau_{S_t} / \left(\hat{\tau}_{BAS2} \cdot \alpha_{k_t}\right)$	
		$\nu_{BAS1_{\sigma V}} = \sigma_x / \hat{\sigma}_{VBAS1}$	
Cyclic strength	Load collective Case A or B	$\bar{\nu}_\sigma = \sigma_D / \bar{\sigma}$	≥ 2.5
		$\bar{\nu}_\tau = \tau_D / \bar{\tau}$	
		$\left(\frac{\bar{\sigma}_n}{\sigma_D}\right)^2 + \left(\frac{\bar{\tau}_t}{\tau_D}\right)^2 \le \left(\frac{1{,}0}{\nu}\right)^2$	
Endurance strength	First step of collective Case C	$\nu_\sigma = \sigma_D / \sigma_1$	
		$\nu_\tau = \tau_D / \tau_1$	
		$\left(\frac{\bar{\sigma}_1}{\sigma_D}\right)^2 + \left(\frac{\bar{\tau}_1}{\tau_D}\right)^2 \le \left(\frac{1{,}0}{\nu}\right)^2$	

1) Applies only to hoists; in the case of non-rotating parts no stress concentration factors are needed and the required safety factor shall be ≥ 1.5 with σ_x being replaced by R_{eH} or $R_{p0.2}$.

2) Same as footnote 1), however, the required safety factor shall be ≥ 1.25.

Table B 2-4: Safety factors for shafts, axles and similar parts

Analytical proof	Loading type	Equation for proof of safety	Required safety factor for increased requirements according to section 7 and for refueling machines
Static strength	First step of collective	$\sigma_{F_{min}} = \max \frac{\sigma_{FG}}{\sigma_{F_1}}$	≥ 1.57
		$S_{H_{min_1}} = \max \frac{\sigma_{HG}}{\sigma_{H_1}}$	≥ 1.25
		Proof only required if $N_{ges} < N_Z$	
	Failure of a part for a double drive mechanism chain	$S_{F_{BAS1_{min}}} = \max \frac{\sigma_{FG}}{\sigma_{F_{BAS_1}}}$	≥ 1.57
	Failure of a part for a single drive mechanism chain with safety brake [2)]	$S_{F_{BAS1_{min}}} = \max \frac{\sigma_{FG}}{\sigma_{F_{BAS_1}}}$	
		$S_{F_{BAS2_{min}}} = \max \frac{\sigma_{FG}}{\sigma_{F_{BAS2}}}$	
Cyclic strength	Load collective Case A or B	$\overline{S}_{F_{min}} = \frac{\sigma_{FG}}{\sigma_F}$	≥ 1.76
		$\overline{S}_{H_{min}} = \frac{\sigma_{HG}}{\sigma_H}$	≥ 1.25
Endurance strength	First step of collective Case C	$\overline{S}_{F_{min}} = \frac{\sigma_{FG}}{\sigma_{F_1}}$	≥ 1.76
		$\overline{S}_{H_{min}} = \frac{\sigma_{HG}}{\sigma_{H_1}}$	≥ 1.25

Table B 2-5: Safety factors for pinions according to DIN 3990-11

Analytical proof	Loading type	Equation for proof of safety	Required safety factor for increased requirements according to section 7 and for refueling machines
Static strength	First step of collective	$\nu_{\sigma_1} = \max \frac{\sigma_z}{\sigma_1}$	≥ 1.50
		$\nu_{k_1} = \max \frac{k_z}{k_1}$	≥ 1.25
		Proof only required if $N_{ges} < N_Z$	
	Failure of a part for a double drive mechanism chain	$\nu_{BAS_1} = \max \frac{\sigma_z}{\hat{\sigma}_{BAS_1}}$	≥ 1.35
	Failure of a part for a single drive mechanism chain with safety brake	$\nu_{BAS_1} = \max \frac{\sigma_z}{\hat{\sigma}_{BAS_1}}$	
		$\nu_{BAS_2} = \max \frac{\sigma_z}{\hat{\sigma}_{BAS_2}}$	
Cyclic strength	Load collective Case A or B	$\overline{\nu}_\sigma = \frac{\sigma_D}{\overline{\sigma}}$	≥ 2.5
		$\overline{\nu}_k = \frac{k_D}{\overline{k}}$	≥ 1.6
Endurance strength	First step of collective Case C	$\overline{\nu}_\sigma = \frac{\sigma_D}{\sigma_1}$	≥ 2.5
		$\overline{\nu}_k = \frac{k_D}{k_1}$	≥ 1.6

Table B 2-6: Safety factors for pinions according to Niemann [2]

B 2.3 Lateral transport drives

The requirements in accordance with section B 1.3 shall apply.

B 2.4 Load carrying devices

(1) The requirements under section B 1.4 shall apply.

(2) Section B 2.1 applies to the analytical proofs of supporting structures.

(3) Section B 2.2 applies to the analytical proofs of the machine parts of load hook mounting, grabber, lifting beam and sling, and to the top and bottom blocks.

(4) Section B 1.4.1.5 applies to bolted connections, for the fatigue analysis, however, a safety factor of at least 2.5 shall be verified.

B 3 Analytical proof using the finite element method

B 3.1 General

(1) Besides the analytical proofs described in sections B1 and B2 it is also permitted to perform strength analyses on the basis of the finite element method (FEM) for supporting structures as well as non-rotating machine parts.

(2) When using the finite element method, the requirements of KTA 3201.2, Annex C3 shall be met.

(3) Analytical proofs using finite element calculations are permitted both for proofs based on DIN 15018-1 and for proofs based on DIN EN 13001-3-1.

(4) In the case of proofs based on DIN 15018-1, deviating from the requirements in sections 6, 7 and 8 as well as sections B 1 and B 2 the requirements of section B 3.2 apply to the stress analysis using the finite element method.

(5) In the case of proofs using the partial safety factors concept according to DIN EN 13001-3-1, deviating from the requirements in sections 6, 7 and 8 as well as sections B 1 and B 2 the requirements of section B 3.3 apply to the stress analysis using the finite element method.

B 3.2 Stress analysis for supporting structures using the global safety factor concept in proofs according to DIN 15018-1 and for non-rotating machine parts

B 3.2.1 Stress analysis

(1) Stresses shall be classified in dependence of the cause of stress and its effect on the mechanical behaviour of the part as per section 7.7.2 of KTA 3201.2 into stress categories, i.e. primary stresses, secondary stresses and peak stresses.

(2) For supporting structures and non-rotating machine parts only primary stresses remote from discontinuities shall be considered.

(3) Primary stresses (P) are stresses which satisfy the laws of equilibrium of external forces and moments (loads). Here, membrane stresses (P_m) are defined as the average value of the respective stress component over the section governing the load-bearing behaviour, in the case of plate or shell type structures the average value of the respective stress component distributed across the thickness. Primary bending stresses (P_b) are defined as stresses that can be altered linearly across the considered section and proportionally to the distance from the neutral axis, in the case of plate or shell type structures as the portion of the stresses distributed across the thickness that can be altered linearly.

(4) The equivalent stress intensity shall be derived from the linearised individual stress components.

(5) The location of linearisation outside the area of influence of geometric discontinuities shall be selected such that

a) only primary stress components are covered,

b) the maximum sum of primary stress components is covered.

(6) The requirements of (5) a) und (5) b) are deemed to have generally been met if

a) linearisation is effected at a distance $\sqrt{R \cdot s}$ to the geometric discontinuity in the case of shell-like parts (e.g. skirts, pipes) where R and s are defined as follows:

   R : mean smallest radius of shell

   s : smallest wall thickness

b) linearisation is effected at a distance of half the section diameter in the case of round steel sections, at a distance of half the smallest dimension of cross-section in the case of rectangular steel sections, sheets and plates,

c) linearisation is effected at a distance $\sqrt{R \cdot s}$ to the geometric discontinuity in the case of other shapes where R and s are defined as follows:

   R : half the smallest dimension of rolled section, half the smallest leg width of angle section, radius of bore.

   s : smallest wall thickness

Linearisation may also be effected at other distances, but a suitable analytical proof as regards compliance with the requirements of (5) a) and (5) b) shall be performed.

(7) The following shall apply to the equivalent stress intensity derived from the linearised stress components:

a) Remote from the discontinuity the equivalent stress intensity due to the load combinations to be proofed according to DIN 15018-1 shall not exceed the allowable stresses specified in DIN 15018-1.

b) At the discontinuity the equivalent stress intensity may exceed the allowable stresses specified in DIN 15018-1 provided, both the equilibrium of stresses due to local stress redistributions and the allowable stresses are complied with and the equivalent stress intensity does not exceed the following value:

   ba) for load case H $\sigma_v \le 0.8 \cdot R_{p0.2}$

   bb) for load case HZ $\sigma_v \le 0.9 \cdot R_{p0.2}$

   bc) for load case HS $\sigma_v \le R_{p0.2}$

   with $R_{p0.2}$: yield strength

   Here, plausibility checks are allowed to demonstrate possible stress redistributions.

c) The stress limitation for σ_v at the discontinuity need not be satisfied if it can be proved by means of a limit analysis that the allowable lower limit load as per section 7.7.4 of KTA 3201.2 are not exceeded in which case, for the purpose of calculating the lower bound collapse load, the following yield stress values shall be taken

   ca) in load case H: $\sigma_F = 1.0 \cdot R_{p0.2}$

   cb) in load case HZ: $\sigma_F = 1.10 \cdot R_{p0.2}$

   cc) in load case HS: $\sigma_F = 1.20 \cdot R_{p0.2}$

   and the specified load shall not exceed 67 % of the lower bound collapse load in accordance with section 7.7.4.1 of KTA 3201.2.

(8) For the evaluation as per (7) the equivalent stress intensity to be taken shall be the maximum of

a) the equivalent stress intensity according to the von Mises theory and

b) the largest principal stress.

(9) For the allowable stresses of weld seams DIN 15018-1 shall apply.

B 3.2.2 Fatigue analysis

(1) For supporting structures, the allowable stresses to be used in the fatigue analysis shall be determined to meet the requirements of DIN 15018-1.

(2) The fatigue analysis when using the finite element method differs from the procedures under sections B 1 and B 2 only with respect to the determination of the nominal stress. Here, the stress intensity determined by means of the stress analysis shall be evaluated on the basis of the linearised individual stress components.

(3) For non-rotating machine parts, the fatigue analysis shall be performed in accordance with sections B 1.2.2 and B 2.2.2 and with the required safety factors shown in **Table B 1-3** and **Table B 2-4**.

(4) The fatigue strength reduction factor may also be determined on the basis of a FEM analysis alternatively to the requirements of B 1.2.2.1 (3). In this case, the fatigue strength reduction factor is the quotient of maximum equivalent stress intensity (non-linerarised) and the equivalent stress intensity derived from primary membrane and bending stresses as per subclause (1).

B 3.3 Stress analysis for supporting structures using the partial safety factors concept according to DIN EN 13001-3-1

B 3.3.1 Static stress analysis

(1) Stresses shall be determined using the loads, load combinations and partial safety factors according to Table 12a of DIN EN 13001-2 and the requirements specified in sections B 1 and B 2.

(2) The stresses so determined shall be classified in dependence of the cause of stress and its effect on the mechanical behaviour of the part as per KTA 3201.2, section 7.7.2 into stress categories, i.e. primary stresses, secondary stresses and peak stresses.

(3) Remote from discontinuities only primary stresses shall be considered (cf. clause B 3.2.1 (3)).

(4) The equivalent stress intensity shall be derived from the linearised individual stress components.

(5) The location of linearisation outside the area of influence of geometric discontinuities shall be selected such that

a) only primary stress components are covered,

b) the maximum sum of primary stress components is covered.

(6) The requirements of (5) a) und (5) b) are deemed to have generally been met if

a) linearisation is effected at a distance $\sqrt{R \cdot s}$ to the geometric discontinuity in the case of shell-like parts (e.g. skirts, pipes) where R and s are defined as follows:

   R : mean smallest radius of shell

   s : smallest wall thickness

b) linearisation is effected at a distance of half the section diameter in the case of round steel sections, at a distance of half the smallest dimension of cross-section in the case of rectangular steel sections, sheets and plates,

c) linearisation is effected at a distance $\sqrt{R \cdot s}$ to the geometric discontinuity in the case of other shapes where R and s are defined as follows:

   R : half the smallest dimension of rolled section, half the smallest leg width of angle section, radius of bore.

   s : smallest wall thickness

Linearisation may also be effected at other distances, but a suitable analytical proof as regards compliance with the requirements of (5) a) and (5) b) shall be performed.

(7) The following shall apply to the equivalent stress intensity derived from the linearised stress components:

a) Remote from the discontinuity the equivalent stress intensity due to the load combinations in consideration of partial safety factors shall not exceed the limit design stress f_{Rd} according to section 5.2 of DIN EN 13001-3-1.

b) At the discontinuity the equivalent stress intensity due to the load combinations in consideration of partial safety factors may exceed the limit design stress f_{Rd} provided, both the equilibrium of stresses due to local stress redistributions and the limit design stress are complied with and the equivalent stress intensity does not exceed the following value:

   $\sigma_{V} \leq 1.2 \cdot f_{Rd}$

   with f_{Rd} : limit design stress

   Here, plausibility checks are allowed to demonstrate possible stress redistributions.

c) The stress limitation for σ_V at the discontinuity need not be satisfied if it can be proved by means of a limit analysis that the allowable lower limit load as per KTA 3201.2, section 7.7.4 (maximum absorbable load when using a linear-elastic/ideal-plastic material behaviour) complies with the equilibrium conditions and that the limit design stress f_{Rd} is not exceeded.

(8) For the evaluation as per (7) the equivalent stress intensity to be taken shall be the maximum of

a) the equivalent stress intensity according to the von Mises theory and

b) the largest principal stress.

(9) For the limit design stresses in welded connections section 5.2.5 of DIN EN 13001-3-1 shall apply.

B 3.3.2 Fatigue analysis

(1) The allowable stresses to be used in the fatigue analysis shall be determined to meet the requirements of DIN EN 13001-3-1.

(2) The fatigue analysis when using the finite element method differs from the procedures under sections B 1 and B 2 only with respect to the determination of the nominal stress. Here, the stress intensity determined by means of the stress analysis shall be evaluated on the basis of the linearised individual stress components.

(3) The fatigue strength reduction factor may also be determined on the basis of a FEM analysis alternatively to the requirements of B 1.2.2.1 (3). In this case, the fatigue strength reduction factor is the quotient of maximum equivalent stress intensity (non-linerarised) and the equivalent stress intensity derived from primary membrane and bending stresses as per subclause (1).

B 4 Nomenclature and physical quantities

Symbol	Physical quantity and designation	Unit
C_i	spring rate	Nm/rad
C_T	tooth bearing error factor	—
D	damping factor	—
J_{ab}	moments of inertia on output side of the cross section analysed	kgmm^2
J_{an}	moments of inertia on input side of the cross section analyzed	kgmm^2
K_n	mathematical product of fatigue strength reduction factor, roughness factor and size factor under normal stress	—
K_t	mathematical product of fatigue strength reduction factor, roughness factor and size factor under torsional stress	—
N_D	number of stress cycles for endurance limit	—
NG	torsional resilience	Rad/Nm
$N_{i\sigma}$, $\hat{N}_{i\sigma}$	number of stress cycles for the moment loading levels in shafts, axles, tooth feet and tooth flanks	—
$N_{i\tau}$, $\hat{N}_{i\tau}$	number of torsional stress cycles for the moment loading levels in shafts	—
N_Z	number of stress cycles for finite-life fatigue	—
R_{eH}	upper yield point	N/mm^2
R_m	tensile strength	N/mm^2
R_{max}	wheel force	N
$R_{p0,2}$	0.2% proof stress	N/mm^2
R_z, R_a	average roughness depth	µm
R_{z100}	average relative roughness depth, based on an axial distance of 100 mm	µm
S_{max}	nominal rope force multiplied by the dynamic factor	N
$S, \overline{S}$	required safety factor	—
$\hat{T}_{AN}$	dynamic moment upon lifting of a set-down load	Nmm
T_B	static moment for maximum operational load	Nmm
$\hat{T}_B$	dynamic moment for maximum operational load	Nmm
$\hat{T}_{BAS_1}$	dynamic moment from load shifting at operational load within one drive mechanism chain	Nmm
$\hat{T}_{BAS_2}$	dynamic moment from vibratory effects of the safety brake for the governing operational load case	Nmm
$\hat{T}_{BR}$	dynamic moment upon braking (lowering)	Nmm
$\hat{T}_{Bre}$	maximum braking moment of the brakes	Nmm
$\hat{T}_{BS}$	dynamic moment upon acceleration (lifting)	Nmm
T_{BS_1}	static moment from operational load within one drive mechanism chain	Nmm
$\hat{T}_{BS_1}$	dynamic moment from operational load within one drive mechanism chain	Nmm
T_L	maximum moment of inertia from dead load and lifting load without consideration of the efficiency	Nmm
T_M	static moment for maximum erection load	Nmm
$\hat{T}_M$	dynamic moment for maximum erection load	Nmm
T_{mot}	maximum motor moment	Nmm
T_0	static moment for no-load travel	Nmm
$\hat{T}_0$	dynamic moment for no-load travel	Nmm
T_R	maximum moment of inertia from frictional forces acting in opposite direction to the lifting or lowering motion	Nmm
T_{SO}	maximum moment for special load case	Nmm
$\hat{T}_{SO}$	dynamic moment for special load case	Nmm
U_i	number of working cycles, i.e. lifting and lowering	—
Z_R	factor for average relative roughness	—
Z_{Sch_i}	number of control steps per working cycle (switching to accelerate and switching to brake are considered one control step each)	—
c	gradient of the part's S-N-curve in the finite-life fatigue range	—
d	diameter	mm
$f_{H\beta}$	flank line deviation	—
f_R	flank direction error	—
f_{Rd}	limit design stress	N/mm^2
f_{Rw}	effective flank direction error	—
f_y	yield stress of material	N/mm^2
h	rope drum wall thickness at the base of the rope grooves	mm
h_i	duty cycle of the hoist leaving times of no-load travel with a dead weight ≤ 30 % of operational load out of consideration	hours
k	head width of crane track	mm
$\overline{k}$	damage equivalent tooth flank load capacity	—
k_a	number of stress cycles per control step	—
k_D, k_0	flank compression endurance limit of pinions	N/mm^2
k_w	effective contact stress of pinions	N/mm^2
k_Z	tooth flank load capacity	N/mm^2
n_i	rotational speed of analysed drive mechanism component	min^{-1}

Symbol	Physical quantity and designation	Unit
p_{maxH}	contact Hertzian stress	N/mm²
p_{zul}	allowable contact stress for parallel keys	N/mm²
r_1	radius of curvature of track head	mm
s	rope groove pitch	mm
$\bar{s}_i$	average path as the sum of lifting and lowering in one working cycle	m
$\hat{t}_i$	total duration of oscillations in one working cycle taking the control switchings for positioning into account	s
$v_{h,max}$	maximum steady hoisting speed	m/s
$\bar{v}_i$	average hoisting speed	m/s
y_K	life time factor for tooth flank load capacity	—
y_G, y_H	coefficient in accordance with Table 121/1 of [2] taking, however, the materials under **Table B 1-4** into account	—
y_R	roughness factor	—
y_S	coefficient in accordance with Table 121/1 of [2]	—
y_V	coefficient in accordance with Table 121/1 of [2]	—
y_σ	life time factor for tooth foot load capacity	—
α_{k_n}	stress concentration factor for normal stresses	—
α_{k_t}	stress concentration factor for torsional stresses	—
α_L	load introduction factor	—
γ	angle of inclination of the part's stress-number diagram in the finite-life fatigue range	—
γ_m	general resistance factor	—
γ_{mf}	fatigue strength specific resistance factor	—
γ_n	risk coefficient	—
γ_p	partial safety factor	—
γ_{sm}	specific resistance factor for material	—
γ_{ss}	specific resistance factor of slip-resistance connection	—
ε	number of torsional stress cycles due to one control switching	—
μ_0	coefficient of friction	—
ν, $\bar{\nu}$	required safety factor	—
ρ_{red}	equivalent radius of curvature at the pitch point	mm
$\bar{\sigma}$	damage-equivalent tensile stress, calculated from the load cycles in Case A and Case B	N/mm²
$\hat{\sigma}_{BAS_1}$	maximum stress due to dynamic moment from load shifting at operational load within one drive mechanism chain	N/mm²
$\hat{\sigma}_{BAS_2}$	maximum stress due to dynamic moment from vibratory effects of the safety brake for the governing load case	N/mm²
σ_D, σ_0	endurance limit for normal stresses or tooth foot	N/mm²
σ_F	effective stress at tooth foot	N/mm²
σ_{FE}	nominal strength at tooth foot	N/mm²
σ_H	effective stress at tooth flank	N/mm²
σ_{FG}	endurance strength and static strength at tooth foot	N/mm²
σ_{HG}	endurance strength and static strength at tooth flank	N/mm²
$\sigma_{H\,lim}$	endurance limit for pitting	N/mm²
σ_n	endurance limit for normal stresses of material test specimen at 50 % survival probability	N/mm²
$\Delta\sigma_{Rd}$	limit design stress range (normal)	N/mm²
$\Delta\sigma_{Sd}$	design stress range (normal)	N/mm²
σ_w	effective tooth foot stress	N/mm²
σ_Z	tooth foot load capacity	N/mm²
$\hat{\sigma}_{V_{BAS_1}}$	maximum equivalent stress due to dynamic moment from load shifting at operational load within one drive mechanism chain	N/mm²
$\hat{\sigma}_{V_{BAS_2}}$	maximum equivalent stress due to dynamic moment from vibratory effects of the safety brake for the governing load case	N/mm²
$\hat{\tau}_{BAS_1}$	maximum torsional stress due to dynamic moment from load shifting at operational load within one drive mechanism chain	N/mm²
$\hat{\tau}_{BAS_2}$	maximum torsional stress due to dynamic moment from vibratory effects of the safety brake for the governing load case	N/mm²
$\bar{\tau}$	damage-equivalent torsional stress, calculated from the load cycles in Case A and Case B	N/mm²
τ_D	endurance limit for torsional stresses	N/mm²
τ_{St}	torsional yield point $\frac{\sigma_x}{\sqrt{3}}$	N/mm²
τ_t	endurance limit for torsional stresses of material test specimen at 50 % survival probability	N/mm²
Φ_2	Dynamic factor on lifting load when hoisting an unrestrained grounded load	—
φ_S	vibration coefficient that takes the dynamic effect due to sudden change in moment into account	—
ψ	dynamic factor	—

Annex C

Stress-number diagram for the fatigue analysis of the materials S235 and S355 according to DIN EN 10025-2

The stress-number diagrams presented in **Tables C-1** and **C-2** as well as in **Figures C-1 to C-10** are allowable maximum stresses according to DIN 15018-1, Table 17 and Table 18. They correspond to the stress collective S_3 in stress ranges N1 to N4 (B4 to B6) DIN 15018-1.

Tables C-1 and **C-2** show examples for the respective salient points of the stress coordinates S_D for R = -1 (alternating loading) and R = 0 (cyclic loading) for notch cases K0 to K4.

The salient points of the stress coordinates $S_{D(R)}$ for other R values shall be determined in accordance with the interrelationships shown in DIN 15018-1 Figure 9. For notch cases K0 to K4, the service life coordinate of the salient point N_D and the slope in the finite-life fatigue range k correspond to the values shown in **Tables C-1** and **C-2** ($N_D = 2.0 \cdot 10^6$; c = 3.32) for all $S_{D(R)}$.

The fatigue analysis shall be based on the requirements under clauses B 1.2.1.3 (3) and B 1.2.1.3 (4).

Ser. no.	Notch case according to DIN 15018-1 Table 10.3	Loading ratio R	Load collective according to DIN 15018-1 Table 14	Parameters of stress-number diagram in double-logarithmic coordinate system		
				Stress coordinate of salient point S_D in N/mm²	Service life coordinate of salient point N_D	Slope k
1	K 0	-1	S_3	84.0	$2.0 \cdot 10^6$	3.32
2	K 1			75.0		
3	K 2			63.0		
4	K 3			45.0		
5	K 4			27.0		

Table C-1: Tabulated values for the S/N diagrams of Figures C-1 to C-5

Ser. no.	Notch case according to DIN 15018-1 Table 10.3	Loading ratio R	Load collective according to DIN 15018-1 Table 14	Parameters of stress-number diagram in double-logarithmic coordinate system		
				Stress coordinate of salient point S_D in N/mm²	Service life coordinate of salient point N_D	Slope k
1	K 0	0	S_3	140.0	$2.0 \cdot 10^6$	3.32
2	K 1			125.0		
3	K 2			105.0		
4	K 3			75.0		
5	K 4			45.0		

Table C-2: Tabulated values for the S/N diagrams of figures C-6 to C-10

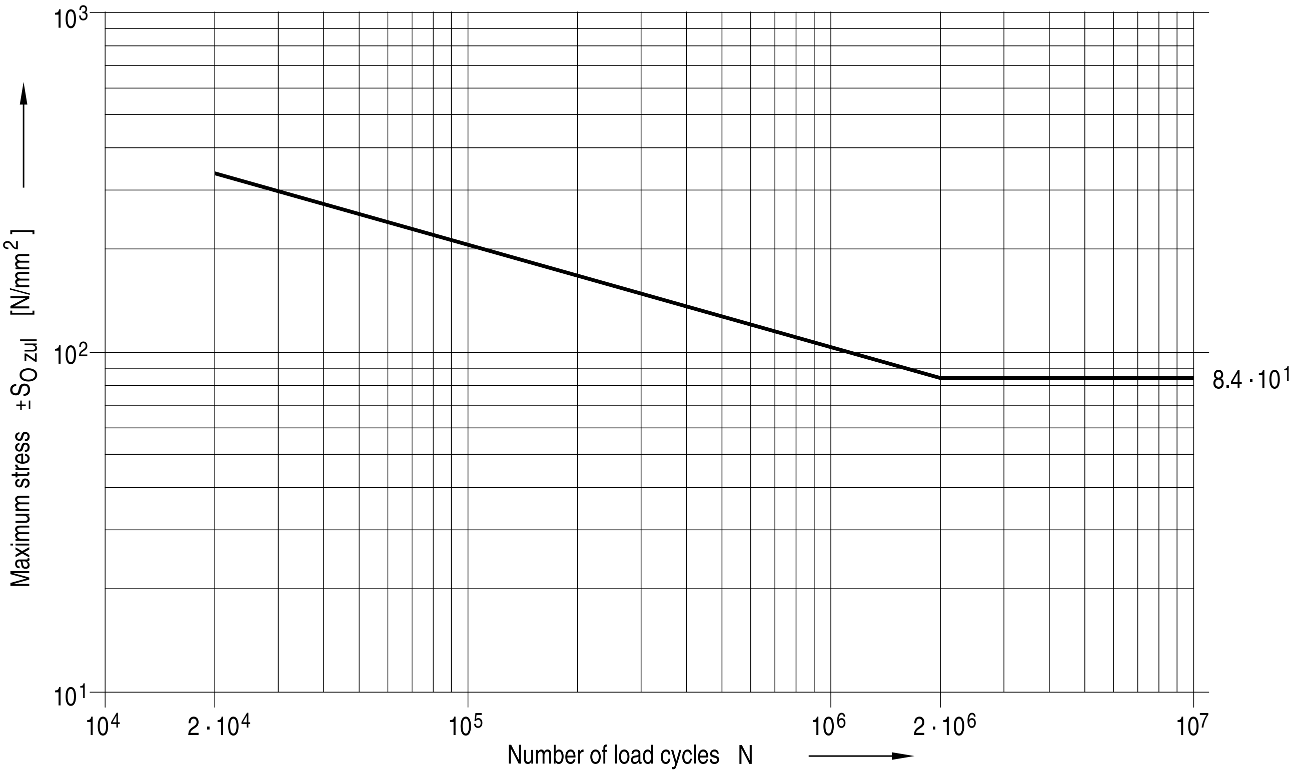


Figure C-1: S/N diagram for notch case K 0 according to DIN 15018-1, R = -1

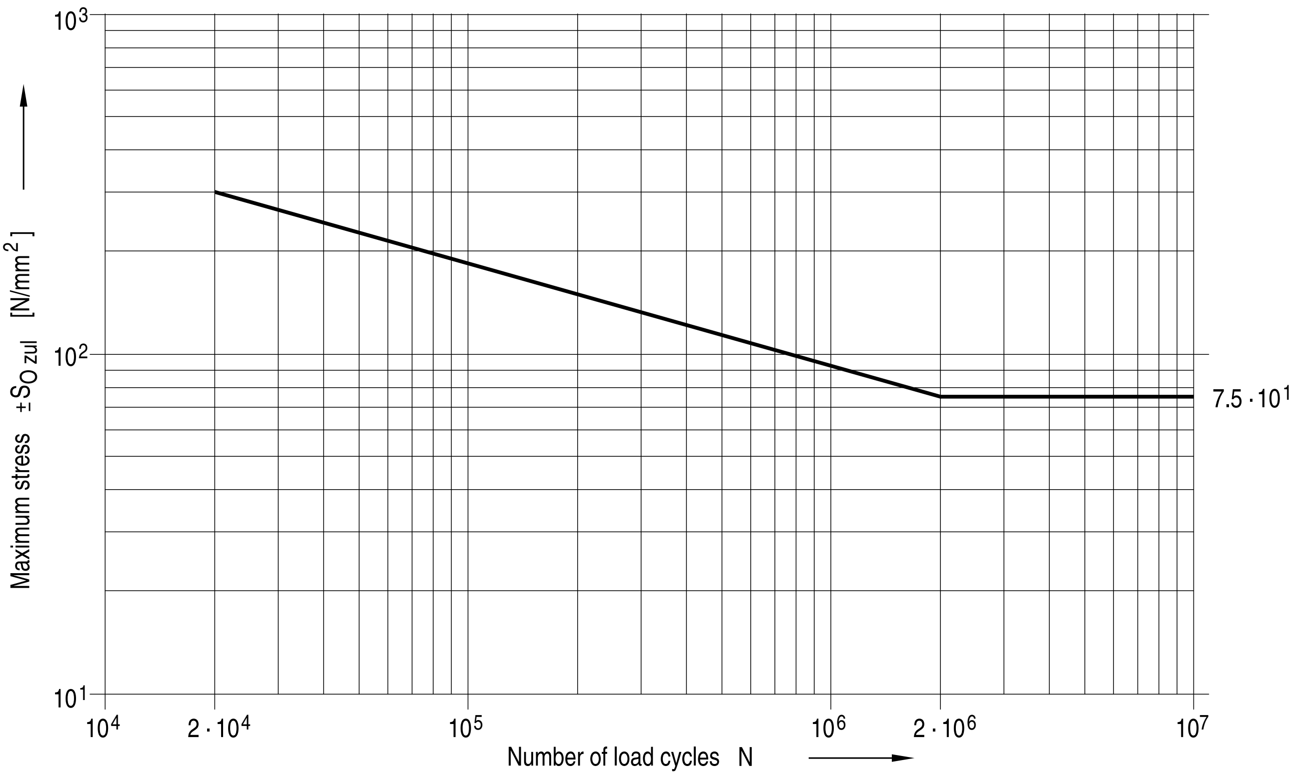


Figure C-2: S/N diagram for notch case K 1 according to DIN 15018-1, R = -1

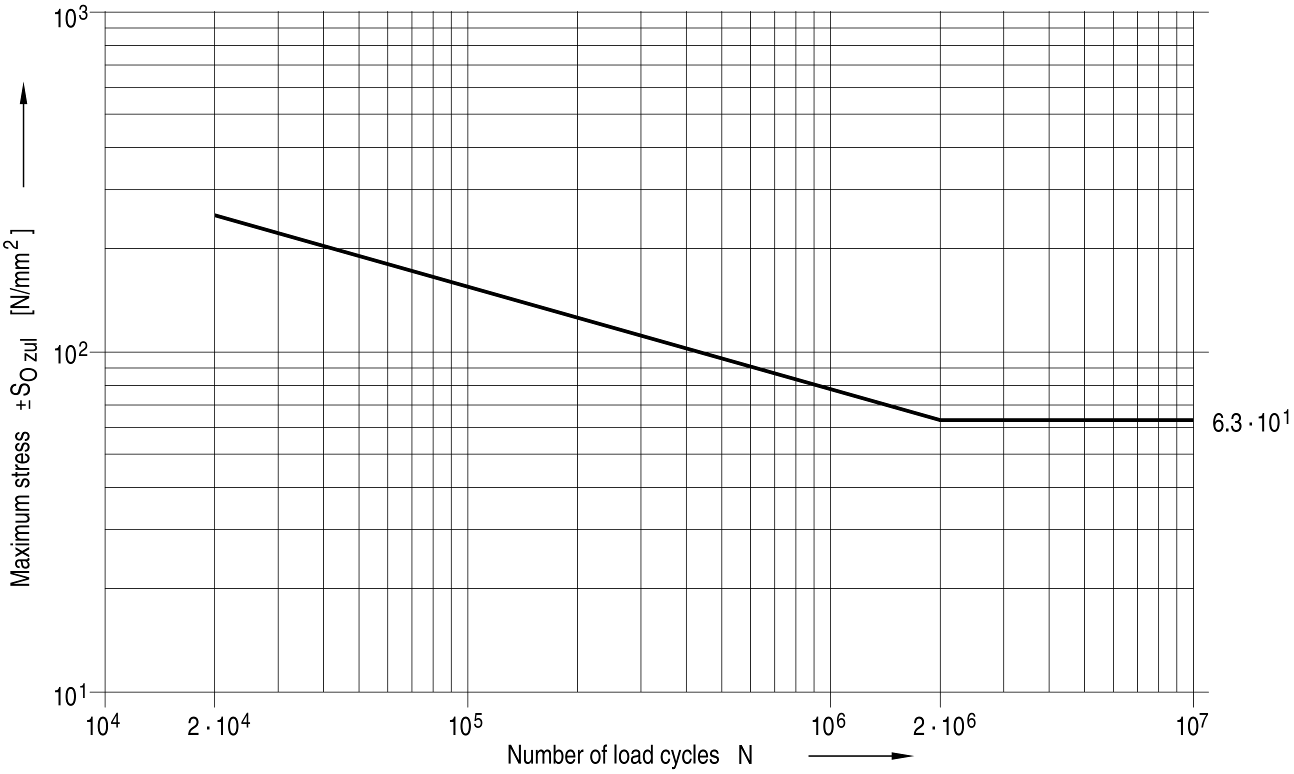


Figure C-3: S/N diagram for notch case K 2 according to DIN 15018-1, R = -1

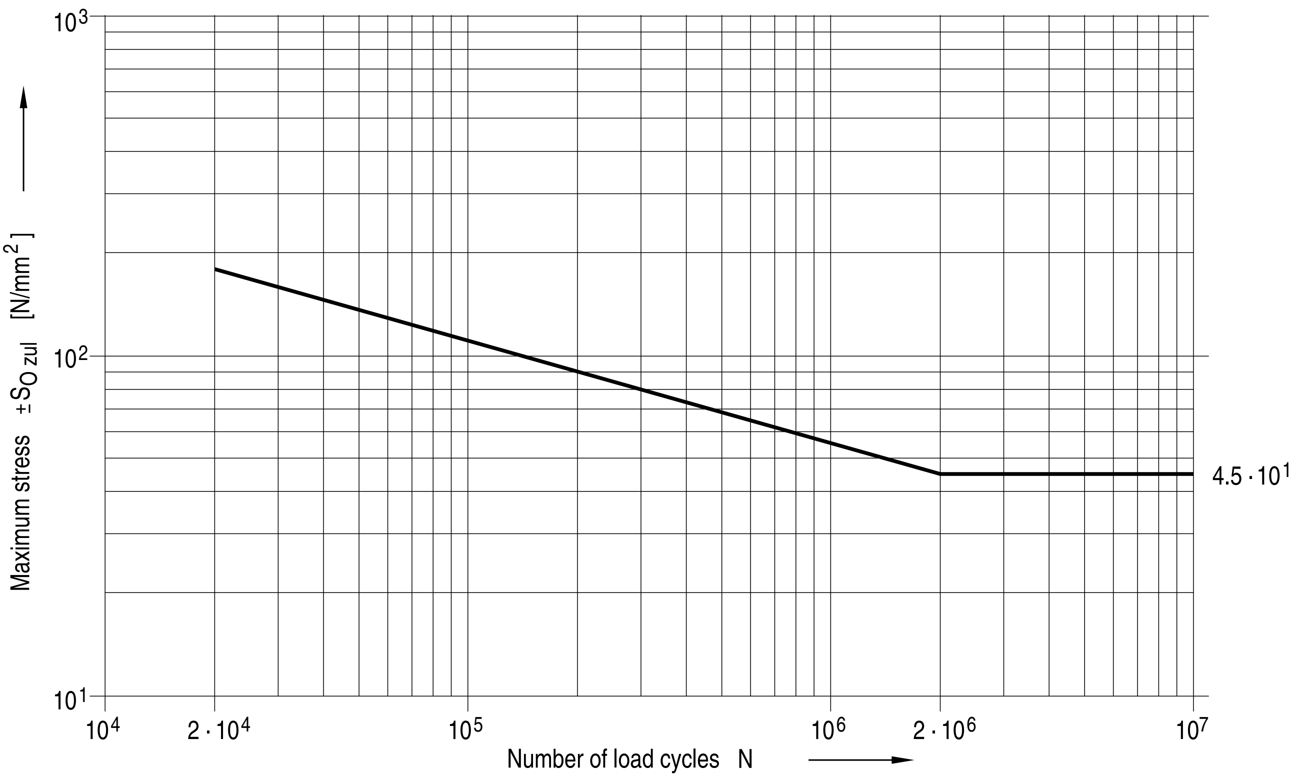


Figure C-4: S/N diagram for notch case K 3 according to DIN 15018-1, R = -1

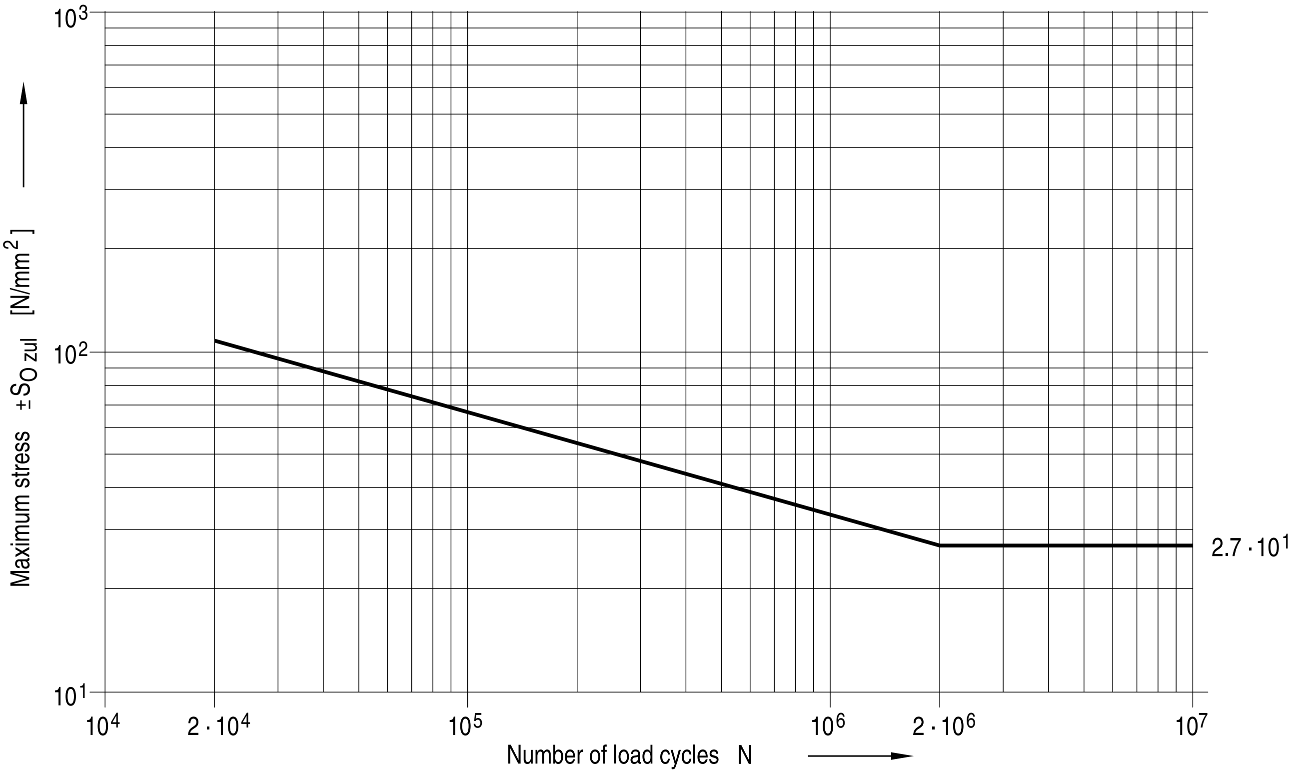


Figure C-5: S/N diagram for notch case K 4 according to DIN 15018-1, R = -1

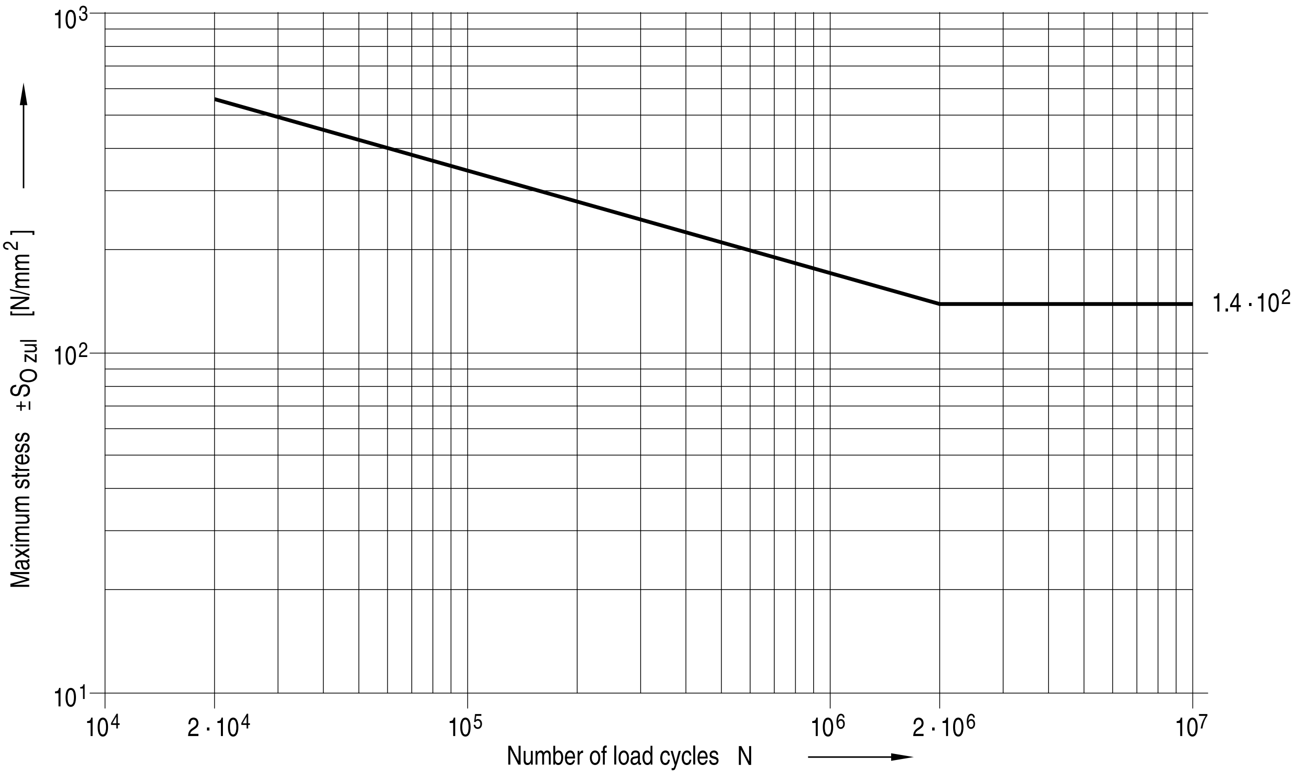


Figure C-6: S/N diagram for notch case K 0 according to DIN 15018-1, R = 0

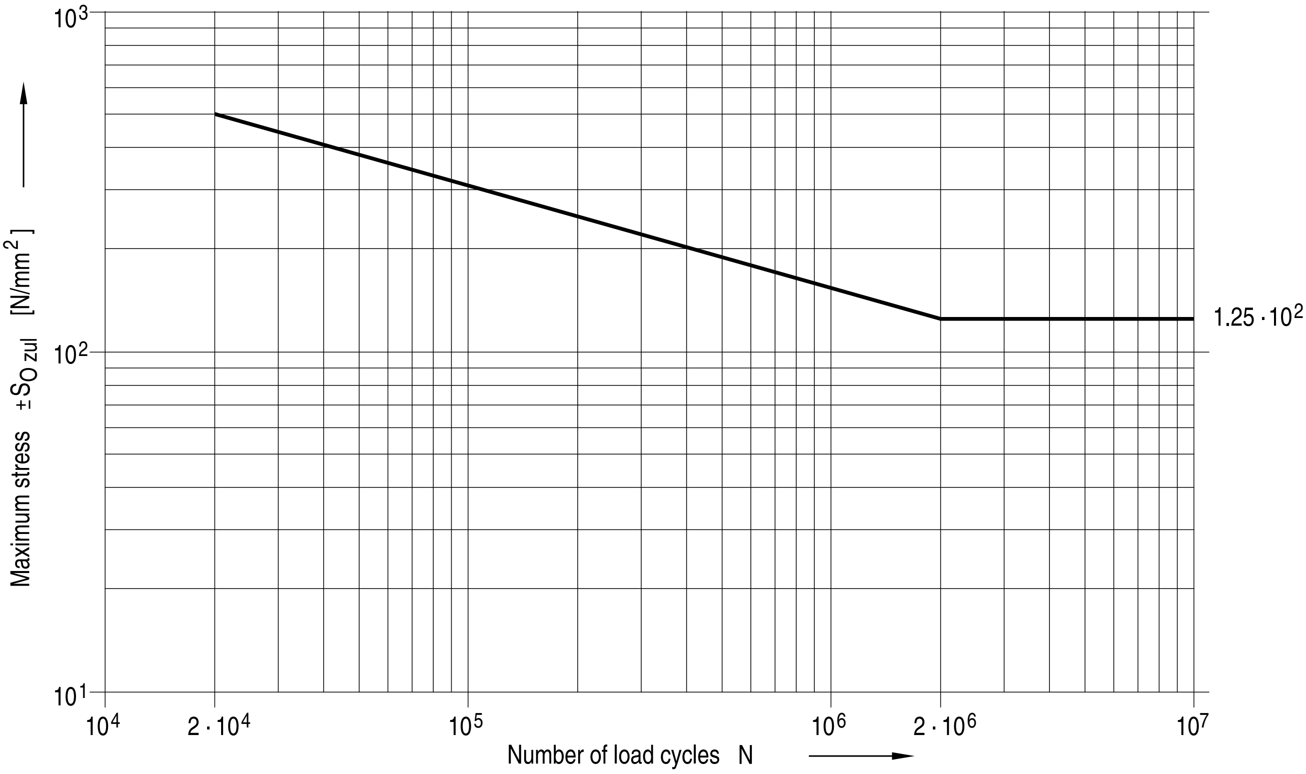


Figure C-7: S/N diagram for notch case K 1 according to DIN 15018-1, R = 0

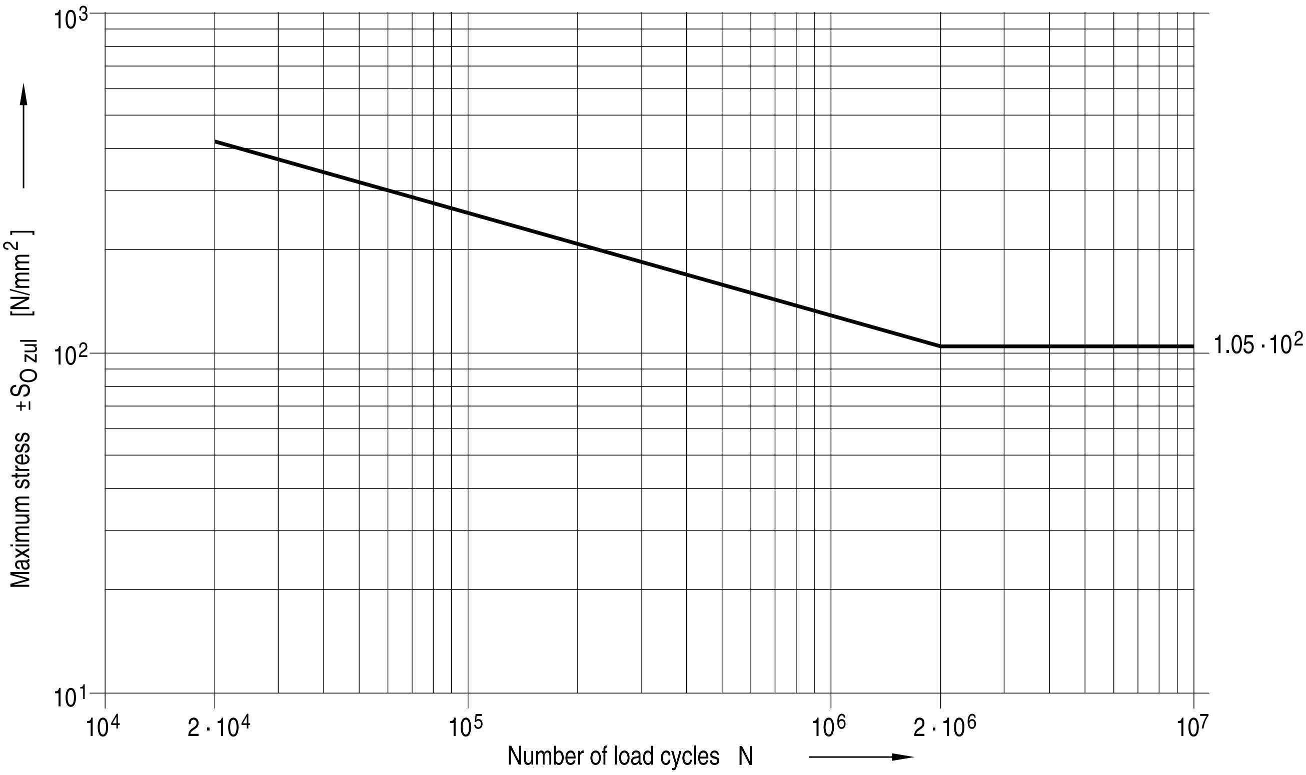


Figure C-8: S/N diagram for notch case K 2 according to DIN 15018-1, R = 0

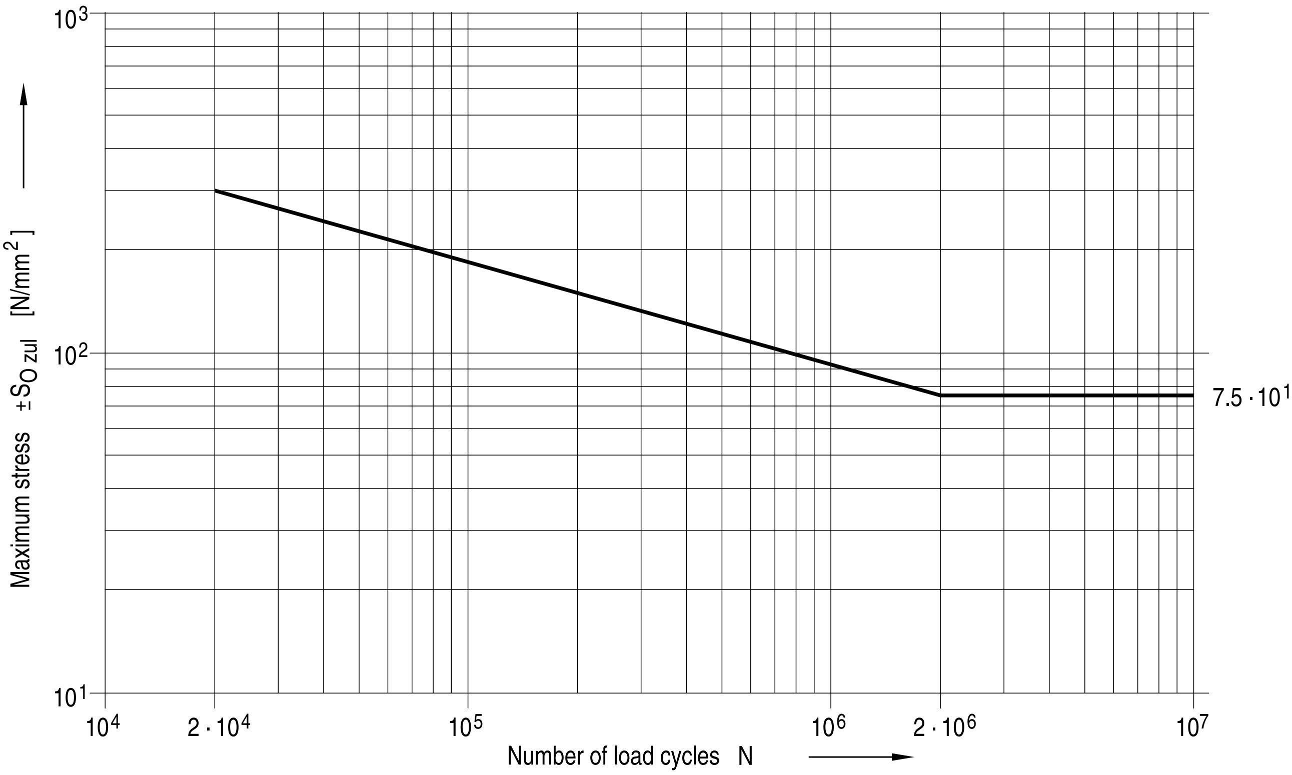


Figure C-9: S/N diagram for notch case K 3 according to DIN 15018-1, R = 0

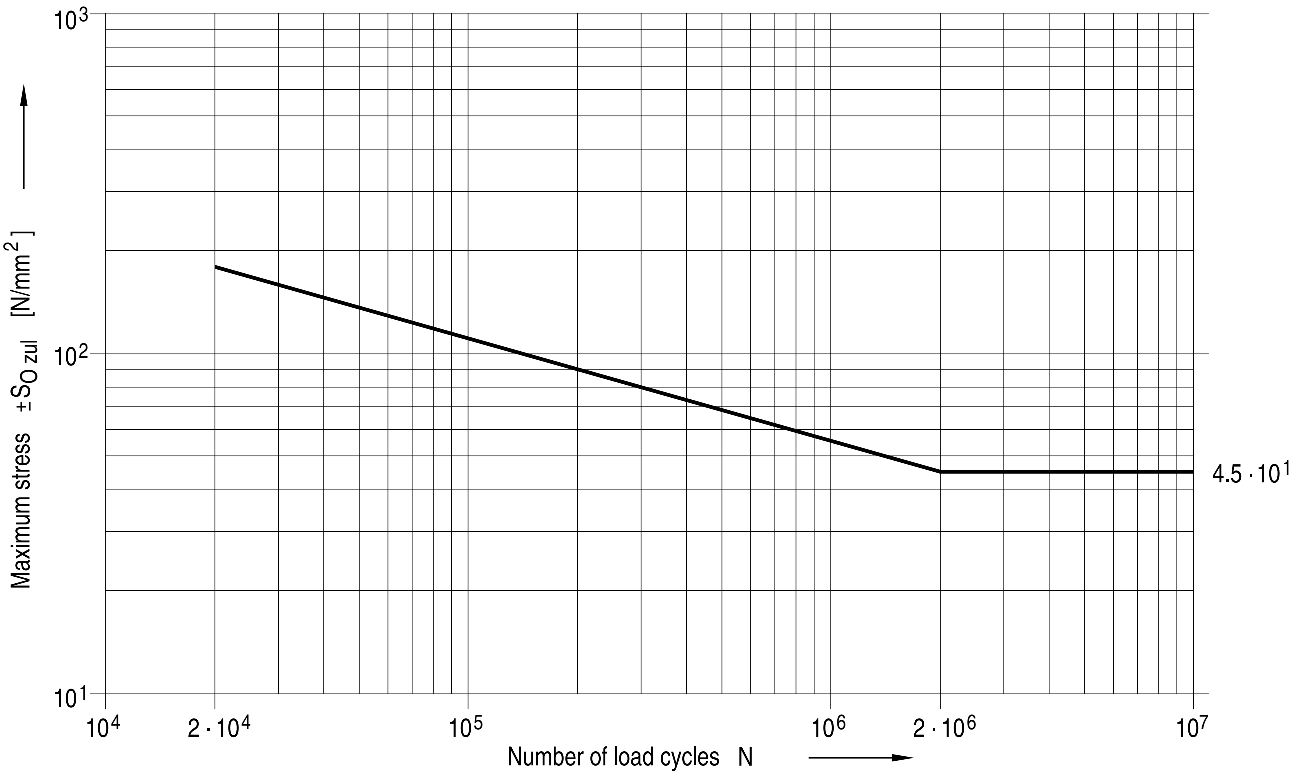


Figure C-10: S/N diagram for notch case K 4 according to DIN 15018-1, R = 0

Annex D

Stress analysis and stress-number diagrams for the fatigue analysis of the steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3

D 1 Allowable stresses for structural members using the austenitic steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3

(1) When using the austenitic steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3, the allowable stresses (H or HZ) for the stress analysis shall be determined such that the safety factors specified for ferritic steels in DIN 15018-1, Tables 10 and 11 are satisfied until attainment of the yield strength $\sigma_{0.2}$.

(2) Supporting structures shall be classified into loading level B3 or B4 according to DIN 15018-1 for the maximum operating load in accordance with sub-clauses 6.1.1 (2) b), 7.1.1 (2) b) or 8.1.1 (2). For selected notch cases and limit stress ratios, the allowable stresses used in the fatigue analysis are shown in **Table D-1** when using the austenitic steels 1.4541, 1.4306 and 1.4571 according to DIN EN 10088-2 or DIN EN 10088-3.

Notch case [1]	Stress [1]	Allowable value in N/mm² for the loading level	
		B3	B4
W 1-1	$\sigma_{Dz(0)}$	247 [2]	247 [2]
W 1-2	$\sigma_{Dz(0)}$	—	162 [2]
K 1	$\sigma_{Dz(0)}$	210 [2]	210 [2]
K 2	$\sigma_{Dz(0)}$	—	174 [2]
K 3	$\sigma_{Dz(0)}$	—	167 [2]
K 4	$\sigma_{Dz(0)}$	150 [2]	80
K 4-R	$\sigma_{\tau(-1)}$	—	103.6

1) Abbreviations in conformance with DIN 15018-1.
2) The stress value indicated was determined on the basis of the characteristic values of **Table D-2**. For the calculatory verification the maximum allowable stresses are limited by the allowable stresses of load case HZ in the stress analysis.

Table D-1: Allowable stresses for the fatigue analysis when using austenitic steels (examples)

D 2 Analytical proof in due consideration of a damage-equivalent stress in accordance with the linear damage rule (Miner's rule))

(1) The S/N diagrams shown in **Table D-2** und **Figures D-1 to D-10** for selected notch cases represent allowable maximum stresses similar to those shown in DIN 15018-1, Table 17 and Table 18. The S/N diagrams correspond to the load collective S_3 in stress cycle ranges N1 to N4 (B4 to B6) DIN 15018-1.

The loading ratio R = 0 (pulsating tensile stress). For the pipe test specimen R = -1 (alternating torsional stress).

The stress values for notch case K4-R are shear stresses and normal stresses for the other notch cases.

(2) The values on which the S/N diagrams (**Figures D-1** to **D-10**) are based are shown in **Table D-2**.

(3) In **Table D-2** and in the S/N diagrams the notations are as follows:

$S_{O,zul}$: allowable maximum stress; synonymous symbol $\sigma_{O,zul}$

S_D : stress coordinate of salient point of S/N diagram des, synonymous symbol σ_D

N : actual number of stress cycles

N_D : service life coordinate of salient point of S/N diagram

k : slope of S/N diagram

(4) For the fatigue analysis the requirements of sub-clauses B 1.2.1.3 (3) and B 1.2.1.3 (4) for case A apply.

where

σ_x : allowable stress for the stress analysis

N_Z : number of stress cycles for finite-life fatigue.

Designation	Notch case 1)	Loading ratio R	Load collective acc. to DIN 15018-1 Table 14	Parameters of stress-number diagram in double-logarithmic coordinate system: Stress coordinate of salient point S_D in N/mm²	Service life coordinate of salient point N_D	Slope k	Scope of application according to [14]
Perforated bar, $K_t = 2.4$	W 1-1 2)	-1	S_3	138.9	$1.32 \cdot 10^6$	13.00	$1.0 \cdot 10^5 < N \leq 1.32 \cdot 10^6$
Perforated bar, $K_t = 2.4$	W 1-1 2)	0		180.0	$1.81 \cdot 10^6$	6.96	$1.0 \cdot 10^5 < N \leq 1.81 \cdot 10^6$
Perforated bar, $K_t = 4.2$	W 1-2 2)	0		104.3	$6.58 \cdot 10^6$	7.93	$1.0 \cdot 10^5 < N \leq 6.58 \cdot 10^6$
Butt joint	K 1	-1		96.1	$2.54 \cdot 10^6$	6.99	$1.0 \cdot 10^5 < N \leq 2.54 \cdot 10^6$
Butt joint	K 1	0		145.9	$2.20 \cdot 10^7$	12.98	$1.0 \cdot 10^5 < N \leq 1.00 \cdot 10^7$
Cruciform joint, double-bevel butt weld, special quality	K 2 2)	0		101.5	$5.58 \cdot 10^6$	6.19	$1.0 \cdot 10^5 < N \leq 5.58 \cdot 10^6$
Cruciform joint double-bevel butt weld, normal quality	K 3	0		88.8	$2.32 \cdot 10^7$	7.51	$1.0 \cdot 10^5 < N \leq 1.00 \cdot 10^7$
Cruciform joint, fillet weld	K 4	-1		20.2	$8.14 \cdot 10^6$	2.89	$1.0 \cdot 10^5 < N \leq 8.14 \cdot 10^6$
Cruciform joint, fillet weld	K 4	0		29.4	$1.01 \cdot 10^7$	3.91	$1.0 \cdot 10^5 < N \leq 1.00 \cdot 10^7$
Pipe test specimen, fillet weld	K 4-R 3)	-1		34.8	$1.32 \cdot 10^7$	3.84	$1.0 \cdot 10^5 < N \leq 1.00 \cdot 10^7$

1) Abbreviations in accordance with DIN 15018-1 section 10.3.

2) For notch cases W 1-1, W 1-2 and K 2 the following applies: at $N > N_D$ is $S_{O,zul} = S_D$

3) The stress values for K 4-R are shear stresses

Table D-2: Tabulated values for the S/N diagrams of figures D-1 to D-10

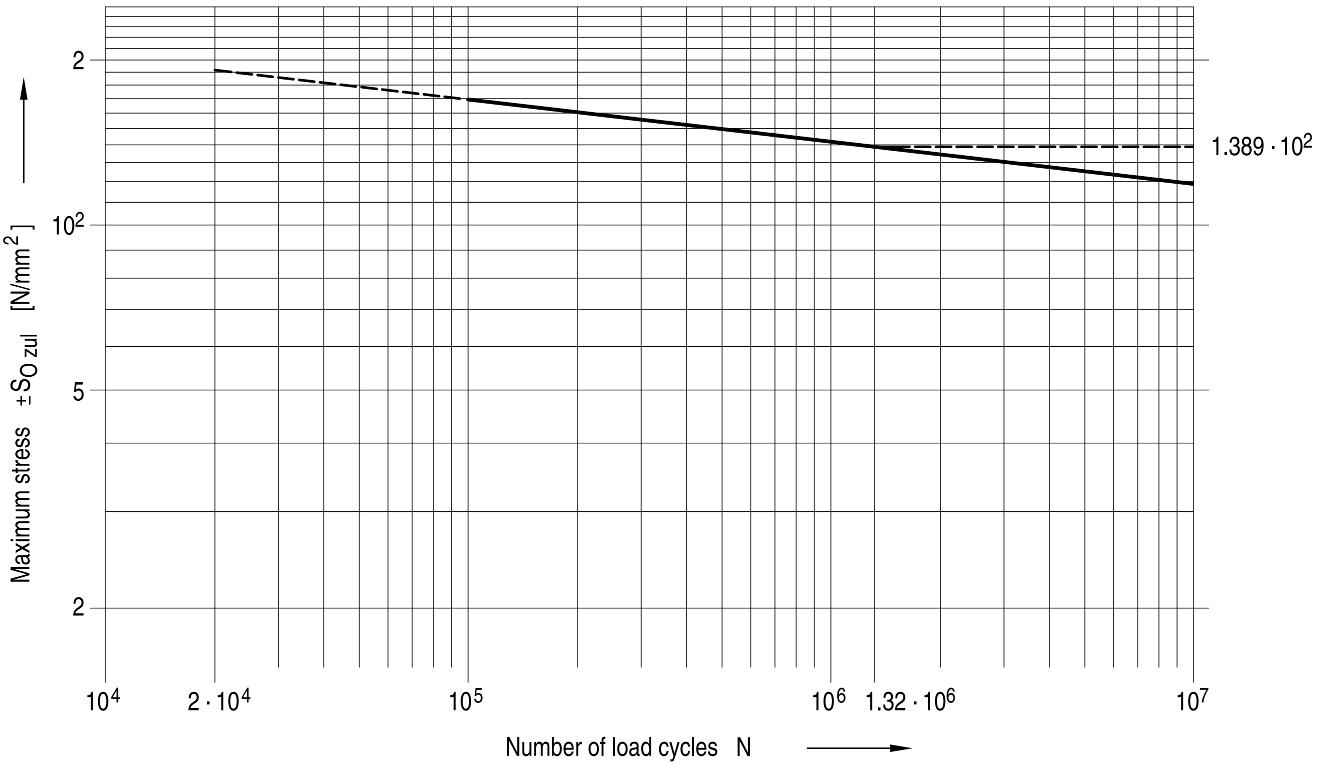


Figure D-1: S/N diagram for notch case W 1-1 (perforated bar, K_t = 2.4), R = -1

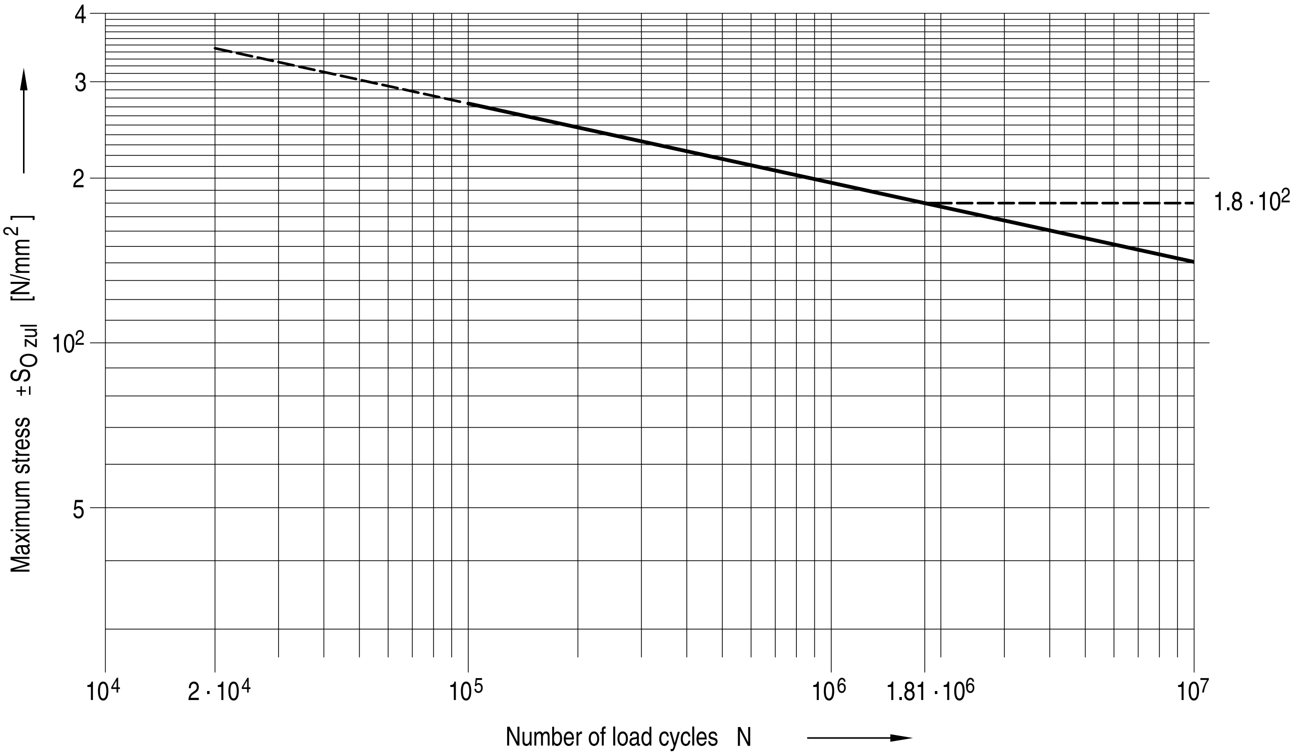


Figure D-2: S/N diagram for notch case W 1-1 (perforated bar, K_t = 2.4), R = 0

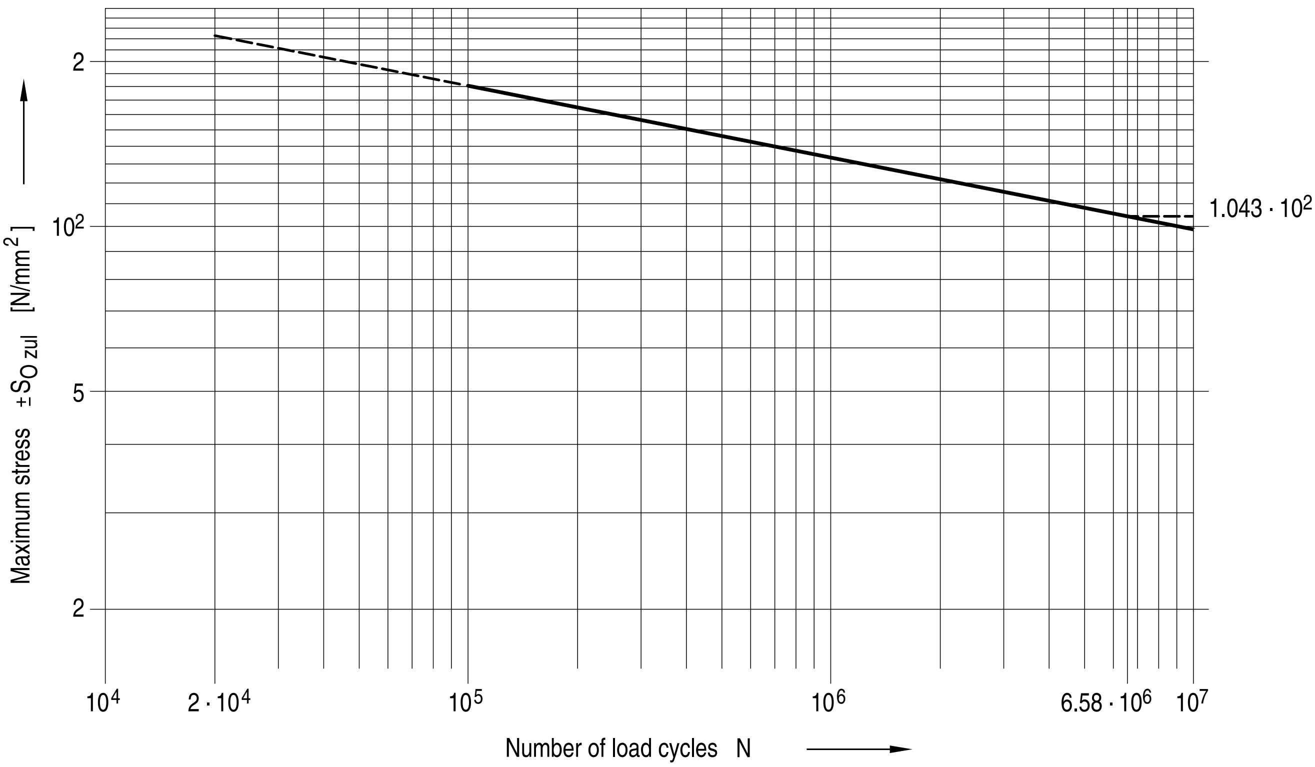


Figure D-3: S/N diagram for notch case W 1-2 (perforated bar, $K_t = 4.2$), R = 0

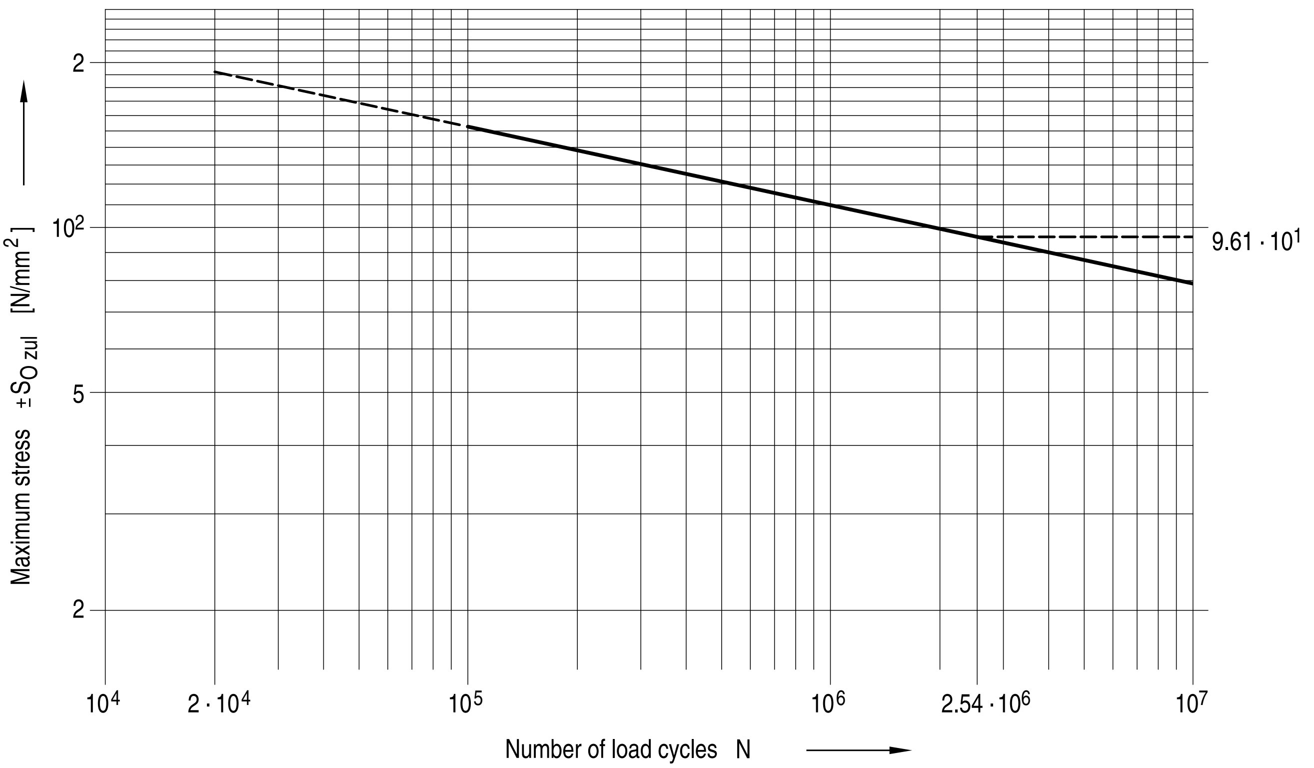


Figure D-4: S/N diagram for notch case K 1 (single-vee butt weld), R = -1

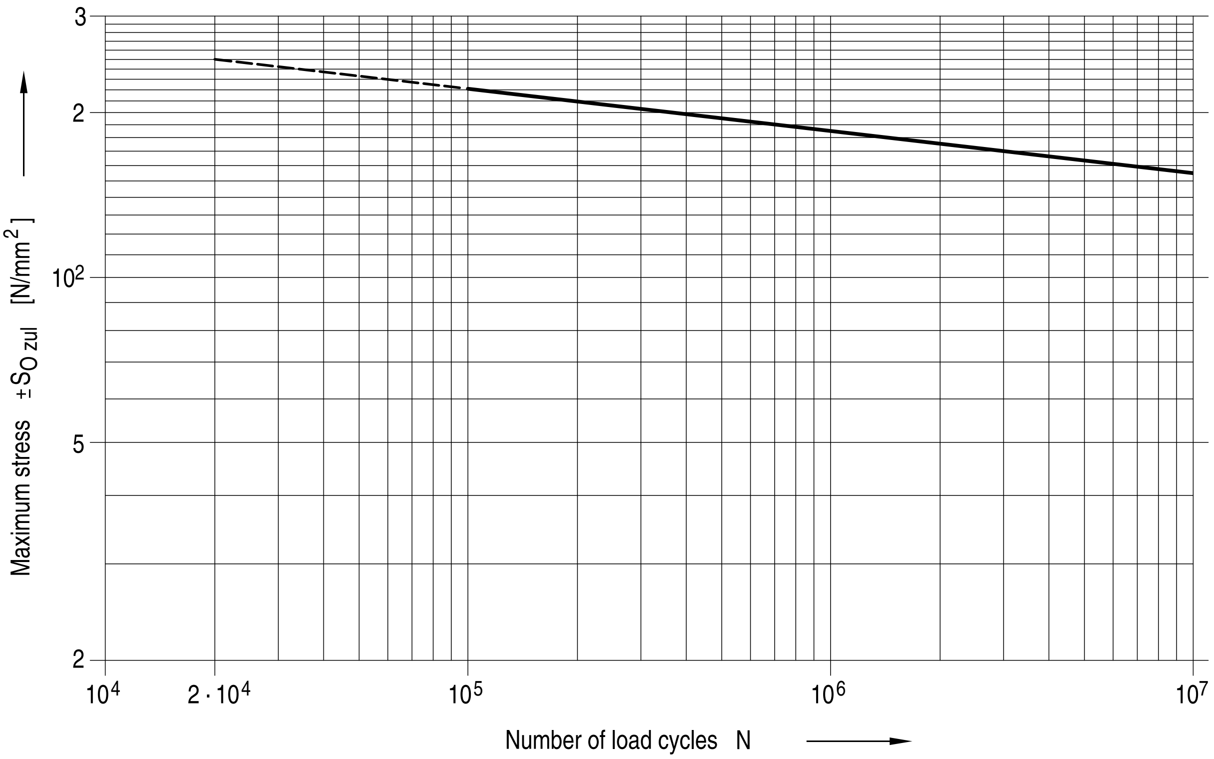


Figure D-5: S/N diagram for notch case K 1 (single-vee butt weld), R = 0

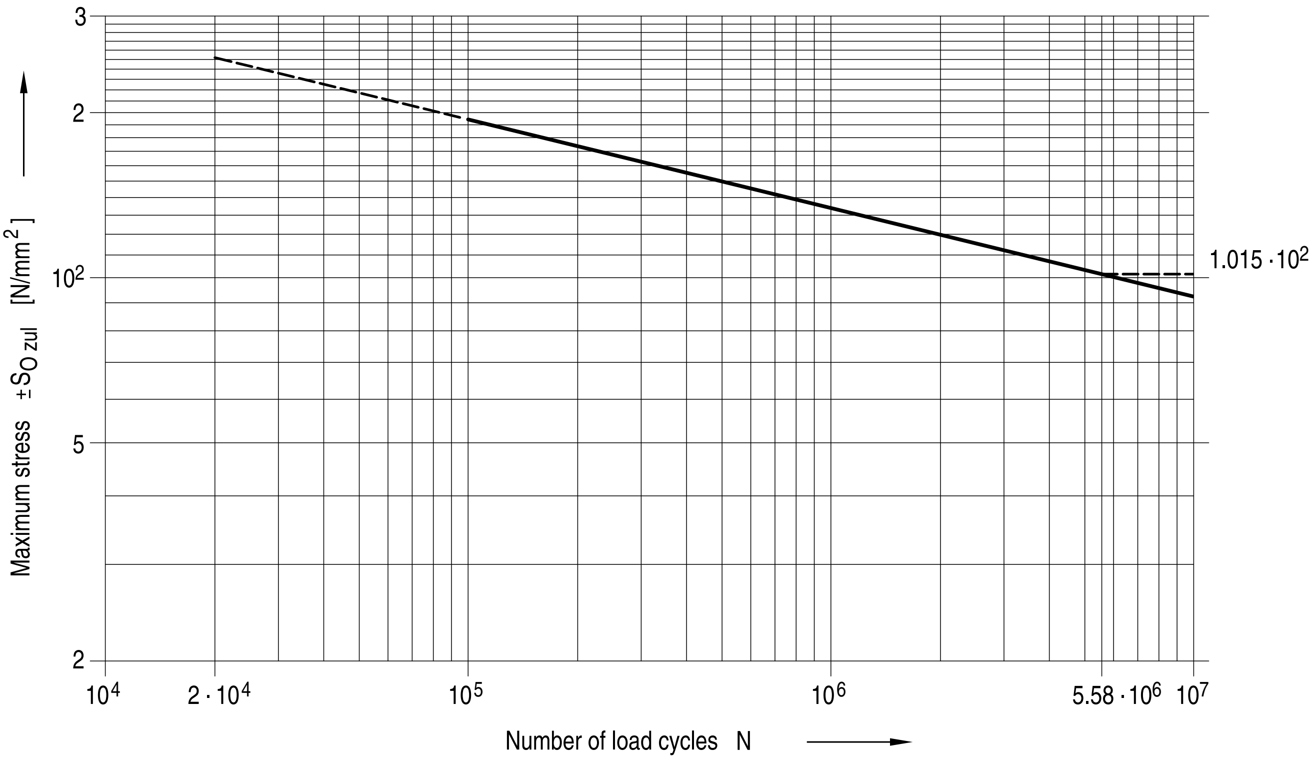


Figure D-6: S/N diagram for notch case K 2 (cruciform joint, double-bevel butt joint, special quality), R = 0

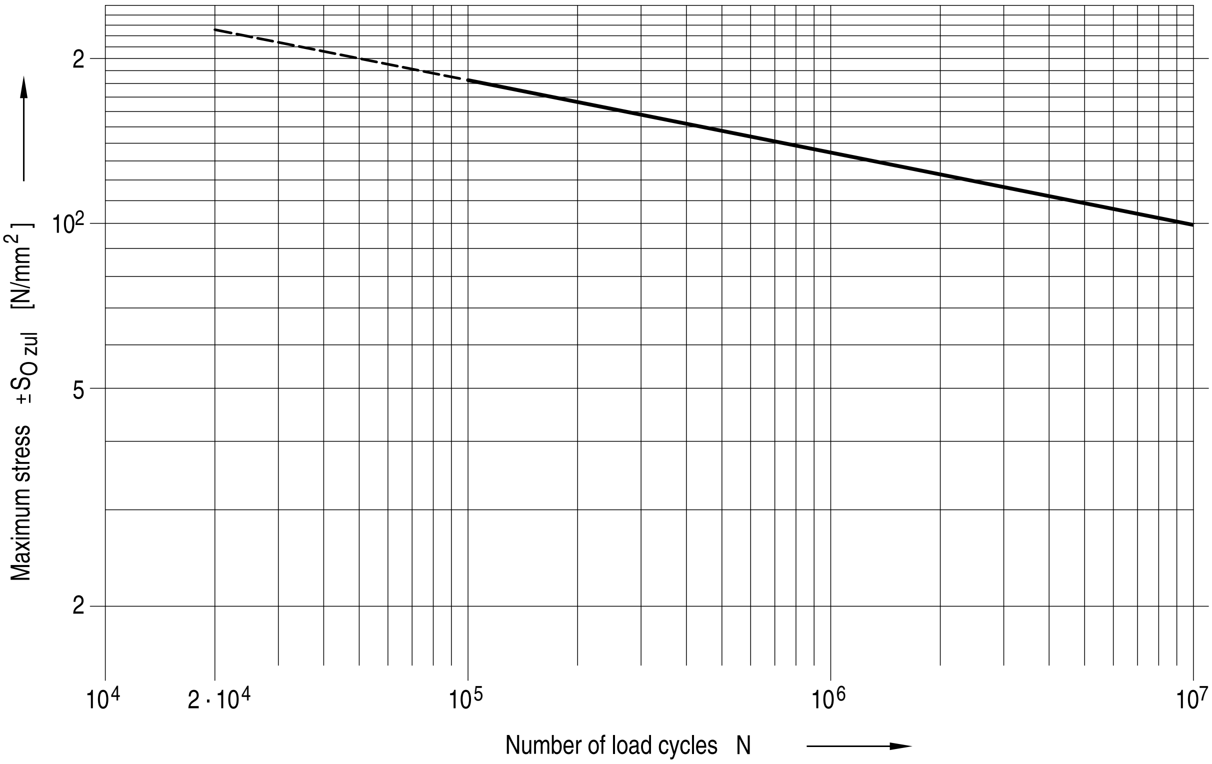


Figure D-7: S/N diagram for notch case K 2 (cruciform joint, double-bevel butt joint, normal quality), R = 0

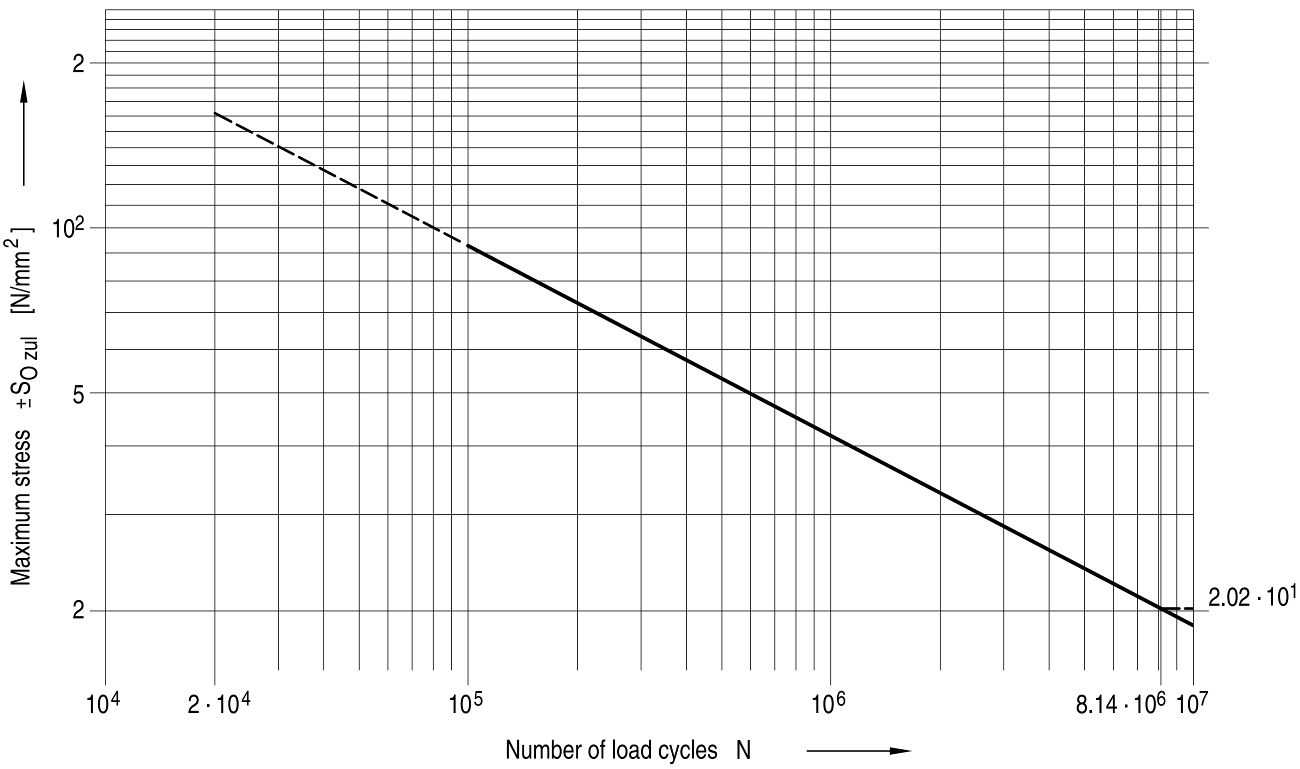


Figure D-8: S/N diagram for notch case K 4 (cruciform joint, fillet weld), R = -1

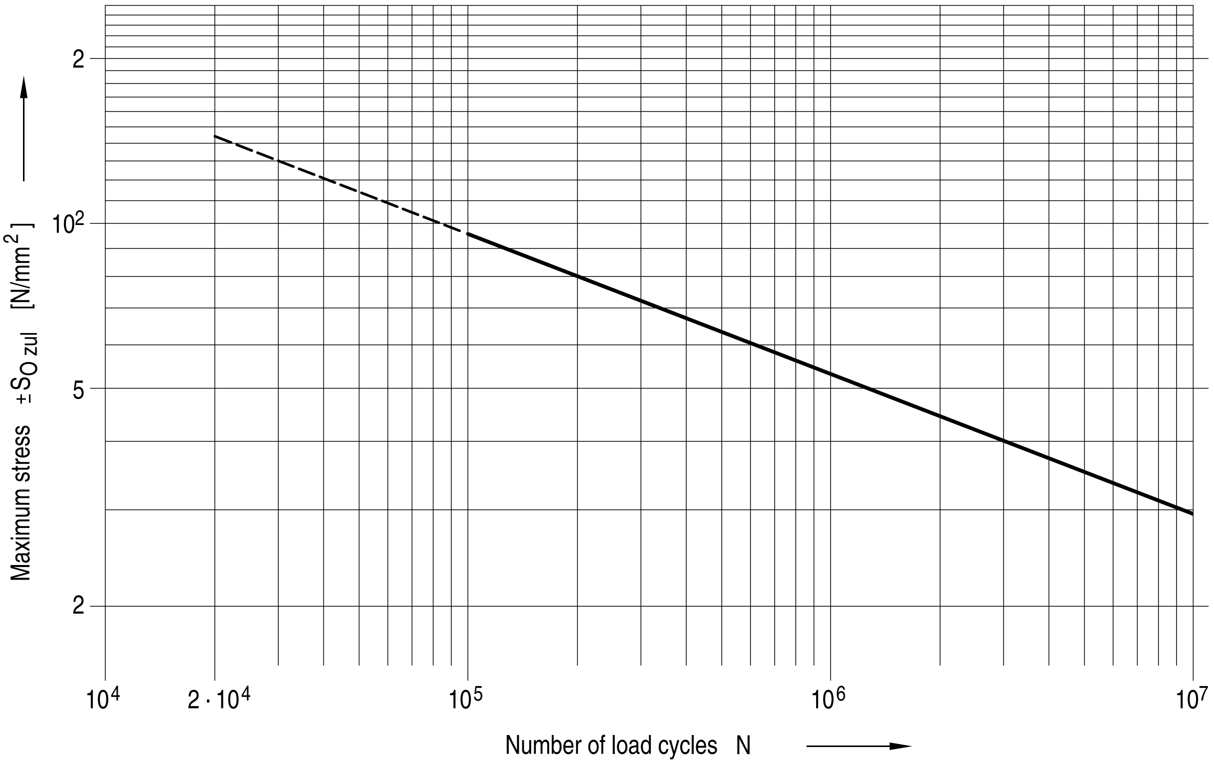


Figure D-9: S/N diagram for notch case K 4 (cruciform joint, fillet weld), R = 0

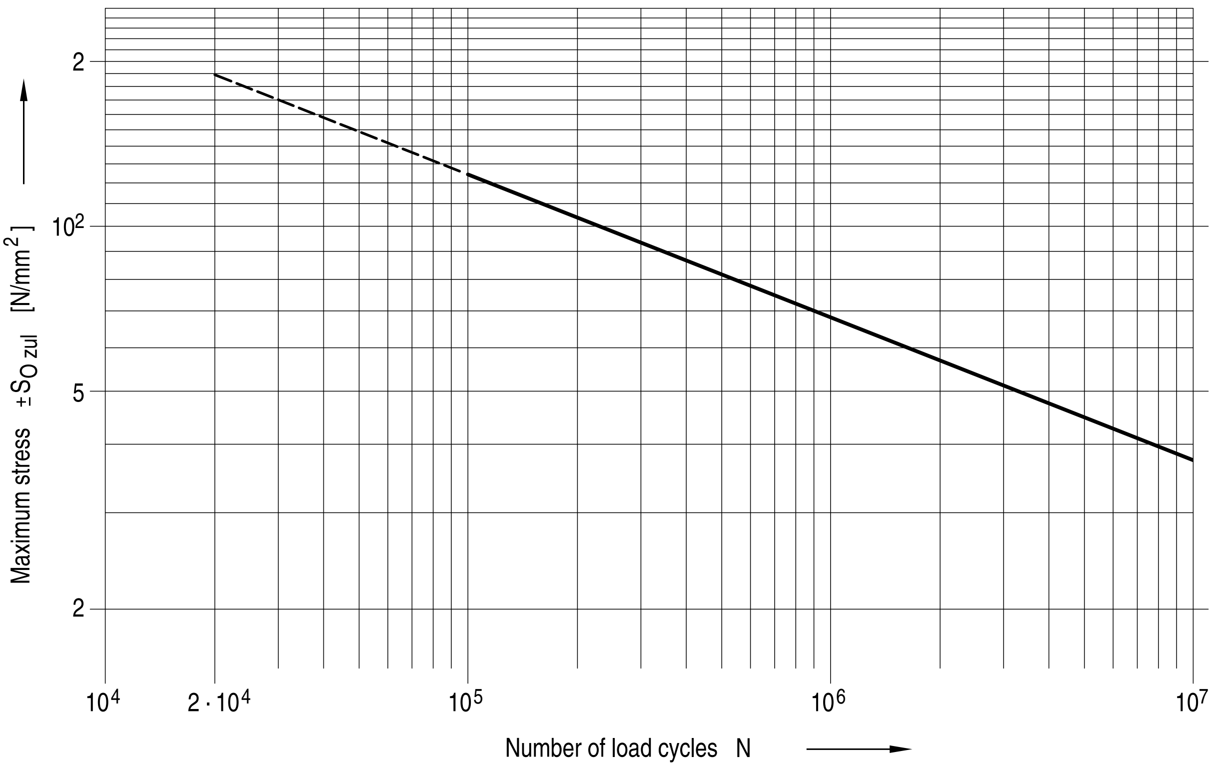


Figure D-10: S/N diagram for notch case K 4-R (pipe test specimen, fillet weld), R = -1

Annex E

Required Performance Levels according to DIN EN ISO 13849-1 for function of safety-related parts of control systems

E 1 General

(1) When applying the requirements according to DIN EN ISO 13849-1 on functions of safety-related parts of control systems in lifting equipment which has to meet the requirements of KTA 3902, sections 4.2, 4.3 or 4.4, the following general principles shall apply:

a) The requirements specified in **Table E-1** shall apply irrespective of the demand rate mentioned in the scope of DIN EN ISO 13849-1.

b) Deviating from the stipulations in section 4.3 of DIN EN ISO 13849-1, the required Performance Levels (PL) shall be determined in accordance with the criteria laid down in section E 2.

E 2 Classification scheme

(1) Performance Level “a“ according to DIN EN ISO 13849-1 is required for operational functions which are of certain safety-related relevance, e.g. if their reliability influences the response frequency of functions for which PL “b”, “c”, “d” or “e” is required.

(2) Performance Level “b“ according to DIN EN ISO 13849-1 is required for operational functions which are of indirect safety-related relevance, e.g. which support the safe operation of lifting equipment (e.g. monitoring of direction of rotation, standstill monitoring, safety-relevant information systems).

(3) Performance Level “c” according to DIN EN ISO 13849-1 is required for safety functions,

a) which are intended to master such operational troubles where the dangerous conditions described in section 4.2 are to be expected, and which are capable of limiting or avoiding such risk (e.g. by manual intervention),

b) which are integrated upstream of the functions of PL “d“ or “e“.

(4) Performance Level “d“ according to DIN EN ISO 13849-1 is required for safety functions which are intended to master operational troubles, and where

a) the dangerous conditions as described under section 4.2 are to be expected and no other possibilities of avoiding such danger or limiting the effects of damage (e.g. by manual intervention) exist,

b) the dangers as described under sections 4.3 or 4.4 are to be expected and possibilities of avoiding such danger or limiting the effects of damage (e.g. by manual intervention) exist.

(5) Performance Level “e“ according to DIN EN ISO 13849-1 is required for safety functions which are intended to master operational troubles where the dangerous conditions as described under sections 4.3 or 4.4 are to be expected and no other possibilities of avoiding such danger or limiting the effects of damage (e.g. by manual intervention) exist.

For safety functions where in case of their failure an event beyond accident planning reference levels of §§ 104 of the Radiation Protection Ordinance is to be assumed and where the function is to be provided by means of software-based systems, the functions shall be of redundant design with one function being classified in PL “e” and one function being independent of the other and of different design to be at least classified in Performance Level “c“.

E 3 Required Performance Levels according to DIN EN ISO 13849-1 for functions of safety-related parts of control systems according to KTA 3902, sections 4.2, 4.3 or 4.4

(1) The typical functions of safety-related parts of control systems in lifting equipment according to KTA 3902, sections 4.2, 4.3 or 4.4 are assigned in **Table E-1** to Performance Levels which satisfy the criteria of section E 2.

N o t e :
See sub-clause 6.5.1 (3) as regards the application of “Safety Integrity Levels” (SIL) specified in the DIN EN standard series 61508 instead of the Performance Levels according to DIN EN ISO 13849-1 laid down in **Table E-1**.

(2) Deviations from the design requirements laid down in **Table E-1** shall be justified in each individual case.

Ser. No.	Function	Requirement according to KTA 3902, clause	Performance Level acc. to DIN EN ISO 13849-1 when classifying lifting equipment acc. to KTA 3902, section			Note
			4.2	4.3	4.4	
	General:					
1.	Switch on/off of lifting equipment, release from control room	6.5.2 (1), 8.5 b)	a	a	a	
2.	Emergency-off	6.5.4.1 (5)	d	d	d	For wireless control systems: “Stop“
3.	Emergency-off switch for the supervising person when applying the “four-eyes principle“	6.5.4.1 (6)	d	d	— [1]	For wireless control systems: “Stop“
4.	Reporting, warning and alarm signals	6.5.4.2	a	a	a	

[1] This function is not required, since the absence of this function does not lead to inadmissible safety-related effects.

Table E-1: Assignment of typical functions of safety-related parts of control systems in lifting equipment according to sections 4.2 to 4.4 to the required Performance Levels according to DIN EN ISO 13849-1

Ser. No.	Function	Requirement according to KTA 3902, clause	Performance Level acc. to DIN EN ISO 13849-1 when classifying lifting equipment acc. to KTA 3902, section 4.2	4.3	4.4	Note
5.	Operational status messages signalling such conditions as are triggered by safety-related activities or from which safety-related activities are derived	6.5.4.2	b	b	b	e.g. check-back signal of load limit transition switch
6.	Operational functions and drive control	6.5.4.1	a	a	a	e.g. control functions of master controller, mode selector switch for control commands for drive control system (e.g. set point signals)
7.	Running time or load collective meter for engagement of safety brake	6.5.2 (5), 7.5 b)	a	a	a	
8.	Mutual interlocking of control points	6.5.4.1 (7)	a	a	a	The emergency-off switch shall also be effective at switched-off control points (except for: stop function on wireless controls).
9.	Phase-sequence relays and a phase conductor monitor	6.5.2 (2)	a	a	a	
10.	Overload protective devices for motors	6.5.2 (3)	a	a	a	
11.	**Hoists and lateral transport drives:** Speed limiters at travelling and hoist end positions	6.5.3 (5)	a	a	a	
12.	a) Switch-off if allowable speed at travelling end position is exceeded	6.5.3 (5)	c	c	d	
	b) Switch-off if allowable speed at hoist end is exceeded: First switch-off device	6.5.3 (5), 7.5	d	e	e	For examples see **Figures E-1** and **E-4**.
	Second switch-off device [1]		— [2]	c	— [2]	
13.	Operational travel limiters	6.5.3 (1) and (3)	a	a	a	Switch-off at operationally allowable lateral transport drive or hoist end positions
14.	Safety travel limiters of lateral transport drives	6.5.3 (1)	c	c	d	
15.	Standstill monitoring	6.5.2 (8)	b	b	b	
16.	Enforced zero position	6.5.4.1 (1)	a	a	a	
17.	Monitoring of direction during start-up from standstill in case of converter drives	6.5.2 (8)	b	b	b	
18.	Interlocking of lateral transport drive and hoist movements	6.5.3 (6)	c	c	— [3]	
19.	Interlocking of lateral transport drive and hoist movement as well as limitation of lateral movement	8.5 a), 8.5 f), 8.5 g), 8.5 l)	— [3]	— [3]	d	

[1] Only if, in case of failure of this function, an event beyond the accident planning reference levels of §§ 104 of the Radiation Protection Ordinance is to be assumed and the function is to be provided by means of software-based systems.

[2] This function is not required, since the absence of this function does not lead to inadmissible safety-related effects.

[3] This function is irrelevant due to technical reasons. The requirements are fulfilled by another function.

Table E-1: Assignment of typical functions of safety-related parts of control systems in lifting equipment according to sections 4.2 to 4.4 to the required Performance Levels according to DIN EN ISO 13849-1 (continued)

Ser. No.	Function	Requirement according to KTA 3902, clause	Performance Level acc. to DIN EN ISO 13849-1 when classifying lifting equipment acc. to KTA 3902, section 4.2	4.3	4.4	Note
	Additional functions for hoists:					
20.	Load indication	7.5 g)	— 1)	a	a	
21.	Switch-off at 110 % of maximum operational load (overload protection)	6.5.2 (4)	c	d	d	
22.	Upstream variable overload protection	7.5 h)	— 1)	b	— 2)	Load limit value to be attained in accordance with the transported load. Category “b” for operational limitations. Where protective functions are to be fulfilled, the requirements of ser. No. 21 “Overload switch-off at attainment of 110 % of maximum operational load“ shall be observed.
23.	Upstream variable overload protection depending on mode of operation	8.5 d)	— 2)	— 2)	c	Load limit value to be activated depending on the mode of operation, e.g. in dependence of the transported load.
24.	Underload protection, slack rope	8.2.1.3.1 (7)	— 2)	— 2)	d	Alarm signal, see 8.5 e)
25.	Engagement of service and auxiliary brake at safety-relevant drive shut-offs	6.5.1 (1)	d	d	d	
26.	Hoist switch-off in case of failure of a part within a double drive mechanism chain or drive mechanism chain with safety brake	7.5 e)	— 2)	b	b	
27.	Monitoring of auxiliary media of systems to take up or dampen load shifting pulses	7.5 f)	— 2)	b	b	
28.	Monitoring of orderly winding up of the rope on the drum	6.5.2 (11)	b	b	b	
29.	Monitoring of outer conductor of the hoist motor	7.5 a)	— 1)	b	b	
30.	Switch-off if allowable lifting or lowering speed is exceeded	6.5.1 (1)	c	c	c	
31.	Gear box break monitoring with triggering of safety brake	7.5 b)				For example see **Figures E-2** and **E-4**.
	First monitoring device		— 2)	e	e	
	Second monitoring device 3)		— 1)	c 4)	— 1)	

1) This function is not required, since the absence of this function does not lead to inadmissible safety-related effects.

2) This function is irrelevant due to technical reasons. The requirements are fulfilled by another function.

3) Only if, in case of failure of this function, an event beyond the accident planning reference levels of §§ 104 of the Radiation Protection Ordinance is to be assumed and the function is to be provided by means of software-based systems.

4) Not required for hoists with a maximum operational load equal to or smaller than 5 t.

Table E-1: Assignment of typical functions of safety-related parts of control systems in lifting equipment according to sections 4.2 to 4.4 to the required Performance Levels according to DIN EN ISO 13849-1 (continued)

Ser. No.	Function	Requirement according to KTA 3902, clause	Performance Level acc. to DIN EN ISO 13849-1 when classifying lifting equipment acc. to KTA 3902, section 4.2	4.3	4.4	Note
32.	Brake monitoring	6.5.2 (6) and 7.5 b)	a	a	a	Position and brake lining thickness monitoring
33.	a) Safety travel limiter, in lift direction First limiter	6.5.3, 7.5 d)	d	e	e	For example see **Figures E-3** and **E-4**.
	Second limiter [1]		— [2]	c	— [2]	
	b) Safety travel limiter, in lowering direction	6.5.3, 6.2.2.3 (3)	c	e	e	
34.	Monitoring of correct sequence during extension and retraction of hoist components	8.5 i)	— [3]	— [3]	c	e.g. by monitoring of height-dependent load at the rope
35.	Set-down prevention	8.5 j)	— [3]	— [3]	a	Supplementary function to become effective before the underload protection responds.
36.	**Functions for electrically driven grabs:** a) opening of grab where mechanical opening interlock is provided	6.5.2 (10)	a	c	c	
	b) opening of grab where no mechanical opening interlock is provided	6.5.2 (10), 8.5 k)	d	Not allowed	e	
37.	Position and condition indications of load grab	6.5.2 (9)	a	a	a	

1) Only if, in case of failure of this function, an event beyond the accident planning reference levels of §§ 104 of the Radiation Protection Ordinance is to be assumed and the function is to be provided by means of software-based systems.

2) This function is not required, since the absence of this function does not lead to inadmissible safety-related effects.

3) This function is irrelevant due to technical reasons. The requirements are fulfilled by another function.

Table E-1: Assignment of typical functions of safety-related parts of control systems in lifting equipment according to sections 4.2 to 4.4 to the required Performance Levels according to DIN EN ISO 13849-1 (continued)

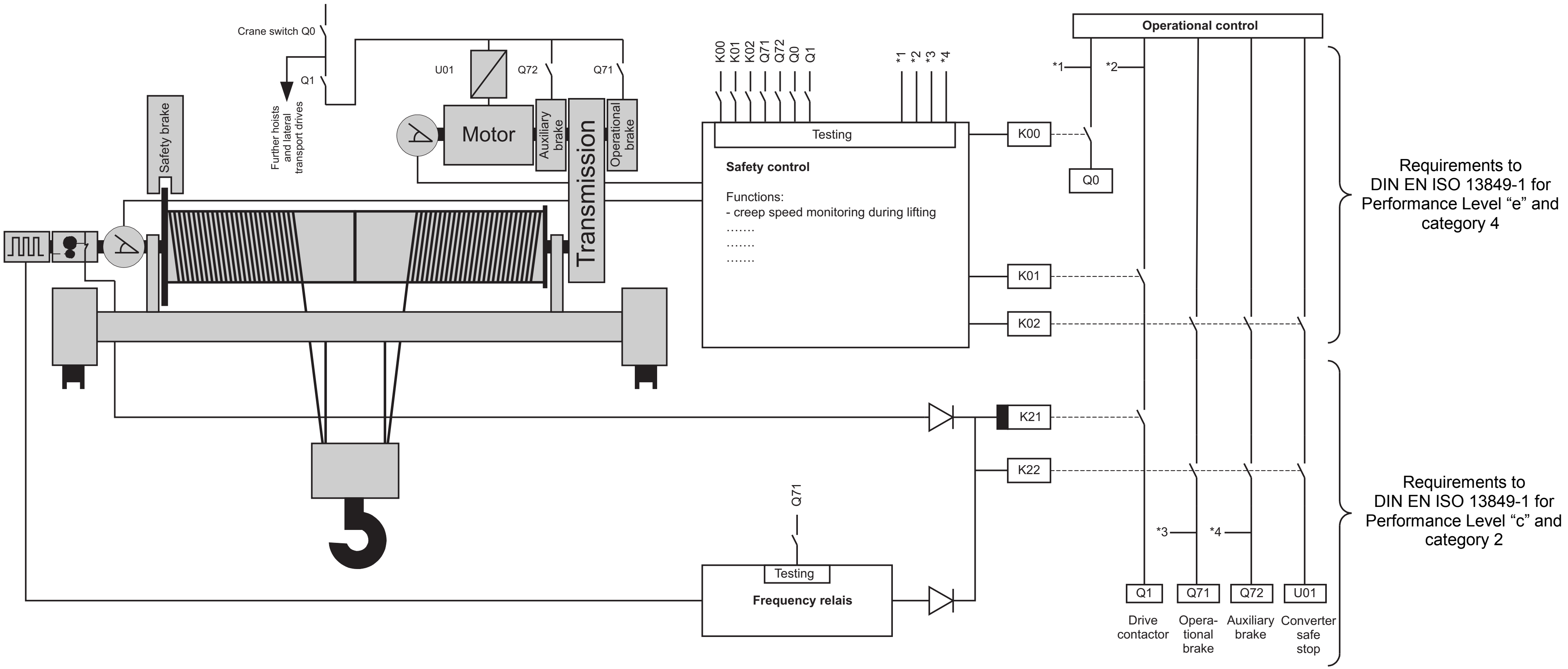


Figure E-1: Example for realization of the requirements specified in Table E-1 for the function ser. no. 12b “Switch-off in case of excess of allowable speed at hoist end” in lifting equipment according to sections 4.3 or 4.4
(Example for hoist with single drive mechanism chain and insufficient travel stop way length upwards upon response of safety travel limiter)

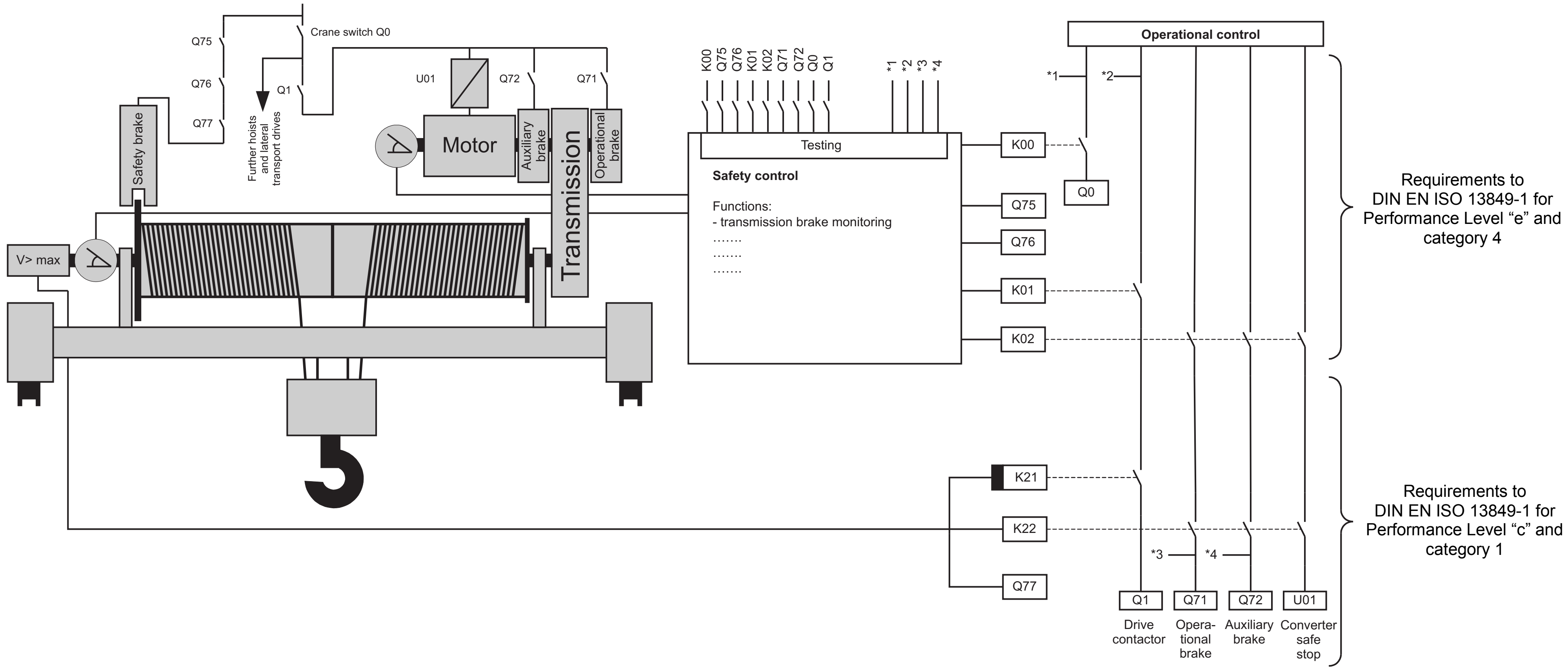


Figure E-2: Example for realization of the requirements specified in Table E-1 for the function ser. no. 31 “Gear box brake monitoring with triggering of safety brake” in lifting equipment according to sections 4.3 or 4.4
(Example for hoist with single drive mechanism chain and safety brake)

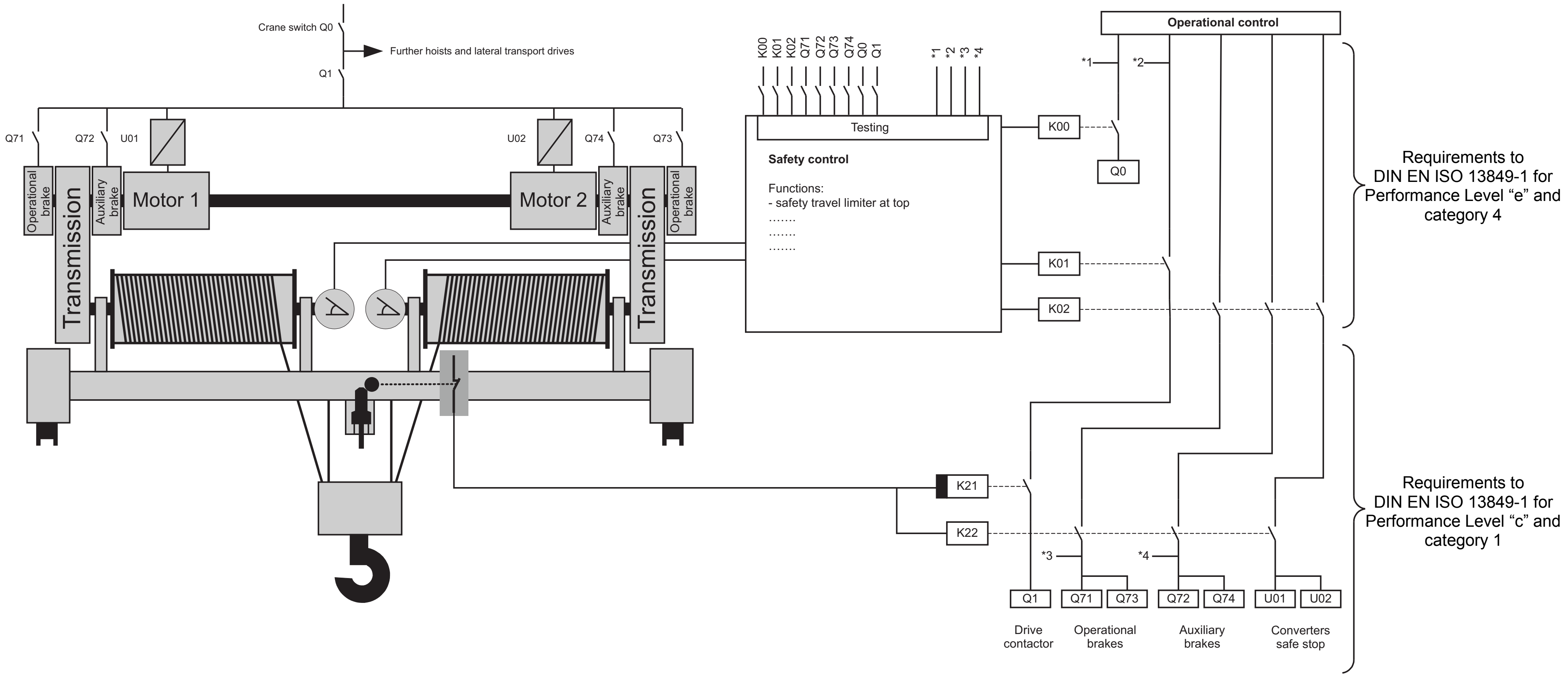


Figure E-3: Example for realization of the requirements specified in Table E-1 for the function ser. no. 33a “Safety travel limiter in lift direction“ in lifting equipment according to sections 4.3 or 4.4
(Example for hoist with double drive mechanism chain and sufficient travel stop path upon response of the safety travel limiter in the main circuit, in lift direction)

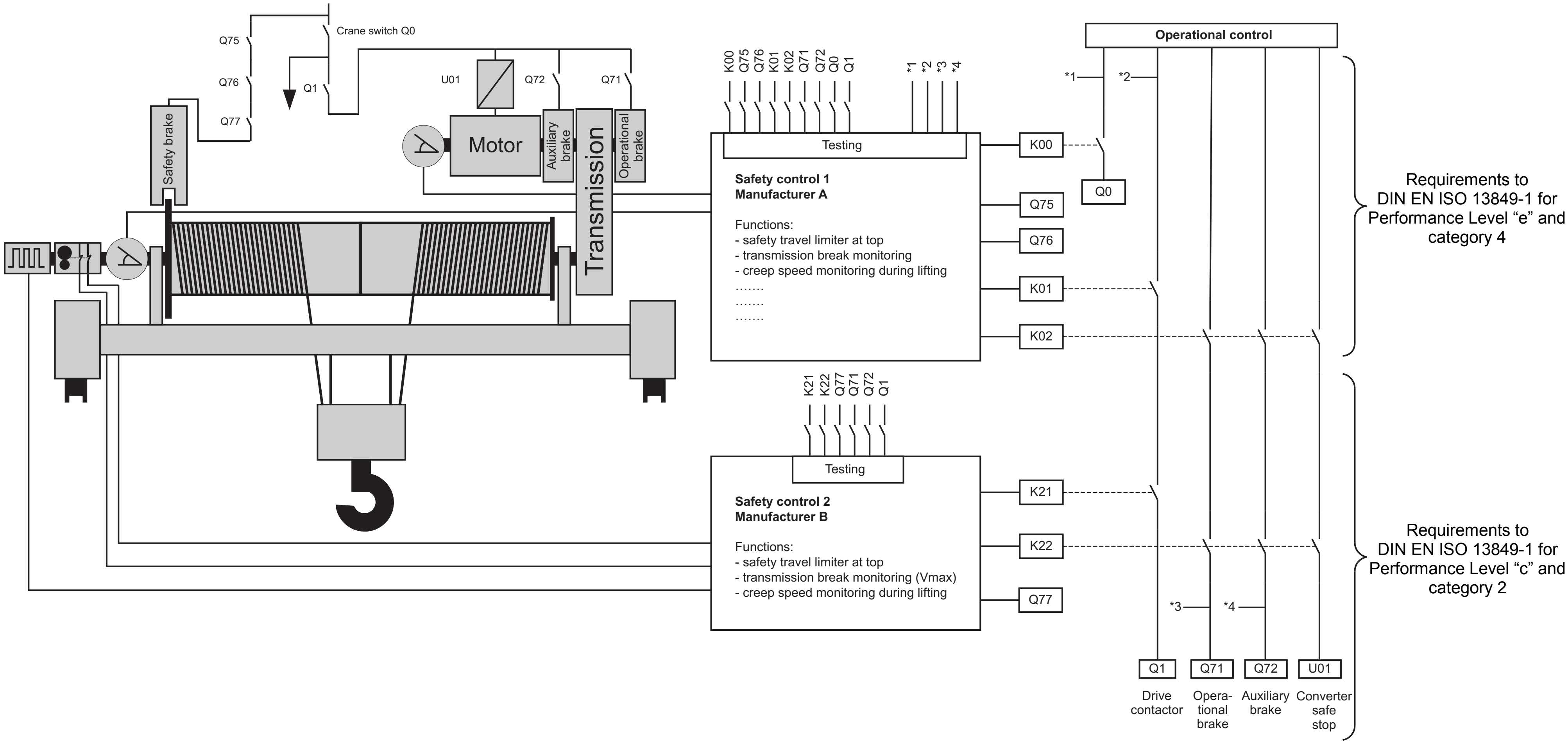


Figure E-4: Example for realization of the requirements specified in Table E-1 for the functions
a) ser. no. 12b "Switch-off in case of excess of allowable speed at hoist end position "
b) ser. no. 31 "Gear box break monitoring with triggering of safety brake"
c) ser. no. 33a "Safety travel limiter in lift direction"
in lifting equipment according to sections 4.3 or 4.4
(Example of hoist with single drive mechanism chain and insufficient travel stop path upon response of the safety travel limiter in the main circuit, in lift direction)

Annex F

Regulations and literature referred to in this Safety Standard

(The references exclusively refer to the version given in this annex. Quotations of regulations referred to therein refer to the version available when the individual reference below was established or issued.)

Directive 2014/33/EU		Directive 2014/33/EU of the European Parliament and of the Council of February 26, 2014 on the harmonisation of the laws of the Member States relating to lifts and safety components for lifts (recast)
Atomic Energy Act (AtG)		Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards (Atomic Energy Act) in the Version Promulgated on July 15, 1985 (BGBl. I, p. 1565), most recently changed by article 239 of the Ordinance dated June 19, 2020 (BGBl. I, p. 1328)
StrlSchG		Act on the Protection against the Harmful Effect of Ionising Radiation (Radiation Protection Act - StrlSchG) of June 27, 2017 (BGBl. I, p. 1966), most recently changed by Article 5, Sec. 1 of the Act dated October 23, 2020 (BGBl. I p. 2232)
StrlSchV		Ordinance on the Protection against the Harmful Effects of Ionising Radiation (Radiation Protection Ordinance - StrlSchV) of November 29, 2018 (BGBl. I, p. 2034, 2036), most recently changed by Article 1 of the Ordinance dated November 20, 2020 (BGBl. I p. 2502)
SiAnf	(2015-03)	Safety Requirements for Nuclear Power Plants (SiAnf) as Promulgated on March 3, 2015 (BAnz AT 30.03.2015 B2)
Interpretations	(2015-03)	Interpretations of the Safety Requirements for Nuclear Power Plants of November 22, 2012, as Amended on March 3rd, 2015 (BAnz. AT 30.03.2015 B3)
KTA 1401	(2017-11)	General Requirements Regarding Quality Assurance
KTA 2201.4	(2012-11)	Design of nuclear power plants against seismic events; Part 4: Components
KTA 3201.2	(2017-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 2: Design and analysis
KTA 3205.1	(2018-10)	Component Support Structures with Non-Integral Connections; Part 1: Component Support Structures with Non-Integral Connections for Components of the Reactor Coolant Pressure Boundary of Light Water Reactors
KTA 3903	(2020-12)	Inspection, testing and operation of lifting equipment in nuclear power plants
DIN EN 81-20	(2014-11)	Safety rules for the construction and installation of lifts - Lifts for the transport of persons and goods - Part 20: Passenger and goods passenger lifts; German version EN 81-20:2014
DIN 743-1	(2012-12)	Shafts and axles, calculation of load capacity - Part 1: General
DIN 743-2	(2012-12)	Shafts and axles, calculation of load capacity - Part 2: Theoretical stress concentration factors and fatigue notch factors
DIN 743-3	(2012-12)	Shafts and axles, calculation of load capacity - Part 3: Strength of materials (Corrigendum 2014-12)
DIN EN 818-2	(2008-12)	Short link chain for lifting purposes. Safety. Part 2: Medium tolerance chain for chain slings. Grade 8; German version EN 818-2:1996+A1:2008
DIN EN 818-4	(2008-12)	Short link chain for lifting purposes – Safety - Part 4: Chain slings - Grade 8; German version EN 818-4:1996+A1:2008
DIN EN 894-1	(2009-01)	Safety of machinery - Ergonomics requirements for the design of displays and control actuators – Part 1: General principles for human interactions with displays and control actuators; German version EN 894-1:1997+A1:2008
DIN EN ISO 898-1	(2013-05)	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread (ISO 898-1:2013); German version EN ISO 898-1:2013
DIN EN ISO 898-2	(2012-08)	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread (ISO 898-2:2012); German version EN ISO 898-2:2012
DIN EN 1090-2	(2018-09)	Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures; German version EN 1090-2:2018
DIN EN 1677-1	(2009-03)	Components for slings. Safety – Part 1: Forged steel components, Grade 8; German version EN 1677-1:2000+A1:2008
DIN EN 1677-2	(2008-06)	Components for slings. Safety – Part 2: Forged steel lifting hooks with latch, Grade 8; German version EN 1677-2:2000+A1:2008 (Correction: 2009-01)

DIN EN 1677-3	(2008-06)	Components for slings. Safety – Part 3: Forged steel self-locking hooks. Grade 8; German version EN 1677-3:2001+A1:2008 (Correction: 2009-01)
DIN EN 1677-4	(2009-03)	Components for slings. Safety – Part 4: Links, grade 8; German version EN 1677-4:2000+A1:2008
DIN EN 1993-1-8/NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-8: Design of joints
DIN EN ISO 3506-1	(2010-04)	Mechanical properties of corrosion-resistant stainless steel fasteners. Part 1: Bolts, screws and studs; (ISO 3506-1:2009); German version EN ISO 3506-1:2009
DIN EN ISO 3506-2	(2010-04)	Mechanical properties of corrosion-resistant stainless steel fasteners. Part 2: Nuts (ISO 3506-2:2009); German version EN ISO 3506-2:2009
DIN 3962-2	(1978-08)	Tolerances for cylindrical gear teeth; tolerances for tooth trace deviations
DIN 3990-5	(1987-12)	Calculation of load capacity of cylindrical gears; endurance limits and material qualities
DIN 3990-11	(1989-02)	Calculation of load capacity of cylindrical gears; application standard for industrial gears; detailed method
DIN EN ISO 5817	(2014-06)	Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections; (ISO 5817:2014); German version EN ISO 5817:2014
DIN EN 10025-2	(2019-10)	Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels; German version EN 10025-2:2019
DIN EN 10088-2	(2014-12)	Stainless steels - Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes; German version EN 10088-2:2014
DIN EN 10088-3	(2014-12)	Stainless steels – Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes; German version EN 10088-3:2014
DIN EN ISO 12100	(2011-03)	Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100:2010); German version EN ISO 12100:2010 (Corrigendum 2013-08)
DIN EN 13001-1	(2015-06)	Cranes - General design - Part 1: General principles and requirements; German version EN 13001-1:2015
DIN EN 13001-2	(2014-12)	Crane safety - General design - Part 2: Load actions; German version EN 13001-2:2014
DIN EN 13001-3-1	(2019-03)	Cranes - General Design - Part 3-1: Limit States and proof competence of steel structure; German version EN 13001-3-1:2012+A2:2018
DIN EN 13411-3	(2011-04)	Terminations for steel wire ropes - Safety - Part 3: Ferrules and ferrule-securing; German version EN 13411-3:2004+A1:2008
DIN EN 13411-4	(2011-06)	Terminations for steel wire ropes - Safety - Part 4: Metal and resin socketing; German version EN 13411-4:2011
DIN EN 13414-1	(2020-03)	Terminations for steel wire ropes - Safety - Part 1: Thimbles for steel wire rope slings; German version EN 13414-1:2003+A2:2008
DIN EN 13414-2	(2009-02)	Terminations for steel wire ropes - Safety - Part 2: Specification for information for use and maintenance to be provided by the manufacturer; German version EN 13414-2:2003+A2:2008
DIN EN ISO 13849-1	(2016-06)	Safety of machinery – Safety-related parts of control systems - Part 1: General principles for design (ISO 13849-1:2015); German version EN ISO 13849-1:2015
DIN EN 13889	(2009-02)	Forged steel shackles for general lifting purposes. Dee shackles and bow shackles. Grade 6. Safety; German version EN 13889:2003+A1:2008
DIN EN ISO 13919-1	(2020-03)	Electron and laser-beam welded joints - Requirements and recommendations on quality levels for imperfections - Part 1: Steel, nickel, titanium and their alloys (ISO 13919-1:2019); German version EN ISO 13919-1:2019
DIN 15003	(1970-02)	Lifting appliances; load suspending devices, loads and forces; definitions
DIN 15018-1	(1984-11)	Cranes; steel structures; verification and analyses
DIN 15018-2	(1984-11)	Cranes; steel structures; principles of design and construction
DIN 15020-1	(1974-02)	Lifting appliances; principles relating to rope drives; calculation and construction
DIN 15070	(1977-12)	Cranes; basic calculation of crane rail wheels
DIN 15071	(1977-12)	Cranes; determination of bearing load of crane rail wheels
DIN 15085	(1977-12)	Lifting appliances; rail wheels, technical conditions
DIN 15400	(1990-06)	Lifting hooks; materials, mechanical properties, lifting capacity and stresses

DIN 15401-1	(1982-11)	Lifting hooks for lifting appliances; single hooks; unmachined parts
DIN 15401-2	(1983-09)	Lifting hooks for lifting appliances; single hooks; finished parts with threaded shank
DIN 15402-1	(1982-11)	Lifting hooks for lifting appliances; ramshorn hooks; unmachined parts
DIN 15402-2	(1983-09)	Lifting hooks for lifting appliances; ramshorn hooks; finished parts with threaded shank
DIN 15413	(1983-08)	Bottom blocks for lifting appliances; lifting hook nuts
DIN 15434-1	(1989-01)	Power transmission engineering; principles for drum- and disc brakes, calculation
DIN EN 60204-32; VDE 0113-32	(2009-03)	Safety of machinery - Electrical equipment of machines - Part 32: Requirements for hoisting machines (IEC 60204-32:2008); German version EN 60204-32:2008
DIN EN 61508-1; VDE 0803-1	(2011-02)	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: General requirements (IEC 61508-1:2010); German version EN 61508-1:2010
DIN EN 61508-2; VDE 0803-2	(2011-02)	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems (IEC 61508-2:2010); German version EN 61508-2:2010
DIN EN 61508-3; VDE 0803-3	(2011-02)	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 3: Software requirements (IEC 61508-3:2010); German version EN 61508-3:2010
DIN EN 61508-4; VDE 0803-4	(2011-02)	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 4: Definitions and abbreviations (IEC 61508-4:2010); German version EN 61508-4:2010
DIN EN 61508-5; VDE 0803-5	(2011-02)	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 5: Examples of methods for the determination of safety integrity levels (IEC 61508-5:2010); German version EN 61508-5:2010
DIN EN 61508-6; VDE 0803-6	(2011-02)	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3 (IEC 61508-6:2010); German version EN 61508-6:2010
DIN EN 61508-7; VDE 0803-7	(2013-09)	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 7: Overview of techniques and measures (IEC 61508-7:2010); German version EN 61508-7:2010
DIN EN 61513; VDE 0491-2	(2002-10)	Nuclear power plants - Instrumentation and control for systems important to safety - General requirements for systems (IEC 61513:2011); German version EN 61513:2013
DIN EN IEC 62138; VDE 0491-3-3	(2020-07)	Nuclear power plants - Instrumentation and control systems important to safety - Software aspects for computer-based systems performing category B or C functions (IEC 62138:2018); German version EN IEC 62138:2019
SEB 666211 Suppl. 1	(1985-08)	Materials handling; hoisting drums; mathematical calculation of the bolted joints of bulldog grips
VDI 2230 Sheet 1	(2015-11)	Systematic calculation of high duty bolted joints; joints with one cylindrical bolt
VDI 3576	(2011-03)	Rails for crane systems - Rail connections, rail beddings, rail fastenings, tolerances for crane tracks

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Annex G (informative)

Changes with respect to the edition 2012-11 and explanations

G 1 Main changes

(1) As an alternative to the dimensioning method using a global safety factor according to DIN 15018-1, for structures the method using partial safety factors according to the standard series DIN EN 13001 was allowed. For this purpose appropriate requirements were included in sections 6 (additional requirements), 7 (increased requirements) and 8 (refueling machines) as well as in Annex B. Requirements for the application of standard series DIN EN 13001 have been laid down such that the design according to DIN EN 13001 leads to a stress utilization which is comparable with the design according to DIN 15018-1. In due consideration of the requirements in clauses 6.1.1 (2), 7.1.1 (2) and 8.1.1 (2) both methods are allowed alternatively, since the verification methodology of both methods (method using a global safety factor and method using partial safety factors) comply with the state of the art and lead to equivalent results. It was necessary to limit the application of standard series DIN EN 13001 to structures, because at the moment there is no complete basis of standards applicable to machine parts.

(2) The requirements for electrical equipment were put more precisely for some clauses in analysis of operational experience in due consideration of current standards (sections 6.5, 7.5 and 8.5 as well as Annex E).

(3) The whole Safety Standard and Annex F "Regulations and literature referred to in this Safety Standard" have been adapted to the current state of standards. For the purpose of adapting the Safety Standard to actual standards, at all locations of the Safety Standard - as far as applicable - the terms "stress analysis" and "fatigue analysis" as well as "gear box housing" are used. In formulations where verification according to certain standards (e.g. DIN 15018-1, DIN 3990-11) is explicitly required, the term "service strength" used in these standards has been retained. However, it was necessary to maintain the reference to DIN 15070 in sections 6.3.1 and B 1.3.1 regardless of the formal replacement of this standard by DIN EN 13001-3-3. It was necessary to maintain the design analysis of drive wheels according to DIN 15070 since the twin-track design concept (method using a global safety factor and method using partial safety factors) which has now been incorporated into KTA 3902 applies only to structures and the design basis for machine parts valid up to now was overall maintained due to a lack of the existing standards.

G 2 Explanations to the changes made compared to the 2012-11 edition

(1) The section "Fundamentals", first subpara. was adapted to the uniform text relevant to all KTA Safety Standards and the second subpara. was supplemented by the stipulations set by the Safety Requirements for Nuclear Power Plants as well as the Interpretations on the Safety Requirements for Nuclear Power Plants.

(2) A definition of "parts in the load path" was added in section 2 "Definitions" to ensure a uniform interpretation of this term.

(3) In section 4 "Special provisions" the following changes were made:

a) The classification criteria are specified on the basis of the danger potential arising from failure of lifting equipment used in nuclear power plants. Based on this, the requirements in all sections of this Safety Standard are formulated on the basis of experience with licencing and supervising procedures in nuclear power plants. It has not been examined whether or under which conditions the requirements laid down in KTA 3902 can be transferred to nuclear facilities outside the scope of KTA 3902, e.g. to interim storage facilities for spent fuel elements, and to the respective danger potential in these facilities in case of lifting equipment failure.

   Note:

   The requirements for technical equipment in interim storage facilities for spent fuel elements are laid down in the "Guidelines for dry cask storage of spent fuel and heat-generating waste" and in the "Guidelines for the storage of radioactive waste with negligible heat generation" of November 22nd, 2013 [see Federal Gazette (Bundesanzeiger) BAnz AT 22.01.2014 B3].

b) The reference to the verification procedure according to section 7 of KTA 3205.1 contained formerly in clause 4.5 (5) was deleted. Instead a reference to the actual version of KTA 3205.1 was added in clauses B 1.1.1 (2), B 1.1.2 (3), B 2.1.1.1 (2) and B 2.1.2.1 (3).

c) The standard DIN EN ISO 12100 (standard which replaced the standards DIN EN 292-1 and DIN EN 292-2 referenced in DIN EN 13557) was included additionally with regard to the ergonomics requirements.

(4) The requirements in section 5 "Lifts in reactor containments" were updated by including the Directive 2014/33/EU and the standard DIN EN 81-20. The term "lifts used for transporting goods and passengers" was included in due consideration of the terms used in current standards for the purpose of clarification.

(5) In section 6 "Additional requirements for cranes, winches, trolleys and load carrying devices" the following changes were made:

a) As an alternative to the dimensioning method using a global safety factor according to DIN 15018-1, for structures the method using partial safety factors according to the standard series DIN EN 13001 was allowed. For this purpose appropriate requirements were included in sections 6.1.1, 6.1.2.2, 6.1.3 and 6.4.1.2. A reference to DIN EN 1090-2 was added in the note contained in section 6.1.3, because there are no requirements regarding the execution of cranes in the standard series DIN EN 13001.

b) In clauses 6.1.3 (3), 6.2.1.3.2 (5) and 6.2.2.3 (5) the standard DIN EN ISO 13919-1 was taken over in addition to DIN EN ISO 5817 as for the assessment of welded connections, since electron-beam and laser welding is allowed too.

c) Since the standard DIN 18800-7 applied up to now regarding preloading of bolts is not valid anymore and because the standard DIN EN 1090-2, which replaced it, requires nominal minimum preloading that leads to higher preload forces than the former requirements in KTA 3902 and also higher than permitted according to DIN EN 13001-3-1, a requirement regarding the preloading of preloaded bolted connections was added in clause 6.1.3 (5) based on DIN EN 1090-2 and the guideline DASt 024 of the German Committee for Steel Construction to maintain the usual practice according to DIN 18800-7. This regulation complies with both the requirements of DIN 15018-1 and the requirements of the standard series DIN EN 13001.

d) In order to avoid misunderstandings, the requirements regarding the overload protection device in 6.2.1.3.1 (1) and 6.5.2 (4) were put more precisely.

e) The provision regarding bolts according to materials test sheet WPB 3.17 laid down up to now in clauses 7.4.1.1 (4) und 8.4.1 (3) was taken over into clauses 6.4.1.1 (4) and 6.4.2.1 (4), since it applies also to lifting equipment according to section 4.2.

f) In section 6.4.1.2 a note was added to explain what is understood by the term “structural steel components” which is used in the current Safety Standard.

g) In clause 6.5.1 (2) c), the reference to DIN EN 62138 Section 6 has been adapted to the current version of this standard.

h) In clause 6.5.1 (3) the words “according to KTA 3902 section 4.2” were deleted, since the requirement applies in general and irrespective of the lifting equipment classification.

The new note clarifies the scope of devices under consideration according to DIN EN ISO 13849-1. The experience gained has shown (see e.g. the information notice WLN 2014-08) that the mechanical connection between sensor and lifting equipment had not always been considered to a sufficient extent.

i) The former clause 6.5.2 (9) was divided into two clauses to separate the requirements regarding the position indication and regarding the interlock.

j) In 6.5.3 (2) requirements regarding the monitoring for detection of a sensor failure due to mechanical reasons were added. The experience gained has shown (see e.g. the information notice WLN 2014-08) that the monitoring of mechanical connection between sensor and lifting equipment has not always been available to a sufficient extent.

The new requirement added in 6.5.3 (2) d) is a clarification to prevent an inappropriate design.

(6) In section 7 the following changes were made:

a) As an alternative to the dimensioning method using a global safety factor according to DIN 15018-1, for structures the method using partial safety factors according to the standard series DIN EN 13001 was allowed. For this purpose appropriate requirements were included in sections 7.1.1, 7.1.2.2 and 7.4.1.2.

b) Since especially in the case of slowly rotating hoists it is difficult to demonstrate that the braking distance of the safety brake does not exceed three times the braking distance of the service brake, but at the same time inadmissible safety-related consequences will be avoided if an appropriate absolute value will not be exceeded, the demonstration based on an absolute value of the braking distance is also permitted. Therefore an appropriate amendment was made in clause 7.2.1.1 (3).

c) In clause 7.2.1.3.1 (3), the formulation was specified more precisely in accordance with the newly introduced definition in 2 (1) “parts in the load path”.

d) In section 7.5 the reference to Annex E was deleted, since this reference is presented in detail in section 6.5 and the requirements of section 6.5 must be fulfilled anyway.

(7) In section 8 the following changes were made:

a) As an alternative to the dimensioning method using a global safety factor according to DIN 15018-1, for structures the method using partial safety factors according to the standard series DIN EN 13001 was allowed. For this purpose appropriate requirements were included in sections 8.1.1, 8.1.2.2 and 8.4.2.

b) In 8.2.1.1 (3) the same amendment regarding the braking distance of the safety brake as in 7.2.1.1 (3) was added.

c) In clause 8.2.1.3.1 (3), the formulation was specified more precisely in accordance with the newly introduced definition in 2 (1) “parts in the load path”.

d) In section 8.5 the reference to Annex E was deleted, since this reference is presented in detail in section 6.5 and the requirements of section 6.5 must be fulfilled anyway.

(8) In Annex B the following changes were made:

a) Requirements regarding the dimensioning method according to the partial safety factors concept were added (sections B 1.1.2, B 2.1.2, B 3.3).

Here, the application of the standard series DIN EN 13001 to austenitic steels was limited to such cases where according to section 6.3.3 of DIN EN 13001-3-1 a fatigue analysis is not required. This restriction is necessary since the edition 2019-03 of DIN EN 13001-3-1 for the first time applies also to austenitic steels according to DIN EN 10088-3, even though this standard in the fatigue analysis makes no difference between ferritic and austenitic steels. The applicability of the fatigue analysis according to DIN EN 13001-3-1 to austenitic steels within the range of application of KTA 3902 could not be verified sufficiently so far. Whenever necessary, requirements regarding the fatigue analysis of austenitic load support steel structures within the range of application of KTA 3902 designed acc. to DIN EN 13001-3-1 shall be fixed in each individual case.

The detailed requirements added in sections B 1.1.2 and B 2.1.2 were defined to ensure both a sufficient design and a stress utilization which is comparable with the design according to DIN 15018-1 as well as to allow that the risk coefficient γ_n according to DIN EN 13001-2 may be taken as 1.0 for the following reasons:

aa) The dynamic factor Φ_2 was specified equally to the dynamic factor[2] required in compliance with Table 2 of DIN 15018-1 according to lifting class H3 (additional requirements) or H4 (increased requirements) for operational loads and according to lifting class H1 for for erection loads.

ab) The wind state “normal” was specified for calculations of the forces due to wind, because the resulting wind pressure corresponds to the value according to DIN 15018-1 applied successfully up to now. The calculation approaches of DIN EN 13001-2 and DIN 15018-1 are different with regard to the aerodynamic coefficients used in the calculation procedures. No special requirements are necessary when DIN EN 13001-2 is used, because lattice structure members are not used in gantry cranes for Nuclear Power Plants and all other aerodynamic coefficients differ by less than 10 %. The different shielding factors have no effect, because they are of no relevance for cranes in Nuclear Power Plants which have a box-type design.

ac) When the proof using the partial safety factors concept according to this KTA Safety Standard is performed, it is ensured by special requirements that the same level of safety is achieved as when DIN 15018-1 is used. The test loads must also meet this level of safety. It is therefore necessary to maintain the test loads required up to now and the smaller test loads allowed according to DIN EN 13001-2 shall be excluded.

ad) According to clause 6.5.3 (5) of KTA 3902 it shall be ensured by technical measures that mechanical travel limiters and safety travel limiters can only be approached with the allowable speed. Therefore, no additional requirements regarding the nominal speed before collision with the buffer have to be added in KTA 3902. The requirements regarding negative wheel loads were taken over from section 4.3.2 of DIN 15018-1.

ae) The specific resistance factor for material of γ_{sm} = 0.95, which is permitted for certain materials according to section 5.2.2 of DIN EN 13001-3-1, is not allowed within the range of application of KTA 3902 to maintain the current safety level of crane systems.

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[2] *In DIN 15018-1 the term “nominal load spectrum factor” is used instead of “dynamic factor”.*

af) In compliance with Annex G of DIN EN 13001-3-1, a value of α_L = 1 was conservatively fixed for the load introduction factor of bolted connections loaded in tension, because the applicability of smaller values can hardly be proved in practice.

ag) The fatigue strength specific resistance factor γ_{mf} for parts, welded connections and also for not hot dip galvanised bolted connections of structures according to section 4.2 was specified to be 1.25 in accordance with Table 9 of DIN EN 13001-3-1. Deviating from Table 9 of DIN EN 13001-3-1, γ_{mf} for bolted connections of structures according to section 4.3 and 4.4 was specified to be 1.5, since a comparison between the limit stress amplitudes according to VDI 2230 Sheet 1 in due consideration of the safety factors required according to KTA 3902 and half the limit design stress range values according to DIN EN 13001-3-1 led to good compliance using the value γ_{mf} = 1.5. Since in VDI 2230 Sheet 1 only an endurance limit reduced by 20% is permitted for hot dip galvanised bolts, fatigue strength specific resistance factor values γ_{mf} increased by 20% were specified for these bolts.

ah) The specifications regarding external events and the safety against the allowable stress range are equivalent to the requirements specified so far.

b) The use of Annexes C and D (stress-number diagrams the application of which is permitted if the operating conditions are exactly known) was limited to the verification method using a global safety factor, because

ba) the values in Annex C have been derived from DIN 15018-1 and cannot simply be applied to the verification method using the partial safety factors concept,

bb) the values in Annex D are based on experiments performed by Bundesanstalt für Materialforschung und -prüfung (BAM) on behalf of the Federal Ministry for the Environment, Nature Conservation and Reactor Safety (BMU) and are valid only for the given materials and notch cases according to DIN 15018-1.

c) For clarification, the formula B 1-6 in B 1.2.1.2 (1) a) has been changed to determine the value h_i (duty cycle of the hoist) required for rotating components. h_i is the input value for formula B 1-9. U_i (number of working cycles) generally is a known value.

d) In B 1.2.3.1 (4) b) the reference to the standard DIN 3962-2 was retained, although it was withdrawn in March 2018 and replaced by the standard DIN ISO 1328-1. An adaptation of the text to the new standard was not considered necessary, because

da) the standard is mentioned in connection with the calculation method according to NIEMANN which today has no priority, but is still considered a proven method and shall be maintained with regard to lifting equipment in existing Nuclear Power Plants,

db) the design of gears according to the valid standard DIN 3990-11 is also permitted so that there is no strong need to adapt the text of this Safety Standard to DIN ISO 1328-1.

e) An error correction was made in equation B 1-31 (equation B 1-25 in the edition 2012-11 of this Safety Standard).

f) It was discussed whether the specifications for the fatigue analysis of bolted connections in section B 1.4.1.5 need to be specified more precisely because the VDI 2230 Sheet 1, on which the verification is based, does not contain any specifications for the range of less than 10^4 stress cycles. After a detailed discussion of the facts, no changes were made to the specifications in Section B 1.4.1.5 for the following reasons:

- If bolted connections are tightened several times, stress amplitudes can occur as a result of the repeated tightening processes which exceed the permissible dynamic strength value at $N_z = 10^4$ according to VDI 2230 Sheet 1, taking into account the safety factors acc. to KTA 3902.
- The requirements specified in KTA 3902 for the dimensioning of bolted connections (see Section B 1.4.1.5) and the increased safety factors for the fatigue analysis compared to VDI 2230 Sheet 1 lead to a safe design of the bolted connections, where in general the required precautions to be taken against damage are also ensured in the case of a (small) number of load changes resulting from dismantling and reassembly processes.
- The discussion of the case did not reveal any indications of safety-related deficits in existing bolted connections that were designed in accordance with the specifications in KTA 3902, which would indicate that the necessary precautions against damage are not ensured.

For special cases of bolted connection design, it was recommended to check the permissibility of extrapolating the Wöhler curve, if necessary taking into account the safety factors used in the verification process, in cases where the stress amplitude from tightening processes exceeds the permissible dynamic strength value at $N_z = 10^4$ according to VDI 2230 Sheet 1.

g) In sections B 3.1 and B 3.3 specifications were added to allow a verification procedure for the design according to the standard series DIN EN 13001.

h) In clauses B 3.2.1 (6) and (7) several modifications and further specifications were made for the purpose of clarification.

i) The yield stress values specified in clause B 3.2.1 (7) c) have been adapted so that - with exclusive reference to $R_{p0.2}$ - they correspond to the values specified in KTA 3201.2, thus

- in load case H a value of $\sigma_F = 1.50 \cdot S_m$
- in load case HZ a value of $\sigma_F = 1.65 \cdot S_m$
- in load case HS a value of $\sigma_F = 1.80 \cdot S_m$

shall be used and the specified loading shall not exceed 67 % of the lower bound collapse load as per clause 7.7.4.1 of KTA 3201.2.xxx

j) B 3.3.1 (7) c) has been modified in order to match the wording in KTA 3201.2.

k) B 3.3.2 (2) has been adapted to the wording in B 3.2.2 (2).

(9) Annexes C and D were only editorially revised with regard to the terms used. However, the application of these Annexes is limited to the verification method using a global safety factor (see explanation under (8) b)).

(10) In Annex E the following changes were made:

a) Section E 1 was added to clarify that the requirements specified in Table E-1 shall apply irrespective of the demand rate mentioned in the scope of DIN EN ISO 13849-1.

b) For the purpose of explanation, footnotes were added for all cells of Table E-1 where no performance level is specified. In serial no. 36 b) it was pointed out that electrically driven grabs without mechanical opening interlock is not allowed for lifting equipment according to section 4.3 of KTA 3902.

(11) Annex F “Regulations and literature referred to in this Safety Standard” was adapted to the current state of standardization.