Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

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 Primary Coolant Circuit of Light Water Reactors

(Komponentenstützkonstruktionen mit nichtintegralen Anschlüssen;
Teil 1: Komponentenstützkonstruktionen mit nichtintegralen Anschlüssen für Primärkreiskomponenten in Leichtwasserreaktoren)

The previous versions of this safety standard
were issued in 1982-06, 1991-06, and 2002-06

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KTA SAFETY STANDARD

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Previous versions of the present safety standard: 2002-06 (BAnz No.189a of October 10, 2002)
1991-06 (BAnz No.118a of June 30, 1992)
1982-06 (BAnz No.215a of November 19, 1982)

Contents

PLEASE NOTE: Only the original German version of the present safety standard represents the joint resolution of the 35-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in Bundesanzeiger (BAnz) of December 12, 2018.
Copies of the German versions of KTA safety standards may be mail-ordered through Wolters Kluwer Deutschland GmbH (info@wolterskluwer.de). Downloads of the English translations are available at the KTA website: 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 present safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, 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 the present 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 (AtG), in the Radiological Protection Law (StrlSchG) as well as the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants (SiAnf) as well as in the Interpretations of the Safety Requirements for Nuclear Power Plants (Interpretations of SiAnf).

(2) Certain requirements regarding passive systems are specified in the Safety Requirements for Nuclear Power Plants (SiAnf), namely in its Sec. 3.1, para. (2) and Sec. 6.4, para. (4). Within its scope the present safety standard, KTA 3205.1, details the measures to be met to fulfill those requirements. In this context, a number of standards from conventional technology, in particular DIN standards, were used and are individually referenced.

(3) Component support structures have the safety-related function of transferring the loads from the supported component parts and components into the load-carrying parts of the plant.

(4) The present safety standard deals with those component support structures with non-integral connections for components of the primary coolant circuit (within the scope specified in safety standard series KTA 3201). Component support structures with non-integral connections for pressure and activity-retaining components of systems outside the primary circuit are dealt with in safety standard KTA 3205.2. Standardized qualification tested supports are dealt with in safety standard KTA 3205.3. Component support structures with integral connections for components of the primary coolant circuit are covered by safety standards KTA 3201.1 to 3201.4.

1 Scope

(1) This safety standard applies to non-integral component supports structures of the Steel Construction Category S1 for components of the primary coolant circuit with design temperatures up to 350 °C in nuclear power plants with light-water reactors. The requirements apply out to and including the connections to the anchor plates or other structural components that are within the jurisdiction of construction supervision.

(2) The components of the primary coolant circuit to be supported include:

a) reactor pressure vessel,

b) steam generators,

c) pressurizers,

d) reactor coolant pumps,

e) pipelines connected to these components and valves installed in such pipelines up to and including the primary isolation valve.

(3) The different requirements for the component support structures shall be specified depending on the safety-related significance of components to be supported. These include:

a) Component support structures that support components of the primary coolant circuit shall basically meet the requirements of the present safety standard (Steel Construction Category S1). The exceptions are supports for pipelines and pumps in the course of the pipelines with a nominal diameter smaller than or equal to DN 100 as well as protective and special constructions. These shall meet the requirements specified in safety standard KTA 3205.2 (Steel Construction Category S2).

b) Component support structures that support components of the systems outside the primary circuit shall basically meet the requirements specified in safety standard KTA 3205.2. The exceptions are steel platforms with supporting functions, supports for pipelines, valves or pumps with a nominal diameter smaller than DN 100 as well as supports of pressure vessels with a weight force smaller than 50 kN and a pressure-times-liter value less than 1000 [bar · l]. These shall meet the requirements specified in technical standards outside of the KTA safety standards (Steel Construction Category S3).

c) Component support structures that support components other than those of the primary circuit and of the systems outside the primary circuit shall meet the requirements specified in technical standards outside of the KTA safety standards (Steel Construction Category S3).

d) The pipe-whip restraints for components of the primary circuit and of the systems outside the primary circuit shall meet the requirements specified in **Appendix D** of the present safety standard.

A schematic categorization of the steel construction of component support structures is shown in **Table 1-1**. The design criteria and verification objectives of the individual load case categories as well as the design situations are listed in **Table 1-2**.

(4) Standardized parts that are stressed or employed in other ways than described in the qualification test specified in the appendices of safety standard KTA 3205.3, or standardized constructions and component parts without a qualification test shall be verified as specified in the present safety standard and – if necessary – their functionality shall be verified based on safety standard KTA 3205.3.

(5) The delimitation of component support structures with non-integral connections specified in the present safety standard from the component support structures with integral connections specified in the safety standards series KTA 3201 is shown in **Figure 1-1**. The component support structure under the present safety standard extends out to the connection to the building structure (e.g., connecting weld, anchor plate, platform). The distance l (decay length) shall be calculated by equation (1-1):

$$l = 0.5 \cdot \sqrt{r \cdot s} \qquad (1\text{-}1)$$

In the case of shell-type support structures

r is the mean radius of the shell (e.g. frames, tubular nozzles)

s is the thickness of the shell.

In the case of other shapes

r is one-half the largest dimension of a flange, T-section, plate or round section or one-half the maximum leg width of an angle section

s is the flange thickness of sections or the plate thickness; s = r/2 for bars.

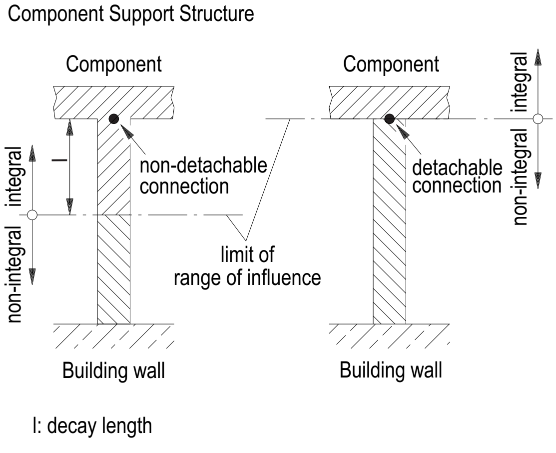


Figure 1-1: Attachment types of the component support structure and range of influence of the component

Ser. No.	Specifications for non-integral component support structures are contained in:		KTA 3205.1	KTA 3205.2	Technical standards other than KTA 1)
			KTA 3205.3		
	Steel structure types:		Components as specified in KTA 3201	Components as specified in KTA 3211	Other components
1	Steel platforms with supporting function		S1	S3 2)	
2a	Pipeline and valve supports, pump supports 3)	> DN 100	S1	S2 5)	S3 2), 5)
2b		≤ DN 100	S2 4), 5)	S3 2), 5)	
3a	Pressure vessel supports	Weight force ≥ 50 kN or pressure-times-liter value ≥ 1000 [bar · l]	S1	S2	S3 2)
3b		Weight force < 50 kN or pressure-times-liter value < 1000 [bar · l]	S1	S3 2)	
4	Protective and special constructions (without Ser. No. 5) including storage facility for new fuel assemblies		S2		S3 2)
5	Pipe-whip restraints		Requirements as specified in Appendix D		–

1) In accordance with acknowledged technical standards.

2) Supporting structures to be designed against earthquakes shall additionally meet the requirements of safety standard KTA 3205.2, Sec. 3.1, Sec. 3.3, para.(2) and Sec. 7.8.3, para. (2).

3) The determining nominal diameter (DN) for a pump is that of its discharge nozzle.

4) Falls within the scope of the present safety standard; however, the certification process shall be as specified in safety standard KTA 3205.2.

5) Irrespective of the categorization, inservice inspections regarding functionality shall be performed over the entire range out to the nearest anchor point.

Table 1-1: Steel construction categories for component support structures

Load case categories (service limit levels as specified in the present safety standard)	Design situations in accordance with DIN EN 1990 and DIN EN 1993	Design criteria
H (main loads) HZ (main and additional loads)	Permanent and temporary	Complete serviceability is available, cyclic loading possible, always reusable.
HS1 (main and special loads)	Unusual (seldom)	Complete serviceability is assumed. After occurrence of such a load case, the respective component support structure may have to be inspected. The inspection criteria shall be specified on a case-by-case basis.
HS2 (main and special loads)	Accidental	Stability and required functionality are sustained (limitation of deformations, e.g., bearing clearance). It shall be checked on a cases-by-case basis whether the respective component support structure must be repaired or exchanged after the occurrence of such a load case.
HS3 (main and special loads)		Sustained stability. Large plastic deformations are allowable. It shall be checked on a cases-by-case basis whether the respective component support structure must be replaced after the occurrence of such a load case.

Table 1-2: Load case categories and associated design criteria

2 Definitions

(1) The present safety standard relies on

a) the nomenclature of the equations as listed in **Appendix C**,

b) the service limit levels as specified in safety standard KTA 3201.2

and the following definitions.

(2) Final document file

The final document file comprises all documents to be maintained during the lifetime of the plant or of the component parts of the plant.

(3) Component support structures with non-integral connections

Component support structures with non-integral connections are structures which are either non-detachably connected to and lying outside of the range of influence (cf. **Figure 1-1**) of the component or which are detachable from the component; these component support structures are intended to transfer loads between the component and the building structure.

(4) Pipe-whip restraints

Pipe-whip restraints are structures intended to prevent the whipping of broken pipelines.

Note:

The requirements for pipe-whip restraints. are specified in Appendix D of the present safety standard

(5) Authorized expert

An authorized expert is the expert person appointed in accordance with § 20 AtG by the proper licensing or supervisory authority for the performance of the tests specified in the present safety standard.

(6) Protective or special structures

Protective or special structures are pipe-whip restraints and other energy-absorbing structural elements.

(7) Equivalent yield stress

The equivalent yield stress, $R_{v0.2}$, is determined from the yield strength or from the yield and ultimate strength; it is a fictive yield strength.

(8) Reference block

A reference block is a material element that in all its test-relevant characteristics (e.g. material, direction of forging, shape, wall thickness) resembles the test object and that incorporates reference characteristics (e.g., grooves, bore holes) that are adapted to the testing task.

(9) Acceptance criteria for non-destructive testing

Acceptance criteria for non-destructive testing are the sum of all specified data on the basis of which it is decided whether an indication of a non-destructive test can be evaluated as being acceptable without any further measures (i.e., the requirements of the test instruction are fulfilled) or whether further measures are required. The acceptance criteria include both quantitative specifications in the form of acceptance limits (e.g., amplitude level, size of indication, distance between indications) and descriptive specifications (e.g., linear or round indication, indication on the surface or inside the body, concentration of indications).

3 Specifications, Design Data Sheets, Documents, Documentation, Design Review, Tests and Inspections

3.1 Specifications

(1) The requirements to be met during fabrication and installation of the component support structures shall be detailed in specifications.

(2) The specifications shall normally, in as far as necessary, present information regarding the following points:

a) description of the component part,

b) spatial boundaries, locations of installation,

c) references to the design data sheet,

d) analysis specifics,

e) materials, material property values,

f) drawings,

g) fabrication and test instructions including specified tolerances,

h) construction supervision and tests and inspections at the manufacturing plant and during assembly, plant and on-site acceptance (final inspection plans),

i) function tests,

j) coating, cleaning, packaging and transport,

k) applicable technical standards, and

l) documentation.

(3) Information on further requirements may be included. If the individual requirements are specified in applicable technical standards, reference shall be made to these standards.

3.2 Design data sheets

The design data sheets shall present information regarding the following points:

a) type of component support structure, steel construction category, seismic classification, execution class for the welds of load-carrying component parts (in accordance with DIN EN 1090).

b) plant facility, plant component, components to be supported,

c) compartment number,

d) level elevation,

e) system designation, e.g., designation of the pipelines in accordance with the Identification System for Power Plants (KKS),

f) characteristic values of possible actions (without partial safety factors) or loadings including load direction, load combination and classification,

g) material and material group,

h) design temperature, operating and design-basis accident temperatures for the component support structures.

i) marks of approval, and

j) if necessary, the required movement capabilities (degrees of freedom) and the deformation limits.

3.3 Design Review Documents

The documents specified under Serial Nos. 1 through 8 and 12 of **Table 3-1** for the component support structures that are listed in **Table 1-1** shall be submitted to the authorized expert for a design review before beginning with the fabrication.

3.4 Documents for the Final Document File

3.4.1 General requirements

(1) The documentation shall ensure traceability of all tests and inspections performed on the component, beginning with its design and onward to the completed fabrication and installation, and of all deviations.

(2) Modified documents shall be serially numbered in accordance with their revision.

(3) The documents shall be compiled in a clear and organized way and shall include a table of contents.

(4) The final document file shall contain all documents and test certificates specified in Sections 6 and 7 in their latest valid versions.

3.4.2 Compiling the documentation

(1) The documentation of the manufacturing documents shall be compiled concurrent with manufacturing by a central division of the manufacturer.

(2) By the time of final testing, all manufacturing documents required for the documentation shall have been made available.

(3) The compilation of all these documents shall have been completed by the time the component is installed.

(4) All documents pertaining to the assembly tasks shall have been made available by the time of the hot functional run.

3.4.3 Repair procedure plans

(1) Each individual repair procedure plan and the associated documents shall be marked with an “R” in addition to the actual designation and test number of the respective test schedule.

(2) The documentation of repair weldings – in addition to listing the weld parameters, the valid welding procedure qualification test and the preheat temperatures – shall present a detailed description of the repair welding, its correlation to the component part and its weld and the exact measurements.

Serial No.	**Design and Manufacturing Documents for the Final Document File**
1	Table of contents
2	Design data sheets (cf. Section 3)
3	Parts lists 1) and bill of materials 1) including the Inspection Certificates in accordance with DIN EN 10204. The manufacturer, the licensee and the authorized expert will have affixed marks of approval to these lists of materials confirming that the tests were properly performed.
4	Construction drawings
5	Adjustment settings (in case of movable hanger and supports) 1)
6	Analyses (including specification of the building structure interaction loads or the actions on the structural connection)
7	Final inspection plans: Independent of whether or not a test certificate is required, the manufacturer, the licensee and the authorized expert will have affixed marks of approval to these final inspection plans confirming that the tests were properly performed.
8	Welding schedule (plus heat treatment plan, if required) and weld location lists also specifying the execution class. Superordinate welding schedules are allowable (e.g., weld-joint form dependent welding schedule)
9	Production weld tests as specified under Section 7.4.3 (if required)
10	Welding records or summary certificates: The welding records shall contain all data as specified under Section 7.4.6. Summary certificates shall meet the requirements of Section 7.4.6, para. (6).
11	Heat treatment plan and records as specified under Section 7.4.3 (if required)
12	Test instructions for the non-destructive testing (if required)
13	Test records for the non-destructive tests performed
14	Non-conformance reports (repair documents, tolerated deviations)
15	Summary certificates 1) All test certificates shall be compiled in a list of certificates

1) may be integrated in the construction drawings

Table 3-1: Design and manufacturing documents for the final document file

4 Analysis

4.1 General Requirements

4.1.1 Choosing the certification procedures

(1) Within the scope of the present safety standard two certification procedures are allowable:

a) certification procedure using partial safety factors in accordance with the Eurocode (DIN EN 1990, DIN EN 1991 and DIN EN 1993-1),

b) certification procedure using a global safety factor (σ_{zul}-concept).

The application of these procedures is detailed in the following subsections and paragraphs.

(2) Component support structures for newly to be constructed systems shall be calculated by applying the certification procedure using partial safety factors in accordance with the Eurocodes DIN EN 1990, DIN EN 1991 and DIN EN 1993-1. New component support structures for existing systems, the latter of which were calculated by applying the procedure using a global safety factor (σ_{zul}-concept), either one of the procedures (paragraph (1) a) or b)) may, coequally, be applied.

(3) The simultaneous application of both procedures within the overall certification process for a component support structure is basically not allowable. The exception is the dimensioning of component parts in accordance with a different body of technical standards, provided, the respective component parts are not monolithically connected to the overall support structure and neither the transfer of the stress resultants within the overall support structure nor the overall stability are affected.

(4) Within the framework of design, the loadings or actions shall be allocated (as shown in **Table 1-2** and the exemplary allocation in **Table 4-1)** to the

a) design situations related to civil engineering (permanent, variable, accidental) or

b) load case categories (H, HZ, HS1, HS2/HS3).

Note:

The allocation of the design categories A1, A2 and A3 in accordance with DIN 25444 are shown in **Table 4-1**.

(5) Component support structures fabricated from ferritic steels which, in addition to the simple column-buckling, require additional certifications of stability (lateral torsional buckling or buckling in case of plate and shell structures), shall basically be verified by the certification procedure using partial safety factors. Upon agreement with the authorized expert other certification procedures (e.g., finite element method) may be applied.

(6) In addition to the procedures specified under paragraph (1), special certifications according to the calculation methods described in safety standard KTA 3201.2, Appendix C (e.g., finite element method, elasto-plastic procedure), may by applied both for component support structures for newly to be constructed systems as well as for new component support structures for existing systems.

(7) Component support structures fabricated from austenitic materials that require proofs of stability shall be verified applying the certification procedure using partial safety factors.

4.1.2 Extent of the certification process

(1) All of the required certifications shall be carried out completely and shall be clearly arranged and reviewable. The analyses shall be self-consistent and shall present unambiguous data for the construction drawings. This means, they shall not rely on any data from other calculations without quoting the source or showing how they were derived.

(2) The certification process shall deliver information on

a) actions and combinations of actions, design values of resistances and certification of the limit conditions, or

b) loads and load combinations, allowable stresses and stress analyses.

(3) If necessary, the distribution of the loading over time shall be taken into consideration observing all operating and test conditions (e.g., temperature, pressure wave, jet impingement forces).

(4) Supports for highly dynamic loads (e.g., vibration dampers) shall be subjected to a fatigue analysis. In the case of primarily static loads the cyclic strength or fatigue analysis may be waived. Primarily static loads exist if no highly dynamic loads (e.g., caused by pressure pulses, external vibration excitation, turbulences) affect the component support structures.

Note:

Fatigue analyses are detailed, depending on procedure and application, e.g., in safety standard KTA 3201.2, DIN EN 1993-1-9 and VDI 2230.

4.1.3 Basics of the certification process

(1) The analytical certifications shall basically be performed based on the beam bending theory, rod and bar statics or the theory of plate and shell structures. Numeric methods (e.g., finite element method) may also be applied.

(2) Depending on the type of support structure the stress analysis shall be performed typically for a beam support structure or for a plate and shell support structure,

(3) Utilization of plastic behavior is allowable. In these cases, the reaction on the supported component shall be taken into account. Additional details are specified in Sections 4.2 and 4.3. Whip restraints shall be verified a specified Appendix D.

(4) Dynamic loadings may be accounted for by static equivalent loads. Additional details are specified in Sections 4.2 and 4.3.

(5) The analytical certifications may be replaced or supplemented by experimental certifications. The program for these experiments shall be specified in agreement with the authorized expert.

(6) In individual cases the characteristic mechanical properties for the analyses may be obtained from the Inspection Certificates in accordance with DIN EN 10204.

(7) The yield strength, R_{eH}, and the 0.2 % proof stress, $R_{p0.2}$, may be considered as equivalent unless otherwise specified in **Table 4-4** and **Table 4-5**.

(8) In the case of T-joints of hollow sections the failure mechanisms of DIN EN 1993-1-8 shall be taken into account.

(9) The slenderness ratio of component parts subjected to compressive loadings may not be larger than 150.

4.1.4 Temperature influence

(1) The analysis temperature at the connection between component and support structure shall be set equal to the temperature of the component during specified normal operation.

Note:

The temperature distribution in the pipe enclosing component parts is specified, e.g., in safety standard KTA 3205.3.

(2) Component support structures that must fulfill their safety-related function during design basis accidents shall be designed taking the temperature of the component part at the point in time of the action or load case into account.

(3) In the case of the steels S235 (St 37) and S355 (St 52) the yield strength and tensile strength for temperatures higher than 80 °C shall be reduced by the factor k shown in **Figure 4-1**. In the case of other materials (cf. Section 6) where the yield strength at elevated temperatures is not available, the reduction factor to be used shall be that for S355.

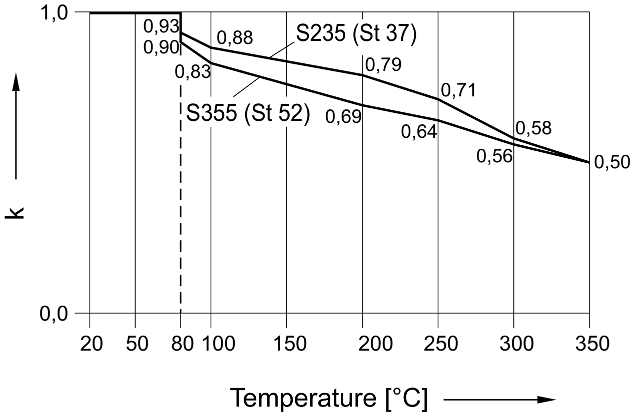


Figure 4-1: Reduction factor, k, for determining the yield strength at elevated temperatures and the tensile strength in dependence of the temperature

The following equations shall be applied:

$$R_{eHT} = k \cdot R_{eH} \qquad (4\text{-}1)$$

$$R_{p0.2T} = k \cdot R_{p0.2} \qquad (4\text{-}2)$$

$$f_{yT} = k \cdot f_y \qquad (4\text{-}3)$$

$$f_{uT} = k \cdot f_u \qquad (4\text{-}4)$$

Here means:

f_{yT}	nominal value of the yield strength at temperature (T)
f_y	nominal value of the yield strength at room temperature (RT)
f_{uT}	nominal value of the tensile strength at temperature (T)
f_u	nominal value of the tensile strength at room temperature (RT)
R_{eHT}	yield strength at temperature (T)
R_{eH}	yield strength at room temperature (RT)
$R_{p0.2T}$	0.2 % proof stress at temperature (T)
$R_{p0,2}$	0.2 % proof stress at room temperature (RT)

(4) The temperature dependence of the elastic modulus, of the shear modulus and of the coefficient of thermal expansion does not need to be considered.

(5) In case structural measures (e.g., expansion sleeves, slotted holes) are provided that create sufficient expansion possibilities, then no restraint loadings within the component support structure need to be analytically certified. Likewise, no restraint loadings within the component support structure need to be considered, provided, it is verified that the fictive free temperature expansion of the respective component part does not exceed a value of 1 mm.

(6) Forces due to restrained thermal expansion of the component support structure shall be considered together with the building structure interaction loads.

(7) For bolts at temperatures higher than 80 °C, the allowable stress limits shall be determined from the engineering standard for the product or the material. In the case of bolts of Property Classes 4.6, 5.6, 8.8, 10.9 and of the bolt materials C35, 24CrMo5 and 21CrMoV5-7 the temperature dependent reduction factor k for the steel S235 (St 37) shown in **Figure 4-1** may be applied.

(8) In the case of high-strength pre-loadable slip-resistant bolted connections at temperatures higher than 100 °C, an additional certification of the load capacity is required to ensure security of the slip-resistant bolted connections.

4.1.5 Load transfer through direct contacts

Compressive forces perpendicular to the contact joint may be considered to be transferred completely through the contact, provided, the following requirements are met:

a) The surfaces of the abutting contact joints shall be flat and parallel to each other.

b) Local instabilities due to fabrication imperfections can be excluded.

c) Lateral shifting of the component parts at the abutting contact joint is excluded.

d) The relative position of the joined abutting components is secured; when proving that the relative position of the abutting component parts is secured friction forces may not be taken into account.

e) A possible gap may not be larger than 0.5 mm.

4.1.6 Friction forces

(1) Friction forces shall be verified only for the combinations of actions 0, 1 and 2 listed in **Table 4-2** or for the load cases H and HZ listed in **Table 4-3**. The friction coefficient, μ, to be applied – without a more detailed certification – for ferritic steels is:

a) $\mu = 0.45$ for steel on steel, unmachined, without lubricant, with coating, or

b) $\mu = 0.30$ for steel on steel, machined (e.g. brushed), no coating.

(2) A smaller friction coefficient is allowable, provided, suitable measures (e.g., provision of gliding plates) are taken. Certificates of these friction coefficients shall be provided.

(3) The friction coefficient for the certification of positional stability of a construction – without a more detailed verification – shall be $\mu = 0.15$. Other friction coefficients are allowable, provided, they are verified.

(4) For slip-resistant bolted connections the minimum friction coefficients in accordance with technical standards (e.g., DIN EN 1993-1-8, Sec. 3.9) shall be used. In case of either one of the following prior treatments of the friction surfaces, a friction coefficient of $\mu = 0.5$ may be applied without a more detailed verification:

a) 2 times flame cleaning, or

b) cast steel grit blasting,

(5) Stainless steel bolts shall not be used for slip-resistant bolted connections unless their effectiveness is experimentally verified for the individual case.

4.2 Certification Procedure Using Partial Safety Factors

(1) The following certificates shall be provided – as far as individually applicable – for all combinations of actions that are simultaneously effective:

a) certificate of the ultimate limit state,

b) certificate of stability (column buckling, lateral torsional buckling, buckling),

c) certificate of positional stability (lateral tilting, sliding, lifting off),

d) certificate of the serviceability limit state. The data – as far as necessary – shall be as specified in the design data sheet. All specifications shall be function oriented.

(2) When determining limit values of the resistance in accordance with DIN EN 1993, the material property values listed in **Table 4-4** shall be used for the yield strength f_y, and the tensile strength f_u.

(3) In case steel castings (ferritic, martensitic, austenitic) are used, the procedures for their analysis shall be specified in agreement with the authorized expert.

4.2.1 Types of actions

Note:

The terms *actions* (permanent, variable, accidental), *action types, combinations of actions, design situations, partial safety factor, ultimate limit state, serviceability limit state* are used as defined in DIN EN 1990 and DIN EN 1993-1.

All actions that are effective individually or in combination with others shall be specified. Partial actions may be neglected, provide, they are comparatively minimal. Typical actions include:

a) Permanent actions G (permanent standard loads): Deadweight of the support structure and weight of the components with filling and insulation (if applicable) – such as, e.g., pipelines – as far as they are not contained in the component loads A through D as specified in safety standard KTA 3201.2.

b) Variable actions Q (temporary standard loads) B1: Longer lasting loads effective during operating hours, e.g., stacking or construction loads, B2: Short temporary loads effective outside of operating hours or only for a short time during operating hours, e.g., stacking loads, test or traffic loads, component loads A, B or P.

c) Accidental actions A (special loads): E.g., component loads C and D; external events such as earthquakes; internal events such as pipe rupture loads, jet impingement forces; pressures and temperatures from design basis accidents.

4.2.2 Certification of limit states

4.2.2.1 Ultimate limit state

The combinations of actions for certifying the ultimate limit state shall be as listed in **Table 4-2** unless deviating values are specified in the design data sheet.

4.2.2.2 Serviceability limit state

The project- and system-oriented combinations of actions for certifying the serviceability limit state shall be as specified in the design data sheet.

4.2.2.3 Static equilibrium

The positional stability (lateral tilting, sliding, lifting off) shall be verified In addition to the two limit states above (paragraphs 4.2.2.1 and 4.2.2.2).

4.2.3 Resistance

The characteristic resistance parameters shall be determined on the basis of the partial safety factors, γ_M, in accordance with DIN EN 1993-1 and the associated national annexes, e.g.:

a) γ_{M0} for the resistance of cross-sections,

b) γ_{M1} for the resistance in case of loss of stability,

c) γ_{M2} for the resistance of cross-sections in case of fracture due to tensile loading.

4.2.4 Certificates

4.2.4.1 General requirements

(1) The certifications required for the limit states of steel components or steel component parts shall be in accordance with DIN EN 1993-1-1, DIN EN 1993-1-3 through DIN EN 1993 -1-10 and DIN EN 1993-1-12. In the case of stainless-steel component parts, the requirements in accordance with DIN EN 1993-1-4 and additionally the general building supervisory approval Z 30.3-6 shall be considered. The deviations specified in this supervisory approval with respect to the technical standards cited above shall be observed.

(2) Force transfers into sections shall be designed in accordance with DIN EN 1993-1-8.

(3) The plastic analysis of the support structure in accordance with DIN EN 1993-1-1, Sec. 5.4.3, is only allowable for a Class 1 cross-section of the materials under Ser. Nos. 1 and 2 of **Table 4-4** and then only for the combinations of actions 4 through 7 of **Table 4-2**. The procedure and the application to other materials shall be specified in agreement with the authorized expert. This method may not be applied to the dynamic analysis using static equivalent loads.

(4) The stress evaluation of plate and shell structures shall be performed in accordance with DIN EN 1993-1-5, DIN EN 1993-1-6 and DIN EN 1993-1-7.

4.2.4.2 Design values for the support capability of qualification tested component parts

(1) Equation (4-5) shall be used for calculating the design value for the load capacity of component parts that were qualification tested as specified in safety standard KTA 3205.3 and that have a load ratio H : HZ : HS equal to 1 : 1.15 : 1.5.

$$F_{Rd} = 1.5\ F_{(\text{Load Case H})} \qquad (4\text{-}5)$$

(2) Equation (4-6) shall be used for component parts that were qualification tested as specified in safety standard KTA 3205.3 and that have a load ratio H : HZ : HS equal to 1 : 1.5 : 1.7.

$$F_{Rd} = 1.7\ F_{(\text{Load Case H})} \qquad (4\text{-}6)$$

4.2.4.3 Certification of serviceability

(1) The limit states of deformations shall be determined and evaluated in accordance with DIN EN 1993-1-1, Sec. 7, if required with regard to fulfilling the function.

(2) In case a plastic analysis of the support structure is performed, the limit states of deformations shall always be determined and certified.

4.3 Procedures Using Allowable Stresses

(1) The following certifications shall be provided – as far as individually applicable – for all load cases and load case combinations with simultaneously effective loadings:

a) general stress analysis,

b) certification of stability,

c) certification of positional stability (lateral tilting, sliding, lifting off),

d) certification of the deformation limits. The data – as far as necessary – shall be as specified in the design data sheet. All specifications shall be function oriented.

(2) In the case of Load Case HS2/HS3, the advantage of plastic behavior may be utilized. In case of austenites, the 0.1 % proof stress, however no more than 360 N/mm^2, may be applied. The procedure shall be specified in agreement with the authorized expert. The deformations shall be verified and evaluated.

(3) Dynamic loadings may be dealt with by static equivalent loads. In this case no advantage of the global plastic behavior (e.g., plastic hinge) may be utilized. The consideration of a local plastic behavior shall be agreed upon by the authorized expert.

(4) If in individual cases special stress analyses must be certified, allowable stresses deviating from those specified under Sections 4.3.3.2 and 4.3.4.5 shall be specified in agreement with the authorized expert.

4.3.1 Loads and Load Cases

All loadings shall be specified that will be effective individually or in combination with other loadings. Partial loads may be neglected, provided, they are comparatively small. The loadings to be considered include:

a) Permanent standard loads: Dead-weight of the support structure and weight of the components with filling and insulation (if applicable, e.g., pipelines) as far as they are not included in the component loads A through D as specified in safety standard KTA 3211.2

b) Temporary standard loads B1: longer lasting loads during operation, e.g., stacking or construction loads, B2: short temporary loads effective outside of operating hours or effective only for a brief time during operation, e.g., stacking, test or traffic loads.

c) Component loads A through D: Loads emanating from the supported component in as far as they are not already accounted for as permanent standard loads under item a).

d) Accidental loads (Special loads): These are. e.g., external events such as earthquakes, or internal events such as pipe rupture loads, jet impingement forces; pressure and temperature from design basis accidents.

4.3.2 Categorization of Loadings

(1) The load combinations shall be specified in the design data sheet in a project- and system-oriented way.

(2) The load combinations shall be allocated to the load case categories (service limit levels) as shown in **Table 4-3** unless deviations from this requirement are specified in the design data sheet.

4.3.3 Dimensioning of rod-/bar-shaped component parts

4.3.3.1 General requirements

(1) The stresses (including reference stresses) shall be determined as specified in Appendix E. This also applies to bolts.

(2) Simple certifications of stability (column buckling) for compression struts of ferritic steels shall be verified as specified in safety standard KTA 3205.2, Appendix A.

(3) The stresses for bearings and hinges shall be determined using standard procedures (e.g., contact pressure, Hertzian contact stress).

4.3.3.2 Allowable stresses

The values for the equivalent yield stress, $R_{v0.2}$, shall be specified depending on the material used as listed in **Table 4-5**. In the case of load cases H, HZ, and HS1/HS2/HS3, the allowable stresses relative to the equivalent yield stress are those listed in **Table 4-6**, **Table 4-7**, **Table 4-9**, and **Table 4-10**.

4.3.3.3 Bolts as fasteners

(1) Bolted connections shall be verified as specified in Appendix E, Section E 4.

(2) The values to be used for the allowable stresses of bolts in Property Classes 4.6, 5.6, 8.8 and 10.9 at temperatures lower than 80 °C shall be as listed in **Table 4-8**.

(3) In the case of bolts not in Property Classes 4.6, 5.6, 8.8 and 10.9, the allowable stresses shall be calculated as shown in **Table 4-10**.

(4) The allowable shear force of the bolt shall be determined by multiplying the bolt's allowable shear stress with the cross-section of the shear area (shaft or core (root) cross-section).

(5) The allowable tension force of the bolt shall be determined by multiplying the bolt's allowable normal stress either, in the case of a metric ISO-thread in accordance with DIN 13-1, with the stress cross-section or, otherwise, with the core (root) cross-section.

Note:

Values for the shaft cross-section, for the core (root) cross-section and for the stress cross-section are listed in **Table 4-11**.

(6) In the case of shear bearing bolted connections with or without fit bolts, the thread regions of which will not be shear-loaded, the individual certifications of simultaneously effective shear and tensile loadings shall be performed mutually independent of each other. In this case, the allowable values for the individual loadings may be fully utilized without the need of verifying a reference stress.

(7) In the case of bolted connections, the thread regions of which will be shear-loaded, the reference stress, σ_V, shall be verified by equation (4-7):

$$\sigma_V = \sqrt{\sigma^2 + 3 \cdot \tau^2} \qquad (4\text{-}7)$$

(8) The allowable bolt bearing shall be verified based on the bolt cross-section as the determining parameter.

(9) The high-strength pre-loaded slip-resistant bolted connections shall be verified as specified under Appendix E, Section E 4.2. For design temperatures higher than 100 °C, an additional certification of the load capacity is required observing the requirements specified in safety standard KTA 3401.4, Sec. 5.4.

(10) High-strength bolts (e.g., Property Classes 8.8 and 10.9) may be used as normally pre-loaded bolts (pre-loaded slip-resistant bolted connection). The pre-load force, the tensile force and the shear force may not exceed the values listed in **Table 4-12** and **Table 4-13**.

Note:

Preload forces for bolted connections made from other materials are specified in VDI 2230 Sheet 1.

(11) In the case of a simultaneous loading of an outer (external) load in the direction and perpendicular to the direction of the bolt axis, the allowable transferrable lateral force in slip-resistant bolted connections without (GV) and with (GVP) fit bolts shall be reduced as specified in Appendix E, equations (E 4-8) and (E 4-9).

4.3.3.4 Welded connections

(1) The allowable stresses for weld seams shall be specified as listed in **Table 4-7**.

(2) The stresses for welded connections shall be calculated as specified in Appendix E, Section E 3. The reference value, σ_V calculated using Appendix E, equation (E 3-7) may only be used for the steels listed in **Table 4-5,** Ser. Nos. 1 and 2. Otherwise, the reference value shall be calculated using Appendix E, equations (E 2-15) and (E 2-16).

Note:

In addition, basic requirements for dissimilar metal welds (e.g., austenitic with ferritic steels) are detailed in the Approval Document Z-30 3.6 and also in DIN EN 1090 and DIN EN 1993-1-8.

(3) In the analyses, the weld seams may only be considered as fillet welds if the opening angle between the flanks of the connected component parts lies in the range between 60° and 120°.

4.3.3.5 Load introduction without stiffeners

(1) In the case of rolled sections with an H-shaped cross-section, forces may be induced without requiring stiffeners, provided,

a) the cyclic strength certification is not decisive, and

b) the girder (beam) cross-section is secured against twisting and lateral movements, and

c) the certification is provided that a load introduction without stiffeners is viable from the viewpoint of statics.

(2) The effective length shall be calculated assuming a 1 : 2.5 incline of the load distribution. Hereby, the web as well as the radius may be considered. The calculation of the effective lengths for the individual cases under items a), b) and c) is shown in **Figure 4-2**.

Note:

Figures 4.2a, 4.2b and 4.2c do not show all forces that lead to an equilibrium state.

(3) The stresses shall meet the following requirements:

– in case algebraic signs of σ_x and σ_z are different and

$$|\sigma_x| > 0.5 \cdot \sigma_{zul} \qquad (4\text{-}8)$$

then

$$\sigma_z = \frac{F}{s \cdot L\ (1.25 - 0.5|\sigma_x|/\sigma_{zul})} \leq \sigma_{zul} \qquad (4\text{-}9)$$

– in all other cases

$$\sigma_z = \frac{F}{s \cdot L} \leq \sigma_{zul} \qquad (4\text{-}10)$$

Nomenclature:

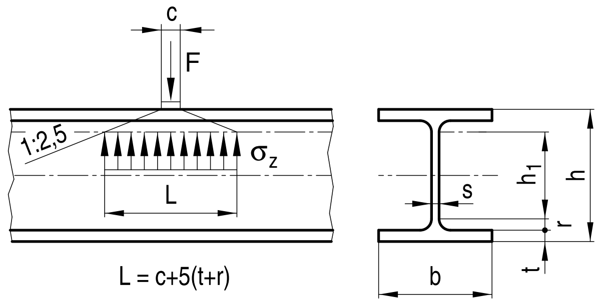
σ_x	normal stress in the decisive cross-section of the girder (beam) as shown in **Figure 4-2**
s	web thickness of the girder (beam)
L	effective length as shown in **Figure 4-2**

(4) In case of a slenderness ratio of the web (ratio of web height to web thickness) that is larger than 60, the safety against buckling shall be verified for the web.

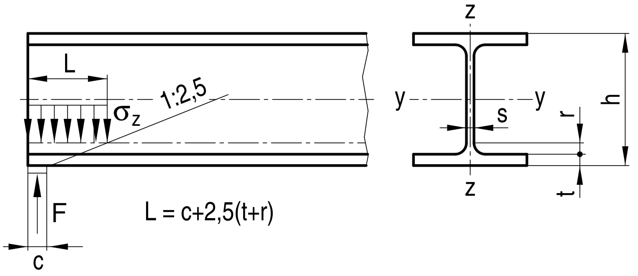
4.3.3.6 Certification of stability

Simple certifications of stability (column buckling) for compression struts of ferritic steels shall be performed as specified in safety standard KTA 3205.2, Appendix A. A reduction of the modulus of elasticity due to elevated temperatures may, generally, be neglected.

a) induction of a concentrated load (identical to the induction of a bearing force at an intermediate support):



b) induction of a bearing load at the end of the girder (beam):



c) girder on girder (beam on beam):

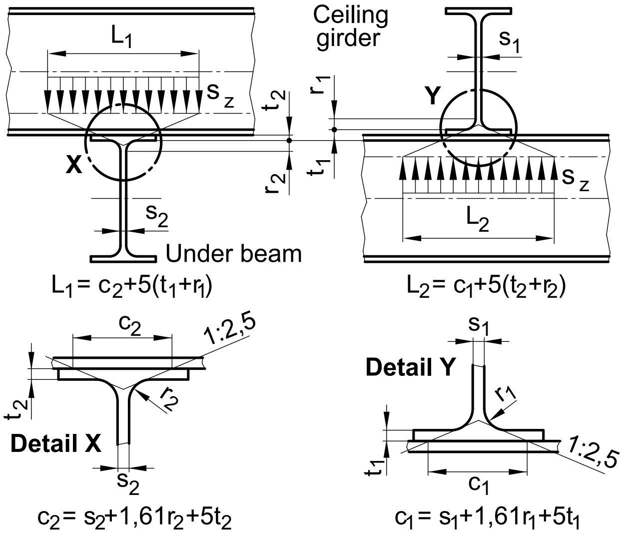


Figure 4-2: Load introduction without stiffeners in case of rolled sections with an H-type cross-section (based on historic standard DIN 18800-1)

4.3.3.7 Certification of deformation

(1) An additional certification of the deformation is only required if the function of the load-bearing component necessitates limiting the deformation.

(2) For the determination of deformations, cross-sectional values may be used without a deduction for the bore hole area.

4.3.3.8 Certification of positional stability

For the certification of positional stability as specified in Appendix E, Section E 5, the stabilizing loads with the factor 1.0 shall be considered for the special load cases.
Destabilizing loads with the factor 1.3 shall be considered for load case HS1 and with the factor 1.15 for load cases HS2 and HS3.

4.3.4 Analysis of other than bar-shaped component parts

4.3.4.1 General requirements

The following requirements apply to the determination of stress resultants and stresses (in accordance with the membrane, plate, shell or volume theory) applying the theory of elasticity to other than bar-shaped component parts and taking geometric discontinuities into account.

4.3.4.2 Design stress intensity, S_m

(1) For ferritic steels the design stress intensity (S_m) shall be determined as follows:

$$S_m = \min\left\{\frac{R_{eHT}}{1.5}; \frac{R_m}{2.4}\right\} \qquad (4\text{-}11)$$

(2) For austenitic steels the design stress intensity (S_m) shall be determined as follows:

$$S_m = \min\left\{\frac{R_{p0.2T}}{2.0}; \frac{R_{mT}}{2.4}\right\} \qquad (4\text{-}12)$$

At design temperatures less than or equal to 350 °C $S_m = \frac{R_m}{2.7}$ may be used instead of $\frac{R_{mT}}{2.4}$.

(3) For ferritic and austenitic steel castings subject to tensile and bending loadings the design stress intensity (S_m) shall be determined as follows:

$$S_m = \frac{R_{p0.2T}}{2.0} \qquad (4\text{-}13)$$

In the case of other loadings equations (4-11) or (4-12) shall be applied. For tensile and bending loadings equations (4-11) and (4-12) shall not be used unless agreed upon by the authorized expert.

(4) For welded connections the design stress intensity (S_m) shall be determined same as for the components, namely by means of equations (4-11) through (4-13).

4.3.4.3 Stress categories

Stress categories (primary and secondary as well as peak stresses) shall be allocated as specified in safety standard KTA 3201.2, Sec. 7.7.2.

4.3.4.4 Stress superposition

The stress superposition and exemplary allocation of service limits to the respective stress categories of the component parts shall be performed as specified in safety standard KTA 3201.2, Secs. 7.7.3.1 through 7.7.3.3.

4.3.4.5 Allowable stresses and stress assessment

(1) The load-case-specific limit values for the stresses and stress ranges to be applied are listed in **Table 4-14**.

(2) The allowable stresses for the load cases H though HS2 shall be determined using the S_m values as specified under Section 4.3.4.2 for the individual decisive temperature. The tensile strength at temperature, R_{mT}, shall be used for the service limit level HS3.

(3) If allowable stresses are specified larger than $R_{p0.2T}$ or R_{eHT}, these shall be assumed as being fictive stresses the adherence to which shall normally achieve a limitation of occurring expansions.

(4) For each of the load cases H through HS3, a reference stress shall be determined for the primary membrane stress, P_m , and for the sum of primary membrane stress plus bending stress, $P_m + P_b$, and this reference stress shall be compared to the allowable values listed in **Table 4-14**.

(5) For the load cases H and HZ, a reference stress range shall be determined for the sum of primary and secondary stresses, $P_m + P_b + Q$, and this reference stress range shall be compared to the allowable values listed in **Table 4-14**.

(6) The certification of the reference stress range may be waived for the sum of primary and secondary stresses, provided, the reference stress determined from $P_m + P_b + Q$ or from $P_l + P_b + Q$ does not exceed the 0.2 % proof stress, $R_{p0.2T}$, or the yield strength, R_{eHT} , in neither of the load cases H or HZ.

(7) The allowable stresses of the component parts listed in **Table 4-7** shall be applied also to the weld seams if the design stress values of the weld additives are equal to or higher than those of the component parts. One-sided fillet welds as listed in **Table 4-7**, Ser. Nos. 3 a and 3 b, may not transfer any bending stresses, P_b, to plate and shell structures.

Designation / Source	**Classification**				
Service limit levels (plant engineering) / KTA 3201.2 and KTA 3211.2	A	B	P	C	D
Load case categories / KTA 3205.1 and KTA 3205.2	H	HZ	HZ	HS1	HS2/HS3
Design situations / DIN EN 1990 and DIN EN 1993	permanent and temporary			accidental	
Design categories / DIN 25449	A1			A2	A3

Table 4-1: Examples for the allocation of various design categories, provided, no deviations are specified in the design data sheet

Ser. No.	**Combinations of actions**			**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Design categories in accordance with DIN 25449			**A1**			**A2**	**A3**			
				Partial safety factors, γ_F, for actions							
1	Permanent actions	Permanent standard loads (e.g., dead weight)		1.35	1.35	1.35	1.35	1.0	1.0	1.0	1,0
2	Temporary actions	Temporary standard loads	B1		1.5	1.5	1.5 3)	1.0 3)	1.0 3)	1,0 3)	1,0 4)
3			B2		1.5	1.5					
4		Component loads P 1)		1.35							
5		Component loads A 1)			1.5 11)						
6		Component loads B 1) 6)				1.5 13)					
7	Accidental actions 2)	Component loads C 1) 6) 7)					1.17				
8		Component loads D1)						1.0		1.0	1,0 4)
9		Temperatures during design basis accidents									1,0
10		Pipe rupture loads, jet impingement forces 5) 10)							1.0		
11		Additional loads from external events 8) from the component structure itself 9)								1.0	
12				**Safety factors for load combinations, ψ 12)**							
				1,0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

1) The component loads A through D and P correspond to loads allocated to the service limit values A through D and P as specified in safety standard KTA 3201.2.

2) The design data sheet shall include a detailed list of the accidental actions allocated to the various steel constructions.

3) Only if a simultaneous occurrence of accidental actions must be assumed (e.g., according to probability considerations in the individual case).

4) Only if a simultaneous occurrence with design basis accident temperatures must be assumed (e.g., according to probability considerations in the individual case).

5) The temperature specific yield strength shall be assumed for the jet impingement area.

6) Including loads from restrained thermal expansion and boundary displacements.

7) Including loads from restrained thermal expansion of the support structure.

8) Design basis earthquake and burst-pressure wave, airplane crash, blast-pressure wave.

9) Regarding the loading of the support structure itself caused by its oscillation behavior during an external event, the superposition of unidirectional loading parameters from various excitation directions is specified in safety standard KTA 2201.1, Sec. 4.3.1.

10) Pipe rupture loads and jet impingement forces do not need to be assumed as occurring simultaneously.

11) A reduced safety factor of 1.35 may be assumed to account for the ratio of water content to component load.

12) In well-founded cases smaller safety factors for load combinations than 1.0 are allowable.

13) If a more accurate knowledge of the actions is available, a value of 1.35 is allowable in well-founded cases.

Table 4-2: Partial safety factors, γ_F, for actions, and safety factors for load combinations, ψ

Ser. No.	Actions			Load combinations (Superposition of the actions)							
				0	1	2	3	4	5	6	7
				Load case categories (service limit levels)							
				HZ	H	HZ	HS1	HS2/HS3 11)			
	Design categories in accordance with DIN 25449			A1			A2	A3			
1	Standard loads	Permanent standard loads (e.g., dead weight)		X	X	X	X	X	X	X	X
2		Temporary standard loads	B1		X	X	X 3)	X 3)	X 3)	X 3)	X 4)
3			B2		X	X					
4		Component loads P 1)		X							
5		Component loads A 1)			X						
6		Component loads B 1) 6)				X					
7	Special loads 2)	Component loads C 1) 6) 7)					X				
8		Component loads D 1)						X		X	X 4)
9		Temperatures during design basis accidents									X
10		Pipe rupture loads, jet impingement forces 5) 10)							X		
11		Additional loads from external events 8) from the component structure itself 9)								X	

1) The component loads A through D and P correspond to loads allocated to the service limit values A through D and P as specified in safety standard KTA 3201.2.

2) The design data sheet shall include a detailed list of the special loads allocated to the various steel constructions.

3) Only if a simultaneous occurrence of special loads must be assumed (e.g., according to probability considerations in the individual case).

4) Only if a simultaneous occurrence with design basis accident temperatures must be assumed (e.g., according to probability considerations in the individual case).

5) For the jet impingement area, the temperature specific yield strength shall be assumed.

6) Including loads from restrained thermal expansion and boundary displacements.

7) Including loads from restrained thermal expansion of the support structure.

8) Design basis earthquake and burst-pressure wave, airplane crash, blast-pressure wave.

9) Regarding the loading of the support structure itself caused by its oscillation behavior during an external event, the superposition of unidirectional loading parameters from various excitation directions is specified in safety standard KTA 2201.1, Sec. 4.3.1.

10) Pipe rupture loads and jet impingements forces do not need to be assumed as occurring simultaneously.

11) The load case categories HS2 and HS3 shall be allocated in the design data sheet in accordance with the individual protective goal of the component support structure. (cf. **Table 1-2)**.

Table 4-3: Load cases and load case categories

Ser. No.	**Usage**	**Material** (to be allocated as listed in **Tables 6-1** through **6-5**)	**Formula symbols in DIN EN 1993**	
			f_y (nominal value of yield strength) corresponds to $R_{v0,2}$	**f_u (nominal value of tensile strength) 3)**
1	Component parts and weld seams	Structural steels	R_{eHT}	R_{mT}
2		Heat resistant and fine-grained steels	R_{eHT}	R_{mT}
3		42CrMo4	$\min\left(R_{eHT};\frac{2}{3}R_m\right)$	R_{mT}
4		Ferritic steels, with the exception of Ser. Nos. 1, 2 and 3	$\min\left(R_{eHT};\frac{2}{3}R_{mT}\right)$ 1)	R_{mT}
5		Stainless austenitic steels	$R_{p0.1T}$ or alternatively 2) $1.2 \cdot R_{p0.2T}$	R_{mT}
6a	Bolts	Property Classes 4.6, 5.6, 8.8 und 10.9	–	R_{mT}
6b		Ferritic steels, with the exception of Ser. No. 6a	R_{eHT}	R_{mT}
6c		Austenitic steels	$R_{p0.2T}$	R_{mT}

1) In case the ratio R_{eH} / R_m is equal to or greater than 0.7, the yield strength reference value $R_{v0.2}$ = min {R_{eHT} ; 1.5/2.4 R_m}. If the yield strength is less pronounced, the values for the 0.2 % proof stress shall be applied.

2) If values for $R_{p1,0T}$ are not available.

3) If R_{mT} is not specified in the material standards, then R_m (R_{eHT}/ R_{eH}) may be used alternatively.

Table 4-4: Material property values for the material-dependent analysis in accordance with DIN EN 1993

Ser. No.	**Usage**	**Material** (allocated as listed in **Tables 6-1** through **6-5**)	**Equivalent Yield Stress, $R_{v0.2}$**
1	Component parts and weld seams	Structural steels	R_{eHT}
2		Heat resistant and fine-grained steels	R_{eHT}
3		42CrMo4	$\min\left(R_{eHT};\frac{2}{3}R_m\right)$
4		Ferritic steels, with the exception of Ser. Nos. 1, 2 and 3	$\min\left(R_{eHT};\frac{2}{3}R_{mT}\right)$ 1)
5		Stainless austenitic steels	1.5 / 1.1 $R_{p0,2T}$
6a	Steel castings 2)	Ferritic / martensitic	$\min\left(R_{eHT};\frac{2}{3}R_{mT}\right)$
6b		Austenitic	1.5 / 1.1 $R_{p0.2T}$
7a	Bolts	Property Classes 4.6, 5.6, 8.8 und 10.9	Allowable stresses. cf. **Table 4-8**
7b		Ferritic steels, with the exception of Ser. No. 6a	R_{eHT}
7c		Austenitic steels	$R_{p0.2T}$

1) In case the ratio R_{eH} / R_m is equal to or greater than 0.7, the equivalent yield strength $R_{v0.2}$ = min {R_{eHT} ; 1.5 / 2.4 R_m}. If the yield strength is less pronounced, the values for the 0.2 % proof stress shall be applied.

2) The value reductions of the tensile and bending loadings as specified in **Table 4-6**, Ser. No. 2b shall be observed.

Table 4-5: Material-dependent equivalent yield stress, $R_{v0.2}$

Ser. No.	Types of Stress			Allowable Stresses (in relation to $R_{v0.2}$)			
				H	HZ	HS1	HS2/ HS3
1	Compression, bending compression (certification of stability)			0.58	0.66	0.75	0.8
2a	Tension and bending tension, compression, bending compression (stress analysis)			0.66 [1]	0.75 [1]	0.85	1.0
2b	Tension and bending tension in steel castings	Ferritic and martensitic steel castings		0.50	0.58	0.65	0.75
		Austenitic steel castings		0.37	0.42	0.48	0.55
3	Shear stress			0.38	0.43	0.50	0.58
4	Reference stress			0.66 [2]	0.75 [2]	0.85 [2]	1.0
5	Allowable bearing pressure [4] for these bolted connections and material thicknesses $\geq$ 3 mm	SL	Bolts (DIN 7990), high-strength bolts (DIN EN 14399-4) or countersunk head bolts (DIN 7969) Bore hole tolerance 0.3 mm $< \Delta d \leq$ 2 mm – without pre-loading [3]	1.17	1.33	1.50	1.75
6		SL	High-strength bolts (DIN EN 14399-4) Bore hole tolerance 0.3 mm $< \Delta d \leq$ 2 mm – not systematic pre-loading: $\geq 0.5 \cdot F_V$	1.58	1.80	2.10	2.4
7		SLP	Fit bolts (DIN 7968) Bore hole tolerance $\Delta d \leq$ 0.3 mm – without pre-loading	1.33	1.50	1.75	2.0
8		SLP	High-strength fit bolts Bore hole tolerance $\Delta d \leq$ 0.3 mm – not systematic pre-loading: $\geq 0.5 \cdot F_V$	1.75	1.96	2.25	2.6
9		GV, GVP	High-strength bolts [5] - bore hole tolerance 0.3 mm $< \Delta d \leq$ 2 mm High-strength fit bolts - bore hole tolerance $\Delta d \leq$ 0.3 mm with pre-load: $1.0 \cdot F_V$	2.00	2.25	2.50	3.0

SL : shear bearing bolted connection
GV : slip-resistant bolted connection
SLP : shear bearing bolted connection with fit bolts
GVP : slip-resistant bolted connection with fit bolts
F_V : pre-load force as specified in **Tables 4-12** and **4-13** for bolt sizes 8.8 and 10.9 respectively; the values, F_V, for other bolt sizes are specified in VDI 2230 Sheet 1

[1] In case of corner stresses due to two-axial bending (local stress amplification), 10 % higher values are allowed (see Appendix E, Section E 2.6).

[2] In case of a local stress limitation, 10 % higher values are allowed.

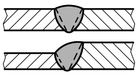
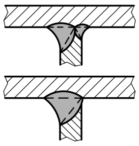
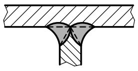
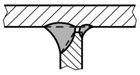
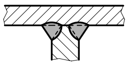
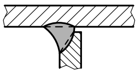
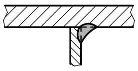
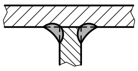
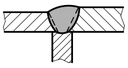
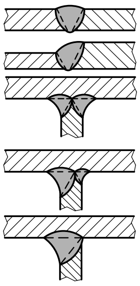
[3] In case of slotted holes, the values shall be applied as 100 % lengthwise and as 70 % crosswise.

[4] Edge distance: in direction of force $2d \leq e \leq \min\{3d; 6t\}$
transverse to direction of force $1.5d \leq e \leq \min\{3d; 6t\}$

Hole spacing: $3d \leq e \leq \min\{6d; 12t\}$
with edge distance (e), hole diameter (d) and smallest sheet thickness (t).

[5] In See Section 4.1.6, para. (4)

Table 4-6: Allowable stresses (in relation to the equivalent yield stress, $R_{v0.2}$, listed in **Table 4-5**) for component parts – with their dependence on the types of stress and load cases

Ser. No.	Type of Weld Seam			Type of Stress	Weld Quality	**S235 (St37) and P265GH (H II) [S355 (St52)] and <Others>** (ferritic and martensitic steel castings) {austenitic steel castings}			
						H	**HZ**	**HS1**	**HS2/HS3**
1a	Full-penetration welds	Butt welds		Compression, bending compression	All weld qualities	0.66 [0.66] <0.66> (0.66) {0.66}	0.75 [0.75] <0.75> (0.75) {0.75}	0.85 [0.85] <0.85> (0.85) {0.85}	1.00 [1.00] <1.00> (1.00) {1.00}
1b		Single bevel groove weld		Tension, bending tension, reference value	Certified weld quality 1)	0.66 [0.66] <0.66> (0.50) {0.37}	0.75 [0.75] <0.75> (0.58) {0.42}	0.85 [0.85] <0.85> (0.65) {0.48}	1.00 [1.00] <1.00> (0.75) {0.55}
1c		Double bevel groove weld			Weld quality not certified	0.56 [0.47] <0.47> (0.35) {0.26}	0.63 [0.53] <0.53> (0.40) {0.29}	0.70 [0.60] <0.57> (0.43) {0.31}	0.84 [0.71] <0.63> (0.48) {0.35}
2a	Not fully penetrating welds	Half-Y welds		Compression, bending compression	All weld qualities	0.66 [0.66] <0.66> (0.66) {0.66}	0.75 [0.75] <0.75> (0.75) {0.75}	0.85 [0.85] <0.85> (0.85) {0.85}	1.00 [1.00] <1.00> (1.00) {1.00}
2b		Double-Half-Y welds		Tension, bending tension, reference value	All weld qualities	0.56 [0.47] <0.47> (0.35) {0.26}	0.63 [0.53] <0.53> (0.40) {0.29}	0.70 [0.60] <0.57> (0.43) {0.31}	0,84 [0,71] <0,63> (0,48) {0,35}
3a	Fillet welds			All stress types (shear stress cf. Ser. No. 5)	All weld qualities	0,56 [0,47] <0,47> (0,35) {0,26}	0.63 [0.53] <0.53> (0.40) {0.29}	0.70 [0.60] <0.57> (0.43) {0.31}	0.84 [0.71] <0.63> (0.48) {0.35}
3b									
3c									
4a	Three-plate welds			Compression, bending compression	All weld qualities	0,66 [0,66] <0,66>	0.75 [0.75] <0.75>	0.85 [0.85] <0.85>	1.00 [1.00] <1.00>
4b				Tension, bending tension, reference value	Certified weld quality 1)	0,66 [0,66] <0,66>	0.75 [0.75] <0.75>	0.85 [0.85] <0.85>	1.00 [1.00] <1.00>
4c					Weld quality not certified 2)	0,56 [0,47] <0,47>	0.63 [0.53] <0.53>	0.70 [0.60] <0.60>	0.84 [0.71] <0.71>
5	All welds			Shear force in seam direction	All weld qualities	0,56 [0,47] <0,37> 3) (0,35) {0,26}	0.63 [0.53] <0.43> 3) (0.40) {0.29}	0.70 [0.60] <0.47> 3) (0.43) {0.31}	0.84 [0.71] <0.50> 3) (0.48) {0.35}

1) cf. Section 7.9.2.4.3 item b) and Section 7.9.2.4.4 item b)

2) Regarding load transfer in a three-plate weld as specified in Appendix E, **Table E 3-1**, Ser. No. 4b, only the line “Weld quality not certified” (4c) may be applied

3) Unless higher values are certified.

Note: The stresses listed under Ser. Nos. 1 through 4 are all directed perpendicular to the direction of the weld seam.

Table 4-7: Allowable stresses (in relation to the equivalent yield stress, $R_{v0.2}$, listed in **Table 4-5**) for weld seams with their dependence of the type of weld seam, type of stress and the load case

Ser. No.	Property Class	Kind of Stress		Load Case H N/mm²	HZ N/mm²	HS1 N/mm²	HS2/HS3 N/mm²
1	4.6	SL	Shear	112	126	146	168
2			Tension	110	125	143	165
3		SLP	Shear	128	147	166	192
4			Tension	110	125	143	165
5	5.6	SL	Shear	160	184	208	240
6			Tension	150	170	195	225
7		SLP	Shear	160	184	208	240
8			Tension	150	170	195	225
9	8.8	SL	Shear	168	189	218	254
10			Tension	252	287	328	379
11		SLP	Shear	196	224	255	298
12			Tension	252	287	328	379
13	10.9	SL	Shear	240	270	312	360
14			Tension	360	410	468	540
15		SLP	Shear	280	320	364	426
16			Tension	360	410	468	540

Note:

The allowable bearing pressure is obtained from the smaller $R_{v0.2}$ value of the bolt and base material as listed in **Table 4-6**.

Table 4-8: Allowable stresses for bolts of Property Classes 4.6, 5.6, 8.8 or 10.9 at temperatures lower than or equal to 80 °C in dependence of the load cases

Kind of Stress	Material	H	HZ	HS1	HS2 / HS3
		Allowable Stresses in N/mm²			
Compression, bending compression, bending tension, bending	S235	160	180	210	235
	S355	240	270	310	355
Hertzian contact pressure 1)	S235	650	800	890	960
	S355	850	1050	1190	1295
Bearing pressure for hinge pins 2)	S235	210	240	275	320
	S355	320	360	415	480
Kind of stress	**Material**	**Allowable Stresses in N/mm²**			
Compression, bending compression, bending tension, bending	all others	0.67	0.75	0.85	1.00
Hertzian contact pressure 1)	all others	2.40	3.00	3.30	3.60
Bearing pressure for hinge pins 2)	all others	0.90	1.00	1.15	1.33

1) For movable bearings with more than 2 rollers these values shall be reduced to 85 %. Such bearings should, however, be avoided where possible.

2) These values apply only to multiple-shear connections

Table 4-9: Allowable stresses (in relation to the equivalent yield stress, $R_{v0.2}$, listed in **Table 4-5**) for bearing parts and hinged joints

Kind of Stress	Load Case			
	H	HZ	HS1	HS2 / HS3
For bolts with $R_{eH} \le 450$ N/mm^2				
Tension	0.47 $R_{v0.2}$	0.52 $R_{v0.2}$	0.61 $R_{v0.2}$	0.69 $R_{v0.2}$
Shear				
For bolts with $R_{eH} > 450$ N/mm^2				
Tension	0.40 $R_{v0.2}$	0.45 $R_{v0.2}$	0.52 $R_{v0.2}$	0.59 $R_{v0.2}$
Shear	0.26 $R_{v0.2}$	0.30 $R_{v0.2}$	0.34 $R_{v0.2}$	0.40 $R_{v0.2}$

Table 4-10: Allowable stress (in relation to the equivalent yield stress, Rv0.2, listed in **Table 4-5**) for bolts and threaded parts not covered by **Table 4-8**

Bolt Size	Shear Area in mm^2		Core (Root) Cross-Section in mm^2	Stress Cross-Section in mm^2
	Bolts (SL-connection)	Fit bolts (SLP-connection)		
M 12	113	133	76.3	84.3
M 16	201	227	144	157
M 20	314	346	225	245
M 22	380	415	282	303
M 24	452	491	324	353
M 27	573	616	427	459
M 30	707	755	519	561
M 36	1018	1075	759	817

SL-connection – shear bearing bolted connection
SLP-connection – shear bearing bolted connection with fit bolts

Table 4-11: Parameters for the cross-sections of bolts with a metric ISO thread (standard thread)

Bolt Size (8.8)	Pre-load force, F_v, in kN	Allowable Lateral Force in kN						Allowable Tensile Force in kN		
		Pre-loaded slip-resistant bolted connection (GV)			Pre-loaded slip-resistant bolted connection with fit bolts (GVP)			GV and GVP		
		H	HZ/HS1	HS2/HS3	H	HZ/HS1	HS2/HS3	H	HZ/HS1	HS2/HS3
M 12	35	14	15.8	17.5	27	30.5	39.2	24.5	28	30.8
M 16	70	28	31.9	35	50.4	57.4	67.2	49	56	61.6
M 20	110	44.8	50.8	56	78.8	89.6	102	78.4	89.6	98.7
M 22	130	53.2	60.6	66.5	93.8	107	122	93.1	106	117
M 24	150	61.6	70	77	110	125	145	108	123	136
M 27	200	81.2	92.4	102	141	161	181	142	162	179
M 30	245	98	111	123	172	196	223	172	196	216
M 36	355	143	162	179	248	283	316	250	286	314

Table 4-12: Allowable forces per bolt and friction surface in case of pre-loaded connections with bolts of **Property Class 8.8**

Bolt Size (10.9)	**Pre-load force, F_v, in kN**	**Allowable Lateral Force in kN**						**Allowable Tensile Force in kN**		
		Pre-loaded slip-resistant bolted connection (GV)			**Pre-loaded slip-resistant bolted connection with fit bolts (GVP)**			**GV and GVP**		
		H	HZ/HS1	HS2/HS3	H	HZ/HS1	HS2/HS3	H	HZ/HS1	HS2/HS3
M 12	50	20	22.5	25	38.5	43.5	56	35	40	44
M 16	100	40	45.5	50	72	82	96	70	80	88
M 20	160	64	72.5	80	112.5	128	146	112	128	141
M 22	190	76	86.5	95	134	153	174	133	152	167
M 24	220	88	100	110	156.5	178.5	207	154	176	194
M 27	290	116	132	145	202	230.5	258	203	232	255
M 30	350	140	159	175	245.5	280	318	245	280	308
M 36	510	204	232	255	354.5	404	451	357	408	449

Table 4-13: Allowable forces per bolt and friction surface in case of pre-loaded connections with bolts of **Property Class 10.9**

Load Cases	P_m	P_l, $(P_m + P_b)$ or $(P_l + P_b)$	$P_m + P_b + Q$ or $P_l + P_b + Q$
H	$1.00 \cdot S_m$	$1.20 \cdot S_m$	$2.50 \cdot S_m$ [1)]
HZ	$1.15 \cdot S_m$	$1.38 \cdot S_m$	$2.88 \cdot S_m$ [1)]
HS1	$1.30 \cdot S_m$	$1.56 \cdot S_m$	–
HS2	$1.50 \cdot S_m$	$1.80 \cdot S_m$	–
HS3	$0.7 \cdot R_{mT}$	R_{mT}	–

[1)] In the case of a certification by means of an elastic fatigue analysis as specified in safety standard KTA 3201.2, Sec. 7.8.3, or the elasto-plastic fatigue analysis as specified in safety standard KTA 3201.2, Sec. 7.8.4, these values may be exceeded.

Table 4-14: Allowable stresses and stress ranges for plate and shell structures

5 Design

5.1 General Requirements

(1) Steel structures shall be designed and constructed observing the acknowledged technical standards (in particular DIN EN 1090 and 1993) and such that the design is ensured to be

a) functional,

b) load conform,

c) appropriate to the material,

d) suited for manufacturing (i.e., fabrication and testing), and

e) maintenance friendly

and that interactions between these requirements are taken into account.

(2) For the component support structures in Steel Construction Category S1 dealt with in the present safety standard, the execution class (EXC) shall be specified by applying the procedure in accordance with DIN EN 1090. Consequence Class CC3 shall be applied to the load-carrying component parts.

5.2 Requirements

(1) The design and construction (bearing conditions, function of supports, mutual interaction) shall be such that the assumptions applied in the design analysis of the component are met.

(2) The design shall consider the possibility for higher-load support conditions due to plastic deformations. Stability-critical designs and constructions that could lead to a sudden failure of the component parts shall be avoided (e.g., by lateral-tilt protection or other stiffeners).

(3) In particular, the load transfer locations and the load bearing locations shall be secured against local instabilities.

(4) Those parts that are required to be removed for maintenance or testing shall normally be possible to disassemble with a least possible radiation exposure of the personnel. The decontamination requirements shall be observed.

(5) A sufficient accessibility of the components and their support structures shall be ensured.

(6) The expansion of the component support structures due to elevated temperatures shall be considered. If necessary, measures allowing for these expansions shall be provided.

(7) The movement of the components due to thermal expansion shall be considered.

(8) The building structure tolerances and anchoring location tolerances shall be considered.

(9) Structural tolerances for new constructions shall be specified in accordance with DIN ISO 2768-1 and DIN ISO 2768-2 and for welded constructions in accordance with DIN EN ISO 13920. The tolerance category shall be chosen with special regard to the individual application. In special cases, adjusted tolerances that are well-founded by design reserves may individually be specified.

(10) Welds welded from both sides shall be preferred to single-side welds. The type of welds shown in **Table 4-7**, Ser. Nos. 3a and 3b, shall only be used for longitudinal fillet welds and for the connection of closed parts. Single-layer welds are only allowed for weld thicknesses less than or equal to 5 mm. The requirements specified under Section 7.9.2.4 shall be noted on the engineering drawing.

(11) In the case of welded component support structures, the testability of the welds (including inservice inspections) shall be considered.

(12) In order to avoid a chipping off of the concrete due to a high thermal input a sufficiently large edge distance shall be observed when welding sections to the anchoring elements; in exceptional cases the thermal input may be reduced by applying only minimally thick weld layers.

(13) In case tensile loading is expected in the through-thickness direction of ferritic steel product forms with a wall thickness (s) larger than 20 mm, the Quality Class Z25 in accordance with DIN EN 10164 shall be verified.

(14) The minimum dimensions for load-bearing parts shall basically be as follows:

a) wall thickness	4 mm,
b) bolts	M 12.

Exceptions are allowed in well-founded cases.

(15) Mechanical connection elements under a predominantly non-static loading shall always be secured. The choice of the securing measure shall take the level of the dynamic loading into account. A regular preloading may be considered as a securing measure. Securing by welds is only allowable in the case of steels and bolt materials that are suited for welding.

(16) At least two bolts shall be used for bolted bar connections.

(17) Slotted holes are allowed; a sufficiently large edge distance shall be observed.

(18) In the case of inclined loading surfaces (e.g., U-sections) the bolt heads or the nuts shall be provided with incline-equalizing – e.g., wedge-shaped – washers.

(19) The data required for tightening preloaded bolts (e.g., necked-down bolts) shall be noted in the construction drawings (e.g., minimum required and maximum allowable torque or rotation angle as well as lubricant).

(20) The thread engagement length of the threaded parts shall normally be 0.8·d taking the material pairing into account; d represents the thread diameter of the threaded part. Shorter thread engagement lengths are allowable in well-founded cases.

Note:

Additional requirements are specified in DIN EN 1992-1-8/NA and VDI 2230 Sheet 1.

(21) In the case of hollow sections, the requirements in accordance with DIN EN 1993-1-8 shall be observed.

(22) Support structures with non-metallic parts including their lubricants shall normally not lose their functional capability during their specified service life.

(23) In the case of sliding supports sufficient clearances shall be provided. An unallowed tilting shall be impossible.

(24) Sliding supports shall be designed and constructed such that unallowed movements are impossible.

(25) Special friction certifications are required for sliding supports with paired austenitic materials.

(26) Paired austenitic materials are allowed in the case of guide bearings for pipelines, provided, the design considers a low surface pressure and sufficient play (2 to 3 mm).

6 Materials and Product Forms

6.1 Allowable materials and product forms

(1) The allowable materials for the various product forms are listed in **Table 6-1** through **Table 6-5**. Other materials than

those listed are allowable, provided, their use for the intended purpose has been agreed upon by the authorized expert.

(2) If a surface protection shall be applied to bolts and nuts, then the bolted connections of Property Classes 8.8 and 10.9 shall be protected against possible damage due to hydrogen embrittlement caused by the surfacing process (e.g., by electro galvanizing).

(3) In case welding tasks are intended for ferritic materials, the carbon equivalent value (CEV) shall be determined and specified (cf. the respective Material Test Sheets – WPB)

(4) For parts not meant to transfer loads and parts of minor importance (e.g. concrete-embedded parts, spacer sheets, washers for bolted connections not regularly preloaded, minor parts, fillers, drainpipes), the materials used shall be in accordance with acknowledged technical standards.

(5) If component parts with an already completed documentation (e.g., storage material) are used, a comparative study shall be performed to show that the requirements of the present safety standard are met.

6.2 Material Testing and Certification

(1) The type and extent of material testing as well as the verification by test certificates in accordance with DIN EN 10204 are specified in the respective Material Test Sheets (WPB), cf. Appendix A; these shall be referenced in the purchase order.

(2) The manufacturer of the component is individually responsible for initiating the execution of the tests and examinations specified in the Material Test Sheets.

(3) In the case of tests and examinations performed by the manufacturer of the product form, this manufacturer shall verify that he has qualified personnel and the required equipment at his disposal for the performance of these tests and examinations. The manufacturer may also employ test equipment and personnel of other organizations, provided, they meet the requirements.

(4) All non-destructive tests performed shall be documented in test reports that shall be countersigned by the authorized inspection representative. All required test results shall be verified in the test certificates.

Ser. No.	WPB	Material Group	Allowable Materials	
1	1.1	Stainless austenitic steels in accordance with DIN EN 10088-2	X5CrNi18-10 X5CrNiMo17-12-2 X6CrNiTi18-10 X6CrNiNb18-10 X6CrNiMoTi17-12-2	(1.4301) (1.4401) (1.4541) (1.4550) (1.4571)
2	1.2	Creep-resisting quenched and tempered steels in accordance with Annex to WPB 1.2	20 MnMoNi 5 5 22 NiMoCr 3 7 1)	(1.6310) (1.6751)
3	1.3	Creep-resisting steels in accordance with DIN EN 10028-2	P265GH P295GH P355GH 16Mo3 13CrMo4-5	(1.0425) (1.0481) (1.0473) (1.5415) (1.7335)
4	1.4	Non-alloy structural steels in accordance with DIN EN 10025-2	S235JR 2) S235J2 S355J2	(1.0038) (1.0117) (1.0577)
5	1.5	Quenched and tempered steels in accordance with 3)		
		DIN EN 10083-2	C35E+QT C45E+QT	(1.1181) (1.1191)
		DIN EN 10083-3	42CrMo4 34CrNiMo6	(1.7225) (1.6582)
6	1.6	Weldable fine-grain structural steels in accordance with		
		DIN EN 10025-3	S275N S355N	(1.0490) (1.0545)
		DIN EN 10025-4	S275M S355M	(1.8818) (1.8823)

1) The requirements for the steel 22 NiMoCr 3 7 shall be specified within the framework of design review.

2) The steel S235JR shall not be used if improved characteristics must be verified in the through-thickness direction as specified in Section 5.2, paragraph (13).

3) A welding-related processing of these steels is not allowed.

Table 6-1: Materials allowed for flat and long product forms (plates, strips, wide flats, sections, rods)

Ser. No.	WPB	Material Group	Allowable Materials
1	2.1	Stainless austenitic steels in accordance with DIN EN 10296-2 or DIN EN 10297-2	X5CrNi18-10 (1.4301) X5CrNiMo17-12-2 (1.4401) X6CrNiTi18-10 (1.4541) X6CrNiNb18-10 (1.4550) X6CrNiMoTi17-12-2 (1.4571)
2	2.2	Non-alloy structural steels in accordance with DIN EN 10219-1	S235JRH (1.0039) S355J2H (1.0576)
3	2.3	Creep-resisting steels in accordance with DIN EN 10216-2	P235GH (1.0345) P265GH (1.0425) 16Mo3 (1.5415) 10CrMo9-10 (1.7380) 13CrMo4-5 (1.7335)
4	2.4	Non-alloy structural steels in accordance with DIN EN 10210-1	S235JRH (1.0039) S275J2H (1.0138) S355J2H (1.0576)
5	2.5	Creep-resisting quenched and tempered structural steel in accordance with Annex to WPB 2.5	20 MnMoNi 5 5 (1.6310)
6	2.6	Creep-resisting fine-grained structural steel in accordance with DIN EN 10216-3 or DIN EN 10217-3	P460NH (1.8935)
7	2.7	Creep-resisting quenched and tempered steel in accordance with DIN EN 10216-2	15NiCuMoNb5-6-4 (1.6368)

Table 6-2: Materials allowed for seamless pipes, welded pipes and hollow sections

Ser. No.	WPB	Material Group	Allowable Materials
1	3.1	Stainless austenitic steels in accordance with DIN EN 10250-4 or DIN EN 10088-3	X5CrNi18-10 (1.4301) X5CrNiMo17-12-2 (1.4401) X6CrNiTi18-10 (1.4541) X6CrNiNb18-10 (1.4550) X6CrNiMoTi17-12-2 (1.4571)
2	3.2	Creep-resisting quenched and tempered steels in accordance with Annex to WPB 3.2	20 MnMoNi 5 5 (1.6310) 22 NiMoCr 3 7 1) (1.6751)
3	3.3	Non-alloy structural steels in accordance with DIN EN 10250-2	S235JRG2 (1.0038) S235J2G3 (1.0116) S355J2G3 (1.0570)
4	3.4	Creep-resisting steels in accordance with DIN EN 10222-2 or DIN EN 10273	P250GH (1.0460) 16Mo3 (1.5415)
5	3.5	Quenched and tempered steels in accordance with 2)	
		DIN EN 10083-2, DIN EN 10269 or SEW 550 3)	C45E+QT (1.1191)
		DIN EN 10083-3, DIN EN 10269 or SEW 550 3)	34CrNiMo6 (1.6582) 42CrMo4 (1.7225)
		DIN EN 10269	21CrMoV5-7 (1.7709)
6	3.6	High-strength quenched and tempered steels in accordance with Annex to WPB 3.6	20 NiCrMo 14 5 (1.6772) 26 NiCrMo 14 6 (1.6958)

1) The requirements for the steel 22 NiMoCr 3 7 shall be specified within the framework of design review.

2) A weld-related processing of these steels is not allowed.

3) SEW 550 shall be used for larger forgings.

Table 6-3: Allowable materials for forgings (rods, plates, other forgings) and rolled bars

Ser. No.	WPB	Material Group	Allowable Materials
1	4.1	Bolts equal to or smaller than M39 in accordance with DIN EN ISO 898-1 Nuts in accordance with DIN EN ISO 898-2 and Table WPB 4.1-1 of Material Test Sheet WPB 4.1	Property Classes 4.6, 5.6, 8.8 and 10.9 Property Classes 5, 8 und 10
2	4.2	High-strength pre-loadable bolted connections equal to or smaller than M39 and assemblies (= bolts, nuts, washers) (HV/HR-Systems) equal to or smaller than M36 Bolts in accordance with DIN EN ISO 898-1, nuts in accordance with DIN EN ISO 898-2 and washers in accordance with DIN EN 10083-2 Assemblies additionally in accordance with DIN EN 14399-2	Property Classes 8.8 / 8 and 10.9 / 10[1] C45 (1.0503) C45E (1.1191) or harder
3	4.3	Bolts and nuts equal to or smaller than M39 in accordance with DIN EN ISO 3506-1 and DIN EN ISO 3506-2	Property Classes 50, 70 oder 80 Steel types A2, A3, A4 und A5
4	4.4	Rods as well as the bolts and nuts machined from these rods with rolled or cut threads without a subsequent heat treatment – made from stainless austenitic steels in accordance with DIN EN 10088-3	X6CrNiTi18-10 (1.4541) X6CrNiNb18-10 (1.4550) X6CrNiMoTi17-12-2 (1.4571)
5	4.5	Rods as well as the bolts and nuts machined from these rods with rolled or cut threads without a subsequent heat treatment – made from quenched and tempered steels in accordance with DIN EN 10269, DIN EN 10083-2 or DIN EN 10083-3 in accordance with Annex to WPB 4.5	C35E (1.1181) C45E (1.1191) X19CrMoNbVN-11-1 (1.4913) 34CrNiMo6 (1.6582) 25CrMo4 (1.7218) 42CrMo4 (1.7225) 21CrMoV5-7 (1.7709) 40CrMoV4-6 (1.7711) 26 NiCrMo 14 6 (1.6958) 20 NiCrMo 14 5 (1.6772)
6	4.6	Rods as well as the bolts and nuts fabricated from these rods with rolled or cut threads and with a subsequent heat treatment – made from creep-resisting quenched and tempered steels in accordance with DIN EN 10269	C35E (1.1181) 25CrMo4 (1.7218) 21CrMoV5-7 (1.7709) 40CrMoV4-6 (1.7711) X19CrMoNbVN-11-1 (1.4913)

[1] High-strength pre-loadable bolted connections of Property Classes 8.8 / 8 und 10.9 / 10 for design temperatures higher than 100 °C, cf. Section 4.1.4, para. (8).

Table 6-4: Materials allowed for bolts or pins, nuts and washers

Ser. No.	WPB	Material Group	Allowable Materials
1	5.1	Ferritic steel castings in accordance with DIN EN 10213 and Annex to WPB 5.1	GS-18 NiMoCr 3 7 (1.6761) GP240GH (1.0619)
2	5.2	Austenitic and martensitic steel castings in accordance with DIN EN 10213	GX5CrNiNb19-11 (1.4552) GX4CrNi13-4 (1.4317)

Table 6-5: Materials allowed for steel castings

7 Manufacturing

7.1 General Requirements

(1) The manufacturer shall ensure the proper performance of all necessary work with due consideration of the requirements specified in safety standard KTA 1401 and the present safety standard.

(2) The manufacturer shall have proper facilities and qualified personnel at his disposal such that the product forms can be properly fabricated, tested and transported. Facilities and personnel of other organizations that are certified to meet these requirements may also be employed.

(3) The manufacturer shall ensure that his products have the required quality. The manufacturer shall employ an effective quality management system (e.g., certified in accordance with DIN EN ISO 9001). The manufacturer shall employ responsible and expert supervisory personnel for all fabrication, test and inspection steps within their range of activity.

(4) The certification of the prerequisites shall be submitted to the authorized expert.

7.2 Suitability of the Manufacturer

The manufacturer shall be verified as having at his disposal a plant-internal fabrication control in accordance with DIN EN 1090-1, Appendix B. The requirements in accordance with DIN EN 1090-2, Appendix A (Table A.3) shall be met regarding the specified execution class.

7.3 Personnel Requirements

7.3.1 Welding supervision

(1) The responsible welding supervisory personnel shall be employees of the manufacturing plant. Their duty shall be to ensure that the technical standards are fulfilled.

(2) If in a manufacturing plant more than one person is assigned to be welding supervisor the areas of responsibility of the individual persons shall be clearly defined with regard to each other.

(3) The welding supervisor superordinate responsibility in accordance with DIN EN ISO 14731 shall have the qualification of a welding engineer.

(4) Welding technicians and welding experts – trained and tested in accordance with DIN EN ISO 14731 – as well as further personnel that due to their experience are suited for certain delimited applications (e.g. welding apprentices) may be deployed in support of the responsible welding supervisor (e.g., as delegates or deputies). These personnel shall normally be employees of the manufacturing plant.

7.3.2 Welders

Constructions may only be welded by welders with a valid test certificate in accordance with DIN EN ISO 9606-1.

7.3.3 Operators of fully mechanized welding equipment

(1) The operators of fully mechanized welding equipment shall be verified in accordance with DIN EN ISO 14732 to prove that they possess sufficient knowledge to operate the equipment. This certification shall be rendered by suitable weld test coupons or by means of welding procedure qualification tests or production weld tests.

(2) The manufacturer shall issue an informal certificate showing when and by which weld test coupons or by which welding procedure qualification tests or production weld tests the operating personnel has obtained their qualification.

7.3.4 Test personnel

The test personnel shall meet the requirements in accordance with DIN EN 1090-2. In the case of the tests as specified in Appendix B, the requirements of Section B 2.1 shall be applied.

7.4 Welding of Component Parts

7.4.1 General requirements

(1) The welding of steel shall be performed observing the general requirements in accordance with DIN EN 1011-1 together with DIN EN 1011-2 for ferritic steels or in accordance with DIN EN 1011-3 for stainless steels.

(2) In addition to the requirements specified in this section, the requirements in accordance with DIN EN 1090-2 shall also be observed.

(3) The welding process may not be started before the following prerequisites are fulfilled:

a) All tests and inspections of the product forms and component parts including tests and inspections of the weld seam area and the weld seam flanks, if so required, shall have been successfully completed and certified.

b) All documents necessary for the welding (e.g., work instruction of the manufacturer, welding schedules, possibly heat treatment plans or final inspection plans and drawings) shall have been provided in close vicinity of the workplace.

(4) The weld seam shall be prepared observing the requirements in accordance with DIN EN 1011-1.

(5) The suitability of the welding process shall be verified by welding procedure qualification tests in accordance with DIN EN ISO 15607, Sec. 6.2. The welding procedure qualification tests shall also fulfill the requirements specified under Section 7.4.2. The production weld tests shall fulfill the requirements specified under Section 7.4.3.

7.4.2 Welding procedure qualification tests

7.4.2.1 General requirements

(1) Welding procedures shall be qualified by fulfilling the requirements in accordance with DIN EN 1090-2, Tables 12 and 13. In case of qualifying the welding procedures in accordance with DIN EN 1090-2, Table 12, only welding procedure qualification tests in accordance with DIN EN ISO 15614-1 or pre-production weld tests in accordance with DIN EN ISO 15613 may be used.

(2) Welding procedure qualification tests shall be performed before beginning with fabrication and shall be performed with participation of the authorized expert or an approved inspection body.

(3) If, for repair weldings on the component part, a modified welding procedure is necessary then an additional welding procedure qualification test shall be performed. This test may be performed in the course of the welding procedure qualification test for the component welding.

(4) A report on the welding procedure qualification test shall be written by the authorized expert or the participating approved inspection body; this report shall include the range of application of the test and the conditions for fabricating the test coupons. The test results shall be documented.

(5) Welding procedure qualification tests performed in accordance with AD 2000-Merkblatt HP 2/1 shall meet the requirements under paragraph (1).

(6) The welding procedure qualification test valid for the manufacturing plant is also valid for welding tasks performed outside of the plant, e.g., at installation sites.

(7) The requirements specified in **Table 7-1** and those in accordance with DIN EN 1011-2 shall be observed when specifying preheat temperatures.

7.4.2.2 Range of application

7.4.2.2.1 Base material

The welding procedure qualification test shall cover all base materials used in the test. If base materials of other compositions are to be included, this shall be documented in the report on the welding procedure qualification test.

7.4.2.2.2 Weld filler materials and consumables

(1) The welding procedure qualification test shall cover the weld filler materials used (e.g., rod electrode including type of coating, strip/wire electrode, weld wire, weld rod) and consumables (inert gasses, fluxes). A change to a different brand name does not require a renewed welding procedure qualification test, provided, the weld filler materials are verified by their qualification tests as being suited for the same range of application,

(2) For inert gasses, a change to another supplier is allowed.

(3) For submerged-arc welding, the same electrode-flux combination of the welding procedure qualification test shall be applied; however, an exchange of wire or strip electrodes with a comparable chemical composition is allowable irrespective of the manufacturer.

(4) An exchange of the type of flux used during welding procedure qualification test is only allowed upon agreement by the authorized expert.

7.4.2.2.3 Heat treatment

The overall annealing duration in the course of the welding procedure qualification test, calculated as the sum of intermediate stress-relievings above 450 °C and final stress-relief heat treatments, may be exceeded by up to 20% when annealing the component parts.

7.4.2.2.4 Period of validity

(1) The period of validity of a welding procedure qualification test shall be 24 months beginning with the date of confirmation by the authorized expert or the participating approved inspection body.

(2) The period of validity may be extended by an additional period of 36 months, provided, within the period of validity, a corresponding production weld test has been performed.

7.4.3 Production weld tests

In the case of steel grades in a strength range above S355, a production weld test is required whenever fabrication is interrupted for longer than one year. The associated tests and examination shall include:

a) visual examination,

b) radiographic examination or ultrasonic testing (not required in case of fillet welds),

c) surface inspection by the magnetic particle or liquid penetrant testing procedure,

d) macro-section examination, and

e) hardness test.

7.4.4 Prerequisites for executing welding tasks

7.4.4.1 General requirements

(1) Welding procedure schedules (WPS) shall be prepared for all welding tasks and shall be based on the welding conditions specified in the welding procedure qualification test.

(2) The weld filler materials and consumables to be used shall have been approved for the base material and shall have been suitability tested in accordance with VdTÜV-Merkblatt 1153.

(3) The storing of weld filler materials and consumables shall meet the requirements of the manufacturer of these materials. The weld filler materials and consumables shall be stored in a dry storage facility.

(4) Alkaline-coated rod electrodes shall be processed in accordance with the requirements of their manufacturer.

(5) The welding equipment for mechanized welding procedures shall be equipped with current and voltage measuring instruments.

7.4.4.2 Preheating

(1) The preheating temperature shall be as specified in the welding procedure schedules (WPS).

(2) The preheating procedure shall be monitored as specified in accordance with DIN EN ISO 13916.

7.4.4.3 Welding in cold-formed zones

The requirements for welding in cold-formed zones shall be applied as specified in accordance with DIN EN 1993-1-8.

7.4.5 Acceptance criteria for weld seams

The acceptance criteria for weld seam irregularities shall be applied as specified in accordance with DIN EN 1090-2, Sec. 7.6.

7.4.6 Welding record

(1) Welds on austenitic steels and high-strength fine-grain steels shall be recorded.

(2) The welding record shall document that the conditions of the design-reviewed welding procedure schedule have been satisfied. The welding record shall indicate in which cases and for what reason deviations from the welding procedure schedule had to be performed. In addition, any unplanned interruptions of the welding tasks as well as other irregularities shall be documented.

(3) The welding record shall be kept by the welding supervisor. In the case of long-duration weldings at least two entries per work shift shall be made within a single welding sequence.

(4) The inspections performed as specified in the final inspection plan shall be clearly marked in the welding record.

(5) Forms shall be used for the welding record (exemplary form: see **Figure 7-1**) and shall be filled in as specified in the welding procedure schedule.

(6) Summary certificate summarizing the individual welding inspections recorded in welding records as in **Figure 7-1** are allowed, provided; the original welding records were signed by the

authorized expert. These summary certificates – instead of the individual welding records – shall become part of the final document file.

(7) Upon completion of the welding tasks, the welding record shall become part of the documentation at the manufacturer.

7.4.7 Temporary welds

Temporary welds shall be included in the welding procedure schedule. They shall be performed as specified in accordance with SEW 088, Sec. 7.2.

7.5 Forming or Shaping of Component Parts

7.5.1 General requirements

Forming or shaping tasks shall be performed in accordance with technical standards or other documents and the procedure shall be agreed upon by the authorized expert.

7.5.2 Certification

(1) The forming or shaping tasks performed shall be verified by the manufacturer this certificate documenting

a) the heating and forming or shaping facilities,

b) the individual forming or shaping steps, and

c) the heat control and its monitoring during forming or shaping.

(2) In the case of component parts that will be normalized or hardened and tempered after forming or shaping, the individual forming or shaping steps do not need to be documented.

7.6 Heat Treatment

7.6.1 General requirements

Note:

The quality requirements regarding the heat treatments are detailed in DIN EN ISO 17663.

(1) Heat treatment plans shall be prepared for all heat treatments to be performed

(2) These plans shall normally, where required, include the following information:

a) the type of heat treatment, e.g. normalizing, quenching and tempering, tempering, stress relieving, solution annealing, stabilizing, soaking,

b) heat treatment facility (furnace or local),

c) time-temperature sequence (heating, holding, cooling),

d) cooling fluids,

e) type and extent of temperature measurements,

f) position of the component parts or test coupons in the heat treatment facility.

(3) Preheating and the post-weld heat treatments are not considered as heat treatment.

(4) The manufacturer shall check the functioning of the heat treatment facilities at regular intervals. The documentation of these checks shall be kept on file.

(5) The necessity and type of post-weld heat treatment shall be specified in the final inspection plan in dependence of the material and thickness of the component.

7.6.2 Certifications

(1) The manufacturer shall document the adherence to the heat treatment plan as specified under Section 7.6.1.

(2) Deviations from the heat treatment plan shall be recorded. The acceptability of such deviations shall be agreed upon between manufacturer and authorized expert.

7.7 Marking

(1) The constructions shall be unambiguously, correctly and indelibly marked including the following information:

a) system designation (e.g., in accordance with the Identification System for Power Plants – KKS),

b) manufacturer.

(2) Regarding their identifiability, the component parts of the construction shall be marked as specified in the Material Test Sheets and in accordance with DIN EN 1090-2, Sec. 6.2.

(3) In case product forms certified by Inspection Certificate 3.1 in accordance with DIN EN 10204 are separated into parts, the identification marking shall be transferred to the individual parts. The marking shall be transferred ensuring that the material certificates can be allocated to the parts. The authorization for transferring the identification markings shall be specified within the framework of the of plant-internal product supervision system.

7.8 Corrosion Protection and Cleanliness

(1) The requirements in accordance with DIN EN 1090-2 shall be applied. In certain cases, additional measures may be required.

(2) The component parts and their surfaces shall normally be such as to allow their decontamination.

(3) Corrosion-effecting contaminations (e.g. chloride-containing or ferritic) shall be avoided on surfaces of stainless steels during fabrication, transport, storage and assembly.

7.9 Final Inspection

7.9.1 General requirements

(1) The extent of inspections and tests as well as the participation of the authorized expert and the purchaser in such tests and inspections shall be specified in the final inspection plan observing the requirements of Sections 6 and 7 as well as of the following Sections 7.9.2 and 7.9.3.

(2) The final inspections shall be confirmed in the course of manufacturing; summary certifications are allowed.

7.9.2 Extent and execution

7.9.2.1 Receiving inspection

During the receiving inspections, the following points shall be checked:

a) stampings and identification markings,

b) dimensions and possible transportation damage,

c) material certificates of the product forms.

7.9.2.2 Inspections prior to beginning of fabrication

(1) Prior to further processing, the product forms shall be checked as follows:

a) checking the transfer of identification markings a specified in the respective Material Test Sheets,

b) checking the list containing the names of the persons entitled to transfer identification markings,

c) transfer of the identification markings for further processing – only in the case of Inspection Certificate 3.1 in accordance with DIN EN 10204.

(2) The validity of the welding procedure qualification tests by the manufacturer as specified under Section 7.4 shall be checked.

(3) The validity of the welders' qualification test certificates shall be checked.

(4) The annealing facilities and welding equipment to be employed shall be checked.

7.9.2.3 In-process inspections

(1) The validity of the production weld tests, where required, shall be checked.

(2) The storage and drying of weld filler materials and consumables shall be checked.

(3) The test sequence during specified heat treatments in accordance with the welding procedure and heat treatment plans shall be observed and verified by:

a) checking the preheating temperature (if preheating is performed),

b) checking the welding process,

c) checking the root layer (as far as possible) by visual examination,

d) checking the heat treatment of welds (where heat treatment is specified in the welding procedure specification).

7.9.2.4 Extent of the non-destructive tests

7.9.2.4.1 Tests under the individual responsibility of the manufacturer

The following non-destructive tests shall be performed:

a) The weld seam areas of sheets and the weld fusion faces shall be non-destructively tested under the individual responsibility of the manufacturer. In the case of fine grain structural steels (as listed in **Table 6-1**), the freedom from cracks shall be verified using a suitable surface inspection procedure as specified under Appendix B.

b) Unless already performed at the product form manufacturer, a check for laminar imperfections in product forms of ferritic steels which are subject to tests and examination as specified under Section 5.2, para. (13), shall be performed under the individual responsibility of the manufacturer as specified in the respective Material Test Sheet. The execution and evaluation shall be performed as specified under Appendix B.

7.9.2.4.2 Visual inspections

The weld seams shall be subjected to visual inspections in accordance with DIN EN ISO 17637. The evaluation shall be performed in accordance with DIN EN ISO 5817 with the quality classes in accordance with DIN EN 1090-2. The visual inspection shall be carried out to the extent as follows:

Manufacturer:	100 %.
Authorized expert:	25 % - at least.

7.9.2.4.3 Surface inspection

(1) The surface inspection shall be performed using a suitable procedure as specified under Appendix B.

(2) Depending of the certification procedure as specified under Section 4, the following tests shall be performed:

a) The extent of non-destructive testing of the weld seams in the load path specified under Section 4.2 shall be as specified in accordance with DIN EN 1090-2 for the execution class as specified under Section 5.1, para. (2). The participation of the authorized expert in these tests shall be specified within the framework of design review of the manufacturing documents.

b) In the case of weld seams, the weld quality of which must be verified as listed under **Table 4-7**, Section 4.3, the extent of non-destructive testing shall be as listed in **Table 7-2**.

7.9.2.4.4 Volumetric testing

(1) Volumetric testing shall normally be performed using the ultrasonic or the radiographic procedure. The execution and evaluation shall be performed as specified under Appendix B.

(2) Depending of the certification procedure as specified under Section 4, the following tests shall be performed:

a) The extent of non-destructive testing of the weld seams in the load path specified under Section 4.2 shall be as specified in accordance with DIN EN 1090-2 for the execution class as specified under Section 5.1, para. (2). The participation of the authorized expert in these tests shall be specified within the framework of design review of the manufacturing documents.

b) In the case of weld seams, the weld quality of which must be verified as listed under **Table 4-7**, Section 4.3, the extent of non-destructive testing shall be as listed in **Table 7-2**.

(3) Ferritic attachment welds shall preferably be subjected to an ultrasonic testing. An additional ultrasonic testing for underbead cracks is required in the case of steels with a yield strength at room temperature $R_{p0,2}$ larger than 355 N/mm^2.

7.9.2.5 Execution of non-destructive tests

Non-destructive testing shall be executed as specified in **Appendix B**.

7.9.2.6 Checking of the finished component support structures

(1) For the acceptance test, the final inspection plans shall be submitted to the authorized expert. The final inspection plans as well as the lists of materials shall be signed and stamped by the authorized expert upon acceptance of the component parts.

(2) The finished component parts shall be subjected to the following checks:

a) checking the conformity with the design review documents (e.g. dimensional check),

b) checking the stamping of the individual parts,

c) checking the adherence to the specified bolt pre-tensioning,

d) checking the coating where specified,

e) checking the completeness of the documentation.

7.9.3 Certification of inspections and checks

(1) The performance of the tests and inspections shall be documented in the test schedule by corresponding stampings. Any deviations shall be recorded.

(2) The numbering of the test records shall be such that mix-ups can be ruled out.

8 Inservice Inspections

(1) Component support structures that must be flexible for their proper functioning shall be subjected to visual examinations within the framework of recurrent walk-through inspections.

(2) The required inservice inspections shall be specified in the testing manual of the power plant. In particular, the extent of testing, the testing intervals, the execution with the help of checklists, the responsibilities for the tests, and the type of documentation shall be specified. With regard to the specification of the extent of testing, footnote 5 of **Table 1-1** shall be observed.

Note:

Detailed requirements regarding inservice inspections are specified in safety standards KTA 3201.4 and KTA 3205.3.

(3) If spring hangers, shock absorbers and vibration dampers are fabricated according to the requirements of the present safety standard, they shall be subjected to inservice inspections as specified in safety standard KTA 3205.3

	Welding Record (SPK)	**SPK** Page: of:
1 Power Plant / Project:	Component:	Subassembly:
KKS 1):	PFP / WPP / Quality Class 2):	Test No.:
Manufacturer:	Order No.:	Marking No. 3):

Welding Procedure Specification (WPS): Weld Location No.:

2		Date: Time:												
3		Welder ID:												
4		Weld Sequence:												
5	Weld Additive	Dimension: [mm]												
		Trademark												
		Melt No.												
		Powder / Batch No.												
6	Weld Seam Actual Data	Position												
		Pre-heating / Interpass Temperature [°C]												
		Weld Additive No.												
		Current [A]												
		Voltage [V]												
		Welding Velocity ① [mm/min]												
		Welding Nozzle No. ①												
		Area (cf. Sketch) ①												
		Bead No. ②												
		Oscillation Width ②												
		Layer No. ②												
7		Remarks:												
	Supervision	Manufacturer (H)												
		Authorized Expert (S)												

① Only for mechanized welding ② Only for manual welding

[1] KKS = Identification System for Power Plants

[2] cross out whichever does not apply

[3] e.g., Melt No. or Coupon No. (not required in connection with PFP [test sequence plan] or WPP [material testing and sampling plan])

Figure 7-1: Sample form of a welding record

	S235 (St 37), P265GH (HII)			**S355 (St 52) and other ferritic steels**		
	Plate Thickness (t) in mm					
	≤ 20	20 < t ≤ 40	> 40	≤ 20	20 < t ≤ 40	> 40
Without preheating	—	Z15 [1]	Z25 [1]	—	Z25 [1]	Z25 [1]
With preheating at about 120 °C ± 20 K	—	—	Z25	—	Z15	Z25

[1] Welding of S355J2+N and other ferritic steels with t > 25 mm, provided, the steels were preheated to 120 °C .

Table 7-1: Required Quality Class for ferritic steel plates stressed in the through-thickness direction

Type of Test	S235 (St 37) S355 (St 52) P265GH (HII) 16Mo3 (15 Mo 3) P235GH (St 35.8)	High-strength, quenched and tempered steels: 15 NiCuMoNb 5-6-4 (15 NiCuMoNb 5) 20 MnMoNi 5 5 22 NiMoCr 3 7	Other Materials
Volumetric testing with ultrasonic or radiographic procedures	Manufacturer: 10 % Authorized expert: randomly	Manufacturer: 100 % Authorized expert: at least 25 %	Manufacturer: 25 % Authorized expert: at least 10 %
Surface inspection	Manufacturer: 10 % Authorized expert: randomly	Manufacturer: 100 % Authorized expert: at least 25 %	Manufacturer: 25 % Authorized expert: at least 10 %

Table 7-2: Extent of non-destructive testing of weld seams where the weld quality has to be verified as specified in **Table 4-7**

Appendix A

Material Test Sheets (WPB)

Listing of the Material Test Sheets (WPB)

WPB	Material Test Sheets for flat and long product forms
1.1	Plates and sheets – made from stainless austenitic steels
1.2	Plates and sheets – made from the creep-resisting, high-temperature quenched and tempered steels 20 MnMoNi 5 5 and 22 NiMoCr 3 7
1.3	Flat products (plates, sheets and bands) – made from creep resisting, quenched and tempered steels
1.4	Flat and long products (plates, sheets, bands, wide flats, sections, rods and bars) – made from non-alloy structural steels
1.5	Flat products (plates, sheets, bands and wide flats) – made from quenched and tempered steels
1.6	Flat and long products (plates, sheets, bands, wide flats, sections, rods and bars) – made from weldable fine-grain structural steels

WPB	Material Test Sheets for seamless or welded pipes and hollow sections
2.1	Seamless and welded pipes – made from stainless austenitic steels
2.2	Cold-formed welded hollow sections – made from non-alloy structural steels
2.3	Seamless pipes – made from creep-resisting, quenched and tempered steels
2.4	Hot manufactured seamless or welded hollow sections – made from non-alloy structural steels
2.5	Seamless rolled or pressed pipes – made from the creep-resisting, quenched and tempered steel 20 MnMoNi 5 5
2.6	Seamless pipes and welded pipes – made from the creep-resisting, fine-grained structural steel P460NH
2.7	Seamless pipes with a nominal wall thickness (s) equal to or smaller than 80 mm – made from the creep-resisting, quenched and tempered steel 15 NiCuMoNb 5-6-4

WPB	Material Test Sheets for forgings (rods and bars, plates and other forgings), rolled rods and bars
3.1	Forgings (rods, plates or other forgings) and forged bars – made from stainless austenitic steels
3.2	Forgings (rods, plates or other forgings) – made from the creep-resisting, quenched and tempered steels 20 MnMoNi 5 5 and 22 NiMoCr 3 7
3.3	Forgings (rods, plates or other forgings) – made from non-alloy structural steels
3.4	Forgings (rods, plates or other forgings) and rolled bars – made from creep-resisting weldable steels
3.5	Rod and bars and forgings with and without threaded ends – made from quenched and tempered steels
3.6	Rod and bars and forgings with and without threaded ends – made from the high-strength, quenched and tempered steels 20 NiCrMo 14 5 and 26 NiCrMo 14 6

WPB	Material Test Sheets for bolts, nuts and washers
4.1	Bolts equal to or smaller than M39 and nuts – by their property classes
4.2	Bolts, nuts and washers for high-strength pre-loadable bolted connections equal to or smaller than M39 and for assemblies (Systems HV / HR) equal to or smaller than M36
4.3	Bolts and nuts equal to or smaller than M39 – made from stainless austenitic steels
4.4	Rods as well as bolts and nuts machined from these rods with rolled or cut threads and no subsequent heat treatment – made from stainless austenitic steels
4.5	Rods as well as bolts and nuts machined from these rods with rolled or cut threads and no subsequent heat treatment – made from creep-resisting quenched and tempered steels
4.6	Rods as well as bolts and nuts hot formed from these rods with rolled or cut threads, subsequently heat treated – made from creep-resisting quenched and tempered steels

WPB	Material Test Sheets for steel castings
5.1	Steel castings – made from the quenched and tempered ferritic casting steels GS-18 NiMoCr 3 7 and GP240GH
5.2	Steel castings – made from the stainless austenitic and martensitic casting steels GX5CrNiNb19-11 and GX4CrNi13-4

MATERIAL TEST SHEET (WPB) **WPB 1.1**

Product form: Plates and sheets

Materials: Stainless austenitic steels in accordance with DIN EN 10088-2 [1)]

X5CrNi18-10	(1.4301)
X5CrNiMo17-12-2	(1.4401)
X6CrNiTi18-10	(1.4541)
X6CrNiNb18-10	(1.4550)
X6CrNiMoTi17-12-2	(1.4571)

Requirements: DIN EN 10088-2 [1)] and as specified in this WPB

In the case of a nominal wall thickness s > 75 mm, the requirements for s = 75 mm in accordance with DIN EN 10088-2 shall be applied.

Specimen sampling and extent of testing: DIN EN 10088-2 and as specified in this WPB

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition: Chemical analysis of the melt(s) and information on the melting process.	3.1
2. Attestation of the heat treatment condition	3.1
3. Tensile test at room temperature	3.1
4. Visual examination and dimensional checks Each sheet or plate: Surface condition at least 1E in accordance with DIN EN 10088-2	3.1
5. Materials identification checks Each sheet or plate: by a suitable procedure.	3.1

Marking – in accordance with DIN EN 10088-2

[1)] Sheet and plates made from the steels listed in accordance with DIN EN 10028-7 may be used, provided, the test and inspections and the attestations specified in this WPB are verified.

MATERIAL TEST SHEET (WPB) **WPB 1.2**

Product form: Plates and sheets

Materials: Creep-resisting, high-temperature quenched and tempered steel:
20 MnMoNi 5 5 (1.6310)
22 NiMoCr 3 7 (1.6751)

Requirements:
20 MnMoNi 5 5 as specified in this WPB and the Annex to this WPB
22 NiMoCr 3 7 requirements shall be specified within the framework of design review

Specimen sampling and extent of testing: as specified in this WPB, in the Annex to this WPB and in accordance with DIN EN 10164

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2.	Attestation of the heat treatment condition including data on the heat treatment temperatures, holding times and cooling-down conditions.	3.1
3.	Tensile test at room temperature in accordance with DIN EN ISO 6892-1 For each sampling location specified under Section 2 of the Annex to this WPB. The values to be determined and certified are: $R_{p0,2}$, R_m, A and Z.	3.2
4.	Tensile test at 350 °C in accordance with DIN EN ISO 6892-2 For one sampling location specified under Section 2 of the Annex to this WPB, if the design temperature is higher than 250 °C. The values to be determined and certified are: $R_{p0,2}$, R_m and A.	3.2
5.	Tensile test at room temperature to determine the percentage reduction of area at fracture Each rolled plate: three tensile specimens in the through-thickness direction in accordance with DIN EN 10164. This test shall be performed only if the sheet or plate is intended for welding during further fabrication and if this welding procedure could lead to tensile stressing in the through-thickness direction. Procedure and requirements as specified in Section 5.2, para. (13).	3.2
6.	Notched bar impact test at ±0 °C in accordance with DIN EN ISO 148-1 Performed for each tensile test under No. 3 of this WPB: one set (= three Charpy-V-notch specimens) The value to be determined and certified is: KV_2.	3.2
7.	Ultrasonic testing of the flat product body Each sheet or plate prior to further weld processing, provided, a verification of tensile quality is required under No. 5 of this WPB. Procedure and requirements as specified in DIN EN 10164.	3.1
8.	Visual examination and dimensional checks Each sheet or plate. Unless the purchase order states differently, the following requirements apply: - regarding surface condition, the requirements of Class B, Subgroup 3, in accordance with DIN EN 10163-1 und DIN EN 10163-2, - regarding maximum thickness of the sheets or plates, the requirements of Class B in accordance with DIN EN 10029, - regarding flatness tolerance, the requirements of Class N in accordance with DIN EN 10029.	3.2
9.	Materials identification checks Each sheet or plate: by a suitable procedure.	3.1

Marking – type of steel, melt number, specimen number, identification markings of manufacturer and of authorized expert, Quality Class Z25 (if it was certified)

Annex to Material Test Sheet WPB 1.2

This Annex details the requirements for plates and sheets made from 20 MnMoNi 5 5 as well as for the tests and examinations of the products made from 20 MnMoNi 5 5 and 22 NiMoCr 3 7.

1 Materials Data and Requirements

1.1 Melting Process

The steel shall basically be molten by the electric-arc process or the basic-oxygen process. If other processes are used, a verification of equivalency is required.

1.2 Chemical Composition

Elements	**Ladle (Cast) Analysis** (mass ratios in %)	
	min.	max.
C	0.17	0.23
Si	0.15	0.30
Mn	1.20	1.50
P	–	0.012
S	–	0.008
Al_{total}	0.010	0.040
Cu	–	0.12
Cr	–	0.20
Ni	0.50	0.80
Mo	0.40	0.55
V	–	0.020
Sn	–	0.011
N_{total}	–	0.013
As	–	0.025

1.3 Mechanical Properties of the Materials

The requirements regarding mechanical properties apply to the final heat treatment condition of the component parts. The following Table lists the minimum values or ranges of these properties.

Quenched and tempered wall thickness (s) in mm	Specimen orientation	$R_{p0,2}$ in MPa at		R_m in MPa at		A in % at		Z in % at	Absorbed impact energy, KV_2, in J at ± 0 °C	
		RT	350 °C	RT	350 °C	RT	350 °C	RT	EW	MW
30 < s ≤ 70	transverse	450	382	590 to 730	530					
70 < s ≤ 150		430	363	570 to 710	510					
150 < s ≤ 200			343			18	16	45	34	41
200 < s ≤ 320		390	343	560 to 700	505					
320 < s ≤ 600			315							
RT – room temperature, EW – single value, MW – average value of three specimens										

1.4 Heat Treatment

(1) The steel is used in its quenched and tempered condition.

Austenitising:	870 °C to 930 °C with subsequent hardening in water.
Tempering:	630 °C to 690 °C.
Stress-relief heat treatment:	580 °C to 620 °C for the last heat treatment. Intermediate annealings may be performed at 550 °C ± 20 K.

Annex to WPB 1.2, contd.

(2) Dependent on the dimensions and chemical composition of the component parts the material manufacturer together with the component manufacturer shall specify the heat-up and cooling rates, the temperatures as well as the holding times such that, under consideration of subsequent heat treatments, the mechanical properties specified under Section 1.3 of this Annex to WPB 1.2 are ensured for the final condition of the entire component.

1.5 Hot Forming or Hot Shaping

The temperature range for hot forming or hot shaping as well as the heat-up and cooling rates shall be chosen in accordance with the specification of the steel manufacturer. After hot forming or hot shaping, a quenching and tempering treatment as specified under Section 1.4 of this Annex to WPB 1.2 is required.

1.6 Oxygen-cutting

(1) A pre-heating is required prior to any oxygen-cutting. The pre-heating temperature shall be at least 150 °C.

(2) In well-founded individual cases, this temperature limit may be reduced, provided, mutual agreement between steel maker, product manufacturer, purchaser, and authorized expert is reached.

2 Sampling

2.1 Heat Treatment Condition of the Test Coupons

The test coupons for the destructive tests shall be taken from the sheets or plates after their last quenching and tempering.

2.2 Test Unit and Sampling Locations

(1) In the case of quenched and tempered wall thicknesses larger than 320 mm, the test coupons for the destructive tests shall be taken, as far as practicable, at least at 1/4 the quenched and tempered wall thickness under the rolled surface and at least at 1/2 the quenched and tempered wall thickness under the face and side surface of the edges straightened for tempering purposes.

In case of a quenched and tempered wall thickness $s \leq 40$ mm, the test coupons may be taken close to the surface.

The specimens shall be taken from the middle of the top end and bottom zones of each rolled plate. In case of a rolled plate length smaller than 5 m, testing of specimens from the mid-top location will suffice.

(2) In the case of quenched and tempered wall thicknesses larger than 320 mm, the sampling locations shall be at least 80 mm under the rolled surface and under the face and side surface of the edges straightened for tempering purposes.

The specimens shall be taken from the middle of the top end and bottom zones of each rolled plate.

2.3 Specimen Orientation

The destructive tests shall be performed on transverse specimens relative to the major forming or shaping direction.

Transverse specimens:
Longitudinal specimen axis shall be transverse to the major forming or shaping direction; for notched-bar impact specimens, the notch axis shall be perpendicular to the plane of the transverse and longitudinal directions.

MATERIAL TEST SHEET (WPB)	**WPB 1.3**
Product form: Flat products (plates, sheets and bands)	
Materials: Creep-resisting, quenched and tempered steels in accordance with DIN EN 10028-2: P265GH (1.0425) P295GH (1.0481) P355GH (1.0473) 16 Mo 3 (1.5415) 13 CrMo 4-5 (1.7335)	
Requirements: DIN EN 10028-1, DIN EN 10028-2 and as specified in this WPB	
Specimen sampling and extent of testing: DIN EN 10028-1, DIN EN 10164 and as specified in this WPB	
Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition Chemical analysis of the melt(s) and information on the melting process. If welding tasks are intended, the carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2. Attestation of the heat treatment condition	3.1
3. Tensile test at room temperature	3.1
4. Tensile test at room temperature to determine percentage reduction of area at fracture: Each rolling plate: three tensile test specimens in the through-thickness direction, in accordance with DIN EN 10164. The tensile test shall be performed if the flat product form is intended for welding during further fabrication and if this welding procedure could lead to tensile stressing in the through-thickness direction. Procedure and requirements as specified under Section 5.2, para. (13).	3.1
5. Notched bar impact test at +20 °C Performed for each tensile test under No. 3 of this of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
6. Ultrasonic testing of the flat product body Each sheet or plate prior to further weld processing, provided, a verification of tensile quality is required under No. 4 of this WPB. Procedure and requirements as specified in DIN EN 10164.	3.1
7. Visual examination and dimensional checks Each product.	3.1
8. Materials identification checks Each product made from 16Mo3 and 13 CrMo 4-5: by a suitable procedure.	3.1
Marking – in accordance with DIN EN 10028-1, additionally Quality Class Z25 (if certified)	

MATERIAL TEST SHEET (WPB) WPB 1.4

Product form: Flat and long products (plates, sheets, bands, wide flats, sections 1), rods and bars)

Materials: Non-alloy structural steels in accordance with DIN EN 10025-2:

S235JR 2)	(1.0038)
S235J2	(1.0117)
S355J2	(1.0577)

Requirements: DIN EN 10025-2 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10025-1, DIN EN 10025-2 (Testing after melting), DIN EN 10164 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical ladle (cast) analysis and information on the melting process(es). If welding task are intended, the carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2.	Attestation of the heat treatment condition	3.1
3.	Tensile test at room temperature One test each per weld, heat treatment lot and range of thickness.	3.1
4.	Tensile test at room temperature to determine percentage reduction of area at fracture on the steels S235J2 und S355J2 Each flat product and section: three tensile test specimens in the through-thickness direction, in accordance with DIN EN 10164. The tensile test shall be performed if the flat products and sections are intended for welding during further fabrication and if this welding procedure could lead to tensile stressing in the through-thickness direction. Procedure and requirements as specified under Section 5.2, para. (13).	3.1
5.	Notched bar impact test at +20 °C for steel S235JR and at -20 °C for steels S235J2 and S355J2 Performed for each tensile test under No. 3 of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
6.	Ultrasonic surface check Each product intended for welding during further fabrication whose tensile quality is required to be verified under No. 4 of this WPB. Procedure and requirements as specified in DIN EN 10164.	3.1
7.	Visual examination and dimensional checks Each product.	3.1

Marking – in accordance with DIN EN 10028-1, additionally Quality Class Z25 (if certified)

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1) Hollow sections are dealt with by WPB 2.2 and WPB 2.4.

2) The steel S235JR shall not be used if improved characteristics in the through-thickness direction must be verified under No. 2 of this WPB.

MATERIAL TEST SHEET (WPB) **WPB 1.5**

Product form: Flat products (plates, sheets, bands and wide flats)

Materials: Quenched and tempered steels [1] in accordance with

DIN EN 10083-2:		DIN EN 10083-3:	
C35E+QT	(1.1181)	42CrMo4	(1.7225)
C45E+QT	(1.1191)	34CrNiMo6	(1.6582)

Requirements: DIN EN 10083-2 or DIN EN 10083-3 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10083-1 and DIN EN 10083-2 or DIN EN 10083-3 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2.	Attestation of the heat treatment condition	3.1
3.	Hardness test for certification of uniform heat treatment: At both ends of each flat product.	3.1
4.	Tensile test at room temperature One test each per melt, heat treatment lot and range of thickness.	3.1
5.	Notched bar impact test at room temperature Performed for each tensile test under No. 4 of this of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
6.	Visual examination and dimensional checks Each product.	3.1
7.	Materials identification checks in case of alloyed steels Each product: by a suitable procedure.	3.1

Marking – type of steel, melt number, specimen number, identification marking of manufacturer

[1] No welding processes are allowed for these steels.

MATERIAL TEST SHEET (WPB) **WPB 1.6**

Product form: Flat and long products (plates, sheets, bands, wide flats, sections, rods and bars)

Materials: Weldable fine-grain structural steels 1) in accordance with

DIN EN 10025-3:		DIN EN 10025-4:	
S275N	(1.0490)	S275M	(1.8818)
S355N	(1.0545)	S355M	(1.8823)

Requirements: DIN EN 10025-3 or DIN EN 10025-4 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10025-1, DIN EN 10025-3 (post-melting tests), DIN EN 10025-4
DIN EN 10164 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process. In case welding tasks are intended, the carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2.	Attestation of the heat treatment condition including data on the heat treatment temperatures, holding times and cooling-down conditions.	3.1
3.	Tensile test at room temperature One test each per weld, heat treatment lot and range of thickness.	3.1
4.	Tensile test at room temperature to determine percentage reduction of area at fracture Each flat product and section: three tensile test specimens in the through-thickness direction, in accordance with DIN EN 10164. The tensile test shall be performed if the flat products and sections are intended for welding during further fabrication and if this welding procedure could lead to tensile stressing in the through-thickness direction. Procedure and requirements as specified under Section 5.2, para. (13).	3.1
5.	Notched bar impact test at +20 °C Performed for each tensile test under No. 3 of this of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
6.	Ultrasonic surface check Each product intended for welding during further fabrication whose tensile quality is required to be verified under No. 4 of this WPB. Procedure and requirements as specified in DIN EN 10164.	3.1
7.	Visual examination and dimensional checks Each product.	3.1

Marking – in accordance with DIN EN 10028-1, additionally Quality Class Z25 (if certified)

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1) Flat products made from the steels P275NH (1.0487) and P355NH (1.0565) in accordance with DIN EN 10028-3 may also be used, provided, the tests and inspections of this WPB were performed and certified.

MATERIAL TEST SHEET (WPB) **WPB 2.1**

Product form: Seamless and welded pipes

Materials: Stainless austenitic steels [1] in accordance with DIN EN 10296-2 and DIN EN 10297-2:

X5CrNi18-10	(1.4301)
X5CrNiMo17-12-2	(1.4401)
X6CrNiTi18-10	(1.4541)
X6CrNiNb18-10	(1.4550)
X6CrNiMoTi17-12-2	(1.4571)

Requirements: DIN EN 10296-2 or DIN EN 10297-2 [2] and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10296-2 or DIN EN 10297-2 and as specified in this WPB

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition: Chemical analysis of the melt(s) and information on the melting process.	3.1
2. Attestation of the heat treatment condition	3.1
3. Tensile test at room temperature	3.1
4. Destructive testing of welded pipes: ring flattening test, drift-expanding test or pipe bending test, ring tensile test or weld seam bending test Type, procedure and evaluation of the tests in accordance with DIN EN 10296-2.	3.1
5. Visual examination and dimensional checks Each pipe. Surface condition at least W1 or W2 in accordance with DIN EN 10296-2 or at least HFD or CFD in accordance with DIN EN 10297-2.	3.1
6. Materials identification checks Each pipe: by a suitable procedure.	3.1

Marking – in accordance with DIN EN 10296-2 or DIN EN 10297-2

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[1] Welded pipes and seamless pipes made of the steels listed in accordance with DIN EN 10216-5, Test Category 1 or 2, or with DIN EN 10217-7, Test Category 1 or 2, may also be used, provided, the tests and inspections of this WPB were performed and certified.

[2] If the analysis requires that the strength values are assured at elevated temperatures, then the welded pipes and the seamless pipes shall be made from the steels listed in accordance with DIN EN 10216-5 or with DIN EN 10217-7

MATERIAL TEST SHEET (WPB) **WPB 2.2**

Product form: Cold-formed welded hollow sections

Materials: Non-alloy structural steels in accordance with DIN EN 10219-1:
S235JRH (1.0039)
S355J2H (1.0576)

Requirements: DIN EN 10219-1, DIN EN 10219-2 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10219-1 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process. In case welding tasks are intended, the carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2.	Attestation of the heat treatment condition	3.1
3.	Tensile test at room temperature One test each per weld, heat treatment lot and range of thickness.	3.1
4.	Notched bar impact test at -20 °C for S355J2H, at +20 °C for S235JRH Performed for each tensile test under No. 3 of this of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
5.	Visual examination and dimensional checks Each hollow section.	3.1
6.	Non-destructive testing of the weld seam Each hollow section: 100 %. Test procedure and Acceptance Class in accordance with DIN EN 10219-1.	3.1

Marking – in accordance with DIN EN 10219-1

MATERIAL TEST SHEET (WPB)	**WPB 2.3**
Product form:	Seamless pipes
Materials:	Creep-resisting, quenched and tempered steels in accordance with DIN EN 10216-2: P235GH (1.0345) P265GH (1.0425) 16Mo3 (1.5415) 10CrMo9-10 (1.7380) 13CrMo4-5 (1.7335)
Requirements:	DIN EN 10216-2 and as specified in this WPB
Specimen sampling and extent of testing:	DIN EN 10216-2, Test Category 1 or 2, and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process. If welding tasks are intended for the steels P235GH and P265GH, their carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2.	Attestation of the heat treatment condition	3.1
3.	Tensile test at room temperature	3.1
4.	Notched bar impact test at ±0° C for P235GH and P265GH at +20 °C for 16Mo3, 10CrMo9-10 and 13CrMo4-5 Performed for each tensile test under No. 3 of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
5.	Destructive testing of welded pipes: ring flattening test, ring tensile test, drift-expanding test or ring expanding test Type, procedure and evaluation of the tests in accordance with DIN EN 10296-2.	3.1
6.	Visual examination and dimensional checks Each pipe.	3.1
7.	Materials identification checks For 16Mo3, 10CrMo9-10 and 13CrMo4-5, each pipe: by a suitable procedure.	3.1

Marking – in accordance with DIN EN 10216-2

MATERIAL TEST SHEET (WPB) **WPB 2.4**

Product form: Hot manufactured seamless or welded hollow sections

Materials: Non-alloy structural steels in accordance with DIN EN 10210-1:

S235JRH	(1.0039)
S275J2H	(1.0138)
S355J2H	(1.0576)

Requirements: DIN EN 10210-1, DIN EN 10210-2 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10210-1 and as specified in this WPB

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition Chemical analysis of the melt(s) and information on the melting process. In case welding tasks are intended, the carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2. Attestation of the heat treatment condition	3.1
3. Tensile test at room temperature One test each per weld, heat treatment lot, range of thickness and fabrication procedure.	3.1
4. Notched bar impact test at -20 °C for S275J2H and S355J2H at +20 °C for S235JRH Performed for each tensile test under No. 3 of this of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
5. Visual examination and dimensional checks Each hollow section.	3.1
6. Destructive testing of welded hollow sections: Each hollow section: 100 % Test procedure and Acceptance Class in accordance with DIN EN 10210-1.	3.1

Marking – in accordance with DIN EN 10210-1

MATERIAL TEST SHEET (WPB)	**WPB 2.5**
Product form: Seamless rolled or pressed pipes	
Material: Creep-resisting quenched and tempered steel: 20 MnMoNi 5 5 (1.6310)	
Requirements: as specified in the Annex to this WPB	
Specimen sampling and extent of testing: as specified in this WPB and the Annex to this WPB	
Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2. Attestation of the heat treatment condition including data on the heat treatment temperatures, holding times and cooling-down conditions.	3.1
3. Tensile test at room temperature in accordance with DIN EN ISO 6892-1 - if the outside diameter is equal to or smaller than 600 mm: one test each per melt, dimension and heat treatment lot; maximum batch size: 20 pipes - if the outside diameter is larger than 600 mm: one test each per fabrication length. The values to be determined and certified are: $R_{p0,2}$, R_m, A and Z.	3.2
4. Tensile test at 350 °C in accordance with DIN EN ISO 6892-2 One test for each per weld, dimension and heat treatment lot if the design temperature is higher than 250 °C. The values to be determined and certified are: $R_{p0,2}$, R_m and A.	3.2
5. Notched bar impact test at ±0 °C in accordance with DIN EN ISO 148-1 Performed for each tensile test under No. 3 of this of this WPB: one set (= three Charpy-V-notch specimens). The value to be determined and certified is: KV_2.	3.2
6. Destructive testing of pipes: Ring flattening test, ring tensile test, drift-expanding test or ring expanding test Both ends of each rolling length; in case of partial lengths without allocation to the rolling length, both ends of each pipe Type, procedure and evaluation of the tests in accordance with DIN EN 10216-2, Test Category 2.	3.2
7. Visual examination and dimensional checks Each pipe. Surface condition in accordance with DIN EN 10216-2.	3.2
8. Materials identification checks Each pipe: by a suitable procedure.	3.1
Marking – type of steel, melt number, specimen or pipe number, identification markings of manufacturer and of authorized expert	

Annex to Material Test Sheet *WPB 2.5*

This Annex specifies detailed requirements for seamless, rolled or pressed pipes made from 20 MnMoNi 5 5 as well as for the tests and examinations of the products.

1 Materials Data and Requirements

1.1 Melting Process

The material shall basically be molten by the electric-arc process or the basic-oxygen process. If other processes are used, a verification of equivalency is required.

Annex to WPB 2.5, contd.

1.2 Chemical Composition

Elements	**Ladle (Cast) Analysis** (mass ratios in %)	
	min.	max.
C	0.17	0.23
Si	0.15	0.30
Mn	1.20	1.50
P	–	0.012
S	–	0.008
Al_{ges}	0.010	0.040
Cu	–	0.12
Cr	–	0.20
Ni	0.50	0.80
Mo	0.40	0.55
V	–	0.020
Sn	–	0.011
N_{ges}	–	0.013
As	–	0.025

1.3 Mechanical Properties of the Material

The requirements regarding mechanical properties apply to the final heat treatment condition of the component parts. The following table lists the minimum values or ranges of these properties.

Nominal wall thickness (s) in mm	Specimen orientation	$R_{p0,2}$ in MPa at		R_m in MPa at		A in % at		Z in % at	Absorbed impact energy, KV_2 in J at ±0 °C	
		RT	350 °C	RT	350 °C	RT	350 °C	RT	EW	MW
15 < s ≤ 100	lengthwise	430	363	570 to 710	513	19	16	45	51	60
	transverse								34	41
100 < s ≤ 200	lengthwise	390	343	560 to 700	510				51	60
	transverse								34	41
RT – room temperature, EW – single value, MW – average value of three specimens										

1.4 Heat Treatment

(1) The steel is used in its quenched and tempered condition.

Austenitising: 870 °C to 930 °C with subsequent hardening in water.
Tempering: 630 °C to 690 °C.
Stress-relief heat treatment: 580 °C to 620 °C for the last heat treatment.
Intermediate annealings may be performed at 550 °C ± 20 K.

(2) Dependent on the dimensions and chemical composition of the component parts the material manufacturer together with the component manufacturer shall specify the heat-up and cooling rates, the temperatures as well as the holding times such that, under consideration of subsequent heat treatments, the mechanical properties specified under Section 1.3 of this Annex to WPB 2.5 are ensured for the final condition of the entire component.

1.5 Hot Forming or Hot Shaping

The temperature range for hot forming or hot shaping as well as the heat-up and cooling rates shall be chosen in accordance with the specification of the steel manufacturer. After hot forming or hot shaping, a quenching and tempering treatment as specified under Section 1.4 of this Annex to WPB 2.5 is required.

1.6 Oxygen-cutting

(1) A pre-heating is required prior to any oxygen-cutting. The pre-heating temperature shall be at least 150 °C.

(2) In well-founded individual cases, this temperature limit may be reduced, provided, mutual agreement between steel maker, product manufacturer, purchaser, and authorized expert is reached.

2 Sampling

2.1 Heat Treatment Condition of the Test Coupons

The test coupons for the destructive tests shall be taken from the pipes after their last quenching and tempering.

2.2 Test Unit and Sampling Locations

The test coupons for the destructive tests shall be taken, as far as practicable, at least at 1/4 the quenched and tempered wall thickness under the rolled surface and at least at 1/2 the quenched and tempered wall thickness under the end face and side surface of the edges straightened for tempering purposes. The specimens shall be taken from one end of the pipes.

2.3 Specimen Orientation

The destructive tests shall be performed, if possible, on transverse, otherwise lengthwise specimens relative to the major forming or shaping direction.

Transverse specimens:

Longitudinal specimen axis shall be transverse to the major forming or shaping direction; for notched-bar impact specimens, the notch axis shall be perpendicular to the plane of the transverse and longitudinal directions.

Lengthwise specimens:

Longitudinal specimen axis shall be parallel to the major forming or shaping direction; for notched-bar impact specimens, the notch axis shall be perpendicular to the plane of the transverse and longitudinal directions.

MATERIAL TEST SHEET (WPB)		**WPB 2.6**
Product form:	Seamless pipes and welded pipes	
Material:	Creep-resisting fine-grained structural steel in accordance with DIN EN 10216-3 or DIN EN 10217-3: P460NH (1.8935)	
Requirements:	DIN EN 10216-3 or DIN EN 10217-3 and as specified in this WPB In case of seamless pipes with a nominal wall thickness 65 < s ≤ 100, the requirements in accordance with DIN EN 10216-3 specified for the absorbed impact energy, KV_2, at s = 65 mm shall be applied.	
Specimen sampling and extent of testing:	DIN EN 10216-3, Test Category 1, or DIN EN 10217-3, Test Category 1	

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process. In case welding tasks are intended, the carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2.	Attestation of the heat treatment condition	3.1
3.	Tensile test at room temperature	3.1
4.	Notched bar impact test at +20 °C Performed for each tensile test under No. 3 of this of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
5.	Destructive testing of pipes: Ring flattening test, ring tensile test, drift-expanding test or ring expanding test Type, procedure and evaluation of the tests in accordance with DIN EN 10216-3 or DIN EN 10217-3	3.1
6.	Visual examination and dimensional checks Each pipe.	3.1
7.	Destructive testing of the weld seam in case of welded pipes Each pipe: 100 %. Test procedure and Acceptance Class in accordance with DIN EN 10217-3.	3.1
8.	Materials identification checks Each pipe: by a suitable procedure.	3.1

Marking – in accordance with DIN EN 10216-3 or DIN EN 10217-3

MATERIAL TEST SHEET (WPB) **WPB 2.7**

Product form: Seamless pipes with a nominal wall thickness s ≤ 80 mm

Material: Creep-resisting quenched and tempered steel:
15 NiCuMoNb 5-6-4 (1.6368)

Requirements: DIN EN 10216-2 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10216-2, Test Category 2, and as specified in this WPB

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2. Attestation of the heat treatment condition including data on the heat treatment temperatures, holding times and cooling-down conditions.	3.1
3. Tensile test at room temperature	3.1
4. Tensile test at 350 °C One sampling location per melt if the design temperature is higher than 100 °C.	3.1
5. Notched bar impact test at +20 °C Performed for each tensile test under No. 3 of this of this WPB, provided, the nominal plate thickness (s) is larger than 10 mm: one set (= three Charpy-V-notch specimens)	3.1
6. Destructive testing of welded pipes: Ring flattening test, ring tensile test, drift-expanding test or ring expanding test Each rolling length: at one end. Type, procedure and evaluation of the tests in accordance with DIN EN 10216-2.	3.1
7. Visual examination and dimensional checks Each pipe.	3.1
8. Materials identification checks Each pipe: by a suitable procedure.	3.1

Marking – in accordance with DIN EN 10216-2

MATERIAL TEST SHEET (WPB) **WPB 3.1**

Product form: Forgings (rods, plates or other forgings) and forged bars

Materials: Stainless austenitic steels in accordance with DIN EN 10250-4 or DIN EN 10088-3 [1]:

X5CrNi18-10	(1.4301)
X5CrNiMo17-12-2	(1.4401)
X6CrNiTi18-10	(1.4541)
X6CrNiNb18-10	(1.4550)
X6CrNiMoTi17-12-2	(1.4571)

Requirements: DIN EN 10250-4 or DIN EN 10088-3 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10250-1 or DIN EN 10088-3 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2.	Attestation of the heat treatment condition	3.1
3.	Tensile test at room temperature	3.1
4.	Visual examination and dimensional checks Each forging: surface condition in accordance with DIN EN 10250-1 or DIN EN 10088-3.	3.1
5.	Materials identification checks Each forging: by a suitable procedure.	3.1
6.	Surface inspection Every forging: 100 % by liquid penetrant testing Procedure and evaluation as specified in Appendix B.	3.1

Marking – in accordance with DIN EN 10250-1 or DIN EN 10088-3

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[1] Forgings and rods made from the steels listed in accordance with DIN EN 10222-5 or DIN EN 10272 may also be used, provided, the tests and inspections under this WPB were performed and certified.

MATERIAL TEST SHEET (WPB)		**WPB 3.2**
Product form:	Forgings (rods, plates or other forgings)	
Materials:	Creep-resisting quenched and tempered steels: 20 MnMoNi 5 5 (1.6310) 22 NiMoCr 3 7 (1.6751)	
Requirements:	20 MnMoNi 5 5 as specified in this WPB and its Annex 22 NiMoCr 3 7 to be specified within framework of the design review	
Specimen sampling and extent of testing:	as specified in this WPB and its Annex	

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2.	Attestation of the heat treatment condition including data on the heat treatment temperatures, holding times and cooling-down conditions.	3.1
3.	Tensile test at room temperature in accordance with DIN EN ISO 6892-1 On each sampling location, as specified und Section 2 of the Annex to this WPB. The values to be determined and certified are: $R_{p0,2}$, R_m, A and Z.	3.2
4.	Tensile test at 350 °C in accordance with DIN EN ISO 6892-2 One sampling location, as specified und Section 2 of the Annex to this WPB if the design temperature is higher than 250 °C. The values to be determined and certified are: $R_{p0,2}$, R_m and A.	3.2
5.	Notched bar impact test at ±0 °C in accordance with DIN EN ISO 148-1 Performed for each tensile test under No. 3 of this WPB: one set (= three Charpy-V-notch specimens). The value to be determined and certified is: KV_2.	3.2
6.	Visual examination and dimensional checks Each forging.	3.2
7.	Materials identification checks Each forging: by a suitable procedure.	3.1
8.	Ultrasonic examination Rods and plates with a product thickness equal to or larger than 30 mm und forgings equal to or larger than 300 kg: each product 100 % Procedure and evaluation as specified in Appendix B.	3.1
9.	Surface inspection Each forging: 100 % by liquid penetrant testing Procedure and evaluation as specified in Appendix B.	3.1

Marking – type of steel, melt number, specimen number, identification markings of manufacturer and of authorized expert

Annex to Material Test Sheet WPB 3.2

This Annex details the requirements for forgings made from 20 MnMoNi 5 5 as well as for the tests and examinations of the products made from 20 MnMoNi 5 5 and 22 NiMoCr 3 7.

1 Materials Data and Requirements

1.1 Melting Process

The material shall basically be molten by the electric-arc process or the basic-oxygen process. If other processes are used, a verification of equivalency is required.

1.2 Chemical composition

Elements	**Ladle (cast) Analysis** (mass ratios in %)	
	min.	max.
C	0.17	0.23
Si	0.15	0.30
Mn	1.20	1.50
P	–	0.012
S	–	0.008
Al_{ges}	0.010	0.040
Cu	–	0.12
Cr	–	0.20
Ni	0.50	0.80
Mo	0.40	0.55
V	–	0.020
Sn	–	0.011
N_{ges}	–	0.013
As	–	0.025

1.3 Mechanical Properties of the Material

The requirements regarding mechanical properties apply to the final heat treatment condition of the component parts. The following table lists the minimum values or ranges of these properties.

Quenched and tempered wall thickness, s in mm	Specimen orientation	$R_{p0,2}$ in MPa at		R_m in MPa at		A in % at		Z in % at	Absorbed impact energy, KV_2 in J bei ±0 °C	
		RT	350 °C	RT	350 °C	RT	350 °C	RT	EW	MW
s < 320	lengthwise / transverse	390	343	560 to 700	504	19	14	45	34	41
s ≥ 320			314							
RT – room temperature, EW – single value, MW – average value of 3 specimens										

1.4 Heat Treatment

(1) The steel is used in its quenched and tempered condition.

Austenitising:	870 °C to 940 °C with subsequent hardening in water.
Tempering:	630 °C to 680 °C.
Stress-relief heat treatment:	580 °C to 620 °C for the last heat treatment. Intermediate annealings may be performed at 550 °C ± 20 K.

(2) Dependent on the dimensions and chemical composition of the component parts the material manufacturer together with the component manufacturer shall specify the heat-up and cooling rates, the temperatures as well as the holding times such that, under consideration of subsequent heat treatments, the mechanical properties specified under Section 1.3 of this Annex to WPB 3.2 are ensured for the final condition of the entire component.

1.6 Oxygen-cutting

(1) A pre-heating is required prior to any oxygen-cutting. The pre-heating temperature shall be at least 150 °C.

(2) In well-founded individual cases, this temperature limit may be reduced, provided, mutual agreement between steel maker, product manufacturer, purchaser, and authorized expert is reached.

2 Sampling

2.1 Heat Treatment Condition of the Test Specimens

The test coupons for the destructive tests shall be taken from the product form after the last quenching and tempering.

2.2 Test Unit and Sampling Location

(1) If only one forging is fabricated from a forging ingot, the specimens shall be taken from the top end and bottom zone. If the cut-off forgings are separated into component parts to be individually quenched and tempered, one sampling location of each component part shall be tested, in which case both the top and bottom zone or each rough forging shall be covered.

(2) For individually quenched and tempered forgings with a length larger than 4 m in the major forming or shaping direction or with a thickness larger than 500 mm, test coupons from both ends shall be tested.

(3) In the case of quenched and tempered wall thicknesses equal to or smaller than 320 mm, the sampling locations shall be at least at 1/4 of the quenched and tempered wall thickness under the major quenched and tempered surface and at 1/2 of the quenched and tempered wall thickness under the face and side surfaces of the edges straightened for heat treatment purposes.

(4) In the case of quenched and tempered wall thicknesses larger than 320 mm, the sampling locations shall be at least 80 mm below the major quenched and tempered surface and at least 160 mm under the face and side surfaces of the edges straightened for heat treatment purposes.

2.3 Specimen Orientation

The destructive tests shall be performed on transverse specimens relative to the major forming or shaping direction.

Transverse specimens:

Longitudinal specimen axis shall be transverse to the major forming or shaping direction; for notched-bar impact specimens, the notch axis shall be perpendicular to the plane of the transverse and longitudinal directions.

MATERIAL TEST SHEET (WPB) **WPB 3.3**

Product form: Forgings (rods, plates or other forgings)

Materials: Non-alloy structural steels in accordance with DIN EN 10250-2:

S235JRG2	(1.0038)
S235J2G3	(1.0116)
S355J2G3	(1.0570)

Requirements: DIN EN 10250-1, DIN EN 10250-2 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10250-1 and as specified in this WPB

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition Chemical analysis of the melt(s) and information on the melting process. In case welding tasks are intended, the carbon equivalent value (CEV) shall be determined and specified in accordance with DIN EN 1011-2.	3.1
2. Attestation of the heat treatment condition	3.1
3. Tensile test at room temperature	3.1
4. Notched bar impact test at -20 °C for S235J2G3 and S355J2G3 at room temperature for S235JRG2 Performed for each tensile test under No. 3 of this of this WPB, provided, the nominal plate thickness (s) is larger than 15 mm: one set (= three Charpy-V-notch specimens)	3.1
5. Visual examination and dimensional checks Each forging.	3.1
6. Ultrasonic examination Rods and plates with a product thickness equal to or larger than 30 mm und forgings equal to or larger than 300 kg: each product 100 % Procedure and evaluation as specified in Appendix B.	3.1

Marking – in accordance with DIN EN 10250-1

MATERIAL TEST SHEET (WPB) **WPB 3.4**

Product form: Forgings (rods, plates or other forgings) and rolled bars

Materials: Creep-resisting weldable steels in accordance with DIN EN 10222-2 or DIN EN 10273:

P250GH	(1.0460)
16Mo3	(1.5415)

Requirements: DIN EN 10222-1 and DIN EN 10222-2 or DIN EN 10273 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10222-1 or DIN EN 10273 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2.	Attestation of the heat treatment condition	3.1
3	Tensile test at room temperature	3.1
4.	Notched bar impact test at room temperature Performed for each tensile test under No. 3 of this WPB: one set (= three Charpy-V-notch specimens).	3.1
5.	Visual examination and dimensional checks Each product.	3.1
6.	Materials identification checks In case of 16Mo3, each product: by a suitable procedure.	3.1
7.	Ultrasonic examination Forged rods and plates with a product thickness equal to or larger than 30 mm and forgings equal to or larger than 300 kg: each product 100 % Procedure and evaluation as specified in Appendix B.	3.1

Marking – in accordance with DIN EN 10222-1 or DIN EN 10273

MATERIAL TEST SHEET (WPB) **WPB 3.5**

Product form: Rod and bars and forgings with and without threaded ends

Materials: Quenched and tempered steels [1]

in accordance with DIN EN 10083-2, SEW 550 [2] or DIN EN 10269:

C45E+QT (1.1191)

in accordance with DIN EN 10083-3, SEW 550 [2] or DIN EN 10269:

42CrMo4 (1.7225)
34CrNiMo6 (1.6582)

in accordance with DIN EN 10269:

21CrMoV5-7 (1.7709)

Requirements: DIN EN 10083-2, DIN EN 10083-3, SEW 550[2] or DIN EN 10269 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10083-1 and DIN EN 10083-2 or DIN EN 10083-3 or SEW 550 or DIN EN 10269 and as specified in this WPB

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2. Attestation of the heat treatment condition	3.1
3. Hardness test to verify a uniform heat treatment Each product at both ends.	3.1
4. Tensile test at room temperature On the hardest and the softest parts of each melt, of each dimensional range and of each heat treatment lot. In the case of hammer forgings, the specimen orientation is to be agreed upon.	3.1
5. Notched bar impact test at +20 °C Performed for each tensile test under No. 4 of this WPB: one set (= three Charpy-V-notch specimens). In the case of hammer forgings, the specimen orientation is to be agreed upon.	3.1
6. Visual examination and dimensional checks Each product; in the case of products with threaded ends: in their finished condition.	3.1
7. Materials identification checks Each product made from alloyed steels: by a suitable procedure.	3.1
8. Ultrasonic examination Rods and bars with a product thickness equal to or larger than 30 mm and forgings equal to or larger than 300 kg: each product 100 % Procedure and evaluation as specified in Appendix B	3.1
9. Surface inspection Each product, provided, no further mechanical processing of the surface is intended: 100 %. Procedure and evaluation as specified in Appendix B.	3.1

Marking – type of steel, melt number, specimen number, identification markings of manufacturer.

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[1] No welding-related processing of these steels is allowed.

[2] SEW 550 shall be applied for larger forgings.

MATERIAL TEST SHEET (WPB)	**WPB 3.6**
Product form: Rod and bars and forgings with and without threaded ends	
Materials: High-strength quenched and tempered steels: 20 NiCrMo 14 5 (1.6772) 26 NiCrMo 14 6 (1.6958)	
Requirements: as specified in this WPB and its Annex	
Specimen sampling and extent of testing: as specified in this WPB and its Annex	
Tests and Inspections	Certification in accordance with DIN EN 10204
1. Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2. Attestation of the heat treatment condition including data on the heat treatment temperatures, holding times and cooling-down conditions.	3.1
3. Hardness test to verify a uniform heat treatment Each product at both ends.	3.1
4. Tensile test at room temperature in accordance with DIN EN ISO 6892-1 On the hardest and the softest product of each melt, of each dimensional range and of each heat treatment lot. In the case of hammer forgings, the specimen orientation requires a special agreement. The values to be determined and certified are: $R_{p0,2}$, R_m and A and Z.	3.2
5. Tensile test at 350 °C in accordance with DIN EN ISO 6892-2 The softest product of each melt, of each dimensional range and of each heat treatment lot if the design temperature is higher than 250 °C. In the case of hammer forgings, the specimen orientation requires a special agreement. The values to be determined and certified are: $R_{p0,2}$; for general information R_m and A.	3.2
6. Notched bar impact test at +20 °C in accordance with DIN EN ISO 148-1 Performed for each tensile test under No. 4 of this WPB: one set (= three Charpy-V-notch specimens). In the case of hammer forgings, the specimen orientation requires a special agreement. The value to be determined and certified is: KV_2.	3.2
7. Visual examination and dimensional checks Each product; in the case of products with threaded ends: in their finished condition.	3.2
8. Materials identification checks Each product: by a suitable procedure.	3.1
9. Ultrasonic testing Rods with a product thickness equal to or larger than 30 mm and forgings equal to or larger than 300 kg: each product 100 % Procedure and evaluation as specified in Appendix B.	3.1
10. Surface inspection Each forging, provided, no further mechanical processing of the surface is intended: 100 % Procedure and evaluation as specified in Appendix B.	3.1
Marking – type of steel, melt number, specimen number, identification markings of manufacturer and of authorized expert	

Annex to Material Test Sheet WPB 3.6

This Annex details the requirements as well as the tests and examinations for rods and forgings made from 20 NiCrMo 14 5 und 26 NiCrMo 14 6

1 Materials Data and Requirements

1.1 Melting Process

The material shall basically be molten by the electric-arc process or the basic-oxygen process. If other processes are used, a verification of equivalency is required.

Annex to WPB 3.6, contd.

1.2 Chemical composition

Elements	**Ladle (cast) Analysis** (mass ratios in %)			
	20 NiCrMo 14 5		26 NiCrMo 14 6	
	min.	max.	min.	max.
C	0.18	0.25	0.25	0.30
Si	0.15	0.40	0.15	0.30
Mn	0.30	0.50	0.20	0.50
P	–	0.020	–	0.020
S	–	0.010	–	0.015
Cr	1.20	1.50	1.20	1.70
Ni	3.40	4.00	3.30	3.80
Mo	0.25	0.50	0.35	0.55
V	–	–	–	0.08
Al	0.005	0.050	0.005	0.050

1.3 Mechanical Properties of the Materials

The requirements regarding mechanical properties apply to the final heat treatment condition of the component parts. The following table lists the minimum values or ranges of these properties

.

Material	Diameter (d) in mm	Specimen orientation	$R_{p0,2}$ in MPa at		R_m in MPa at		A in % at		Z in % at	Absorbed impact energy KV_2 in J at +20 °C	
			RT	350 °C	RT	350 °C	RT	350 °C	RT	EW	MW
20 NiCrMo 14 5 I	$s \leq 130$	length-wise	940	735	1040 to 1240	–	14	–	55	64	75
	$130 < s \leq 200$									52	63
20 NiCrMo 14 5 II	$s \leq 130$		980	785	1080 to 1280	–	14	–	55	64	75
	$130 < s \leq 200$									52	63
26 NiCrMo 14 6	$s \leq 70$		940	765	1040 to 1240	–	14	–	50	55	75
	$70 < s \leq 420$									36	52
RT – room temperature, EW – single value, MW – average value of 3 specimens											

1.4 Heat Treatment

(1) The steel is used in its quenched and tempered condition.

a) Material 20 NiCrMo 14 5

Austenitising: 870 °C to 930 °C with subsequent hardening in water or oil.

Tempering: Annealing level I: 520 °C to 600 °C
Annealing level II: 500 °C to 580 °C.

b) Material 26 NiCrMo 14 6

Austenitising: 840 °C to 870 °C with subsequent hardening in water or oil.

Tempering: 530 °C to 620 °C

(2) Dependent on the dimensions and chemical composition of the component parts the material manufacturer together with the component manufacturer shall specify the heat-up and cooling rates, the temperatures as well as the holding times such that, under consideration of subsequent heat treatments, the mechanical properties specified under Section 1.3 of this Annex to WPB 3.6 are ensured for the final condition of the entire component.

Annex to WPB 3.6, contd.

2 Sampling

2.1 Heat Treatment Condition of the Test Coupons

The test coupons for the destructive tests shall be taken from the product forms after their last quenching and tempering.

2.2 Sampling Location and Specimen Orientation

Diameter, d in mm	Sampling location	Specimen orientation	Depth
d ≤ 40	Beginning or end of the fabrication length	lengthwise	1/2 d
d > 40			1/6 d

MATERIAL TEST SHEET (WPB)		**WPB 4.1**
Product form:	Bolts equal to or smaller than M39 and nuts – by their property classes	
Materials:	Bolts: Property Classes 4.6, 5.6, 8.8 and 10.9 Nuts: Property Classes 5, 8 und 10	
Requirements:	Bolts: Nuts equal to or smaller than M48: Nuts larger than M48:	DIN EN ISO 898-1 and as specified in this WPB DIN EN ISO 898-2 and as specified in this WPB requirements shall be specified within the framework of design review
Specimen sampling and extent of testing:	Bolts: Nuts:	DIN EN ISO 898-1 DIN EN ISO 898-2

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Bolts in accordance with DIN EN ISO 898-1	3.1 / 2.1 [1]
2. Nuts in accordance with DIN EN ISO 898-2 In the case of dimensions larger than M39, the proof load test may be replaced by a hardness test HV 30; the requirements are listed in **Table WPB 4.1-1** of this WPB	2.2
3. Bolts and nuts Dimensional accuracy, identification markings and design shall be verified as being in accordance with the respective product standards Regarding surface condition: requirements are specified in Section 6.	2.2

Marking:

- Bolts in accordance with DIN EN ISO 898-1
- Nuts in accordance with DIN EN ISO 898-2

In addition to the requirements in accordance with DIN EN ISO 898-2, the following hardness values shall be met in case of nuts larger that M39:

Nominal thread diameter (d) in mm	Property Class					
	5		8		10	
	Vickers-Hardness		Vickers- Hardness		Vickers- Hardness	
	min.	max.	min.	max.	min.	max.
M39 < d ≤ M48	128	302	207	353	272	353
d > M48	Requirements to be specified within the framework of design review					

Table WPB 4.1-1: Hardness values

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[1] It is sufficient for nuts to be certified by a Declaration of Compliance with the Order 2.1, provided, the manufacturer has been subjected to an examination in accordance with VdTÜV-Merkblatt 1253/4 by the authorized expert.

MATERIAL TEST SHEET (WPB) **WPB 4.2**

Product forms: Bolts, nuts and washers for high-strength pre-loadable bolted connections equal to or smaller than M39 and for assemblies (systems HV / HR) equal to or smaller than M36

Materials:

Bolts:	Property Classes 8.8 and 10.9
Nuts:	Property Classes 8 and 10
Washers:	C45 (1.0503), C45E (1.1191) in accordance with DIN EN 10083-2 or harder

Requirements:

Bolts:	DIN EN ISO 898-1 and as specified in this WPB
Nuts:	DIN EN ISO 898-2 and as specified in this WPB
Washers:	DIN EN 10083-2 and as specified in this WPB

Additionally for assemblies (Systems HV / HR): DIN EN 14399-2

High-strength pre-loadable bolted connections of Property Classes 8.8 / 8 and 10.9 / 10 for design temperatures higher that 100 °C: as specified under Section 4.1.4, para. (8)

Specimen sampling and extent of testing:

Bolts:	DIN EN ISO 898-1
Nuts:	DIN EN ISO 898-2

Washers (starting material): DIN EN 10083-1 and DIN EN 10083-2

In addition for assemblies (Systems HV / HR): DIN EN 14399-2

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Bolts in accordance with DIN EN ISO 898-1	3.1 / 2.1 [1)]
2.	Nuts in accordance with DIN EN ISO 898-2	2.2
3.	Washers Attestation of the material and heat treatment condition	2.2
4.	Assemblies (Systems HV / HR): in accordance with DIN EN 14399-2	3.1
5.	Bolts, nuts and washers Dimensional accuracy, identification markings and design shall be verified as being in accordance with DIN EN 14399-1. Regarding surface condition: requirements are specified in Section 6.	2.2

Marking:

- Bolts and nuts: in accordance with DIN EN ISO 898-1 or DIN EN ISO 898-2, additionally hardness HV or HR
- Washers: manufacturer mark and hardness HV or HR
- Assemblies (Systems HV / HR): in accordance with DIN EN 14399-2

[1)] It is sufficient for nuts to be certified by a Declaration of Compliance with the Order 2.1, provided, the manufacturer has been subjected to an examination in accordance with VdTÜV-Merkblatt 1253/4 by the authorized expert.

MATERIAL TEST SHEET (WPB) **WPB 4.3**

Product forms: Bolts and nuts equal to or smaller than M39

Materials: Stainless austenitic steels A2, A3, A4 und A5 in Property Classes 50, 70 or 80
in accordance with DIN EN ISO 3506-1 and DIN EN ISO 3506-2

Requirements:
Bolts: DIN EN ISO 3506-1
Nuts: DIN EN ISO 3506-2

Specimen sampling and extent of testing:
Bolts: DIN EN ISO 3506-1 and as specified in this WPB
Nuts: DIN EN ISO 3506-2 and as specified in this WPB

Tests and Inspections	Certification in accordance with DIN EN 10204
1. Destructive tests Bolts in accordance with DIN EN ISO 3506-1 Nuts in accordance with DIN EN ISO 3506-2 Extent of tests as specified in **Table WPB 4.3-1** of this WPB.	3.1 / 2.1 [1]
2. Visual examination, dimensional checks und materials identification checks Tests and inspections shall be performed in accordance with DIN EN ISO 3269 under the responsibility of the manufacturer	2.2 [1]

Marking:

- Bolts: in accordance with DIN EN ISO 3506-1
- Nuts: in accordance with DIN EN ISO 3506-2

Number pieces in the test unit	Number of pieces to be tested
less than 800	1
801 to 1300	2
larger than 1300	3

Table WPB 4.3-1: Number of random specimens to be tested dependent on the number of pieces in the test unit – for the destructive testing of bolts and nuts

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[1] It is sufficient for nuts to be certified by a Declaration of Compliance with the Order 2.1, provided, the manufacturer has been subjected to an examination in accordance with VdTÜV-Merkblatt 1253/4 by the authorized expert.

MATERIAL TEST SHEET (WPB) **WPB 4.4**

Product forms: Rods as well as bolts and nuts machined from the rods with rolled or cut threads and no subsequent heat treatment

Materials: Stainless austenitic steels in accordance with DIN EN 10088-3 [1]:

X6CrNiTi18-10	(1.4541)
X6CrNiNb18-10	(1.4550)
X6CrNiMoTi17-12-2	(1.4571)

Requirements: DIN EN 10088-3

Specimen sampling and extent of testing: DIN EN 10088-3 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Tests and examinations of the starting material:	
1.1	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
1.2	Attestation of the heat treatment condition	3.1
1.3	Tensile test at room temperature	3.1
1.4	Visual examination and dimensional checks: Each rod.	3.1
1.5	Materials identification checks: Each rod: by a suitable procedure.	3.1
2.	Tests and examinations of the finished bolts and nuts:	
2.1	Visual examinations and dimensional checks The bolts and nuts shall be subjected to visual examinations and dimensional checks in accordance with the respective product standards. The requirements of **Tables WPB 4.4-1** and **WPB 4.4-2** shall be applied to the number of random specimens, to the acceptance numbers as well as to the characteristics to be verified. The surface condition of the bolts shall be checked and evaluated in accordance with DIN EN 26157-3 and that of the nuts in accordance with DIN EN ISO 6157-2. Cracks are not allowable.	3.1

Marking – - Starting material: in accordance with DIN EN 10088-3

- Bolts and nuts: manufacturer mark, type of steel, code-ID of the starting material

Main Characteristics	Secondary Characteristics
Dimensional thread limits (trueness of gauge) Force application surfaces for assembly Transition below the bolt head Thread base radius at transition from thread to shaft	Lengths (bolt length, thread length) Deviations of shape and position Contact surfaces Elevations (head elevation, nut elevation) Diameter
Note: Further characteristics as well as their classification may be specified in the purchase order.	

Table WPB 4.4-1: The characteristics of bolts and nuts to be inspected during the dimensional check as well as their classification as main and secondary characteristics

Number Pieces in the Test Unit	Number of Random Specimens				Acceptance Numbers	
	Main Characteristics		Secondary Characteristics		Main Characteristics	Secondary Characteristics
	bolts	nuts	bolts	nuts		
up to 150	32	20	20	13	0	0
151 to 280	32	20	80	50	0	1
281 to 500	125	80	80	50	1	1
501 to 1200	125	80	125	80	1	2
1201 to 3200	200	125	200	125	2	3
3201 to 10000	315	200	315	200	3	5

Table WPB 4.4-2: Number of random specimens to be tested dependent on the number of pieces in the test unit – for the visual examination and dimensional checks of bolts and nuts

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[1] Rods made from the steels in accordance with DIN EN 10222-5 or DIN EN 10272 may also be used, provided, the tests and inspections were performed and certified as specified in this WPB.

MATERIAL TEST SHEET (WPB) **WPB 4.5**

Product forms: Rods as well as bolts and nuts machined from these rods, with rolled or cut threads and no subsequent heat treatment

Materials: Creep-resisting quenched and tempered steels in accordance with DIN EN 10269, DIN EN 10083-2 or DIN EN 10083-3:

C35E	(1.1181)
C45E	(1.1191)
X19 CrMoNbVN 11-1	(1.4913)
34 CrNiMo 6	(1.6582)
25 CrMo 4	(1.7218)
42 CrMo 4	(1.7225)
21 CrMoV 5-7	(1.7709)
40 CrMoV 4-6	(1.7711)

with the Annex to this WPB:

26 NiCrMo 14 6	(1.6958)
20 NiCrMo 14 5	(1.6772)

Requirements: DIN EN 10269, DIN EN 10083-2 or DIN EN 10083-3 or as specified in the Annex to this WPB

Specimen sampling and extent of testing: DIN EN 10269, DIN EN 10083-2 or DIN EN 10083-3 or as specified in the Annex to this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Tests and Inspections of the starting material:	
1.1	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
1.2	Attestation of the heat treatment condition for 20 NiCrMo 14 5 and 26 NiCrMo 14 6 including data on the heat treatment temperatures, holding times and cooling-down conditions.	3.1
1.3	Hardness test after the last heat treatment Each rod at one end: at least three hardness indentations.	3.1
1.4	Tensile test at room temperature in accordance with DIN EN ISO 6892-1 From the hardest and the softest rods of each melt, of each dimensional range and of each heat treatment lot.	3.1 / 3.2 1)
1.5	Notched bar impact test at +20 °C in accordance with DIN EN ISO 148-1 Performed on the hardest rod of each melt, of each dimensional range and of each heat treatment lot: one set (= three Charpy-V-notch specimens). The value to be determined and certified is: KV_2.	3.1 / 3.2 1)
1.6	Visual examination and dimensional checks Each rod.	3.1 / 3.2 1)
1.7	Materials identification checks in the case of alloyed steels Each rod: by a suitable procedure.	3.1
1.8	Ultrasonic examination Rods with a product thickness equal to or larger than 30 mm: each product 100 % Procedure and evaluation as specified in Appendix B	3.1
2.	Tests and inspections of the finished bolts and nuts:	
2.1	Visual examination and dimensional checks The bolts and nuts shall be subjected to visual examinations and dimensional checks in accordance with the respective product standards. The requirements of **Tables WPB 4.5-1** and **WPB 4.5-2** shall be applied to the number of random specimens, to the acceptance numbers as well as to the characteristics to be tested. The surface condition of the bolts shall be checked and evaluated in accordance with DIN EN 26157-3 and that of the nuts in accordance with DIN EN ISO 6157-2. Cracks are not allowable. Regarding surface condition of bolts and nuts made from20 NiCrMo 14 5 (1.6772) und 26 NiCrMo 14 6 (1.6958): requirements are specified in Section 6.	3.1

Marking:

- Starting material: in accordance with DIN EN 10269, DIN EN 10083-2 or DIN EN 10083-3
- Bolts and nuts: manufacturer mark, type of steel, code-ID of the starting material

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1) In the case of 20 NiCrMo 14 5 and 26 NiCrMo 14 6, an Inspection Certificate 3.2 is required.

Main Characteristics	Secondary Characteristics
Dimensional thread limits (trueness of gauge) Force application surfaces for assembly Transition below the bolt head Thread base radius at transition from thread to shaft	Lengths (bolt length, thread length) Deviations of shape and position Contact surfaces Elevations (head elevation, nut elevation) Diameter
Note: Further characteristics as well as their classification may be specified in the purchase order.	

Table WPB 4.5-1: The characteristics of bolts and nuts to be inspected during the dimensional check as well as their classification as main and secondary characteristics

Number Pieces in the Test Unit	Number of Random Specimens				Acceptance Numbers	
	Main Characteristics		Secondary Characteristics		Main Characteristics	Secondary Characteristics
	bolts	nuts	bolts	nuts		
up to 150	32	20	20	13	0	0
151 to 280	32	20	80	50	0	1
281 to 500	125	80	80	50	1	1
501 to 1200	125	80	125	80	1	2
1201 to 3200	200	125	200	125	2	3
3201 to 10000	315	200	315	200	3	5

Table WPB 4.5-2: Number of random specimens to be tested dependent on the number of pieces in the test unit for the visual examination and dimensional checks of bolts and nuts

Annex to Material Test Sheet WPB 4.5

This Annex details the requirements as well as the tests and examinations for rods made from 20 NiCrMo 14 5 und 26 NiCrMo 14 6

1 Materials Data and Requirements

1.1 Melting Process

The material shall basically be molten by the electric-arc process or the basic-oxygen process. If other processes are used, a verification of equivalency is required.

1.2 Chemical composition

Elements	**Ladle (cast) Analysis** (mass ratios in %)			
	20 NiCrMo 14 5		26 NiCrMo 14 6	
	min.	max.	min.	max.
C	0.18	0.25	0.25	0.30
Si	0.15	0.40	0.15	0.30
Mn	0.30	0.50	0.20	0.50
P	–	0.020	–	0.020
S	–	0.010	–	0.015
Cr	1.20	1.50	1.20	1.70
Ni	3.40	4.00	3.30	3.80
Mo	0.25	0.50	0.35	0.55
V	–	–	–	0.08
Al	0.005	0.050	0.005	0.050

Annex to WPB 4.5, contd.

1.3 Mechanical Properties of the Materials

The requirements regarding mechanical properties apply to the final heat treatment condition of the component parts. The following table lists the minimum values or ranges of these properties.

Material	Diameter (d) in mm	Specimen orientation	$R_{p0,2}$ in MPa at		R_m in MPa at		A in % at		Z in % at	Absorbed impact energy, KV_2 in J at +20 °C	
			RT	350 °C	RT	350 °C	RT	350 °C	RT	EW	MW
20 NiCrMo 14 5 I	s ≤ 130	lengthwise	940	735	1040 to 1240	–	14	–	55	64	75
	130 < s ≤ 200									52	63
20 NiCrMo 14 5 II	s ≤ 130		980	785	1080 to 1280	–	14	–	55	64	75
	130 < s ≤ 200									52	63
26 NiCrMo 14 6	s ≤ 70		940	765	1040 to 1240	–	14	–	50	55	75
	70 < s ≤ 420									36	52
RT – room temperature, EW – single value, MW – average value of 3 specimens											

1.4 Heat Treatment

(1) The steel shall be used in the quenched and tempered condition.

a) Material 20 NiCrMo 14 5

Austenitising: 870 °C to 930 °C with subsequent hardening in water or oil.

Tempering: Annealing level I: 520 °C to 600 °C
Annealing level II: 500 °C to 580 °C.

b) Material 26 NiCrMo 14 6

Austenitising: 840 °C to 870 °C with subsequent hardening in water or oil.

Tempering: 530 °C to 620 °C

(2) Dependent on the dimensions and chemical composition of the component parts the material manufacturer together with the component manufacturer shall specify the heat-up and cooling rates, the temperatures as well as the holding times such that, under consideration of subsequent heat treatments, the mechanical properties specified under Section 1.3 of this Annex to WPB 4.5 are ensured for the final condition of the entire component.

2 Sampling

2.1 Heat Treatment Condition of the Test Coupons

The test coupons for destructive tests shall be taken from the product forms after their last quenching and tempering.

2.2 Sampling Locations and Specimen Orientation

Diameter (d) in mm	Sampling location	Specimen orientation	Depth
d ≤ 40	Beginning or end of the fabrication length	lengthwise	1/2 d
d > 40			1/6 d

MATERIAL TEST SHEET (WPB) **WPB 4.6**

Product forms:	Rods as well as bolts and nuts hot formed from these rods with rolled or cut threads and subsequently heat treated
Materials:	Creep-resisting quenched and tempered steels in accordance with DIN EN 10269:

C35E	(1.1181)
X19CrMoNbVN11-1	(1.4913)
25CrMo4	(1.7218)
21CrMoV5-7	(1.7709)
40CrMoV4-6	(1.7711)

Requirements:	DIN EN 10269
Specimen sampling and extent of testing:	DIN EN 10269 and as specified in this WPB

<table>
<tr><th colspan="2">Tests and Inspections</th><th>Certification in accordance with DIN EN 10204</th></tr>
<tr><td colspan="3">1. Tests and Inspections of the starting material:</td></tr>
<tr><td>1.1</td><td>Chemical composition:
Chemical analysis of the melt(s) and information on the melting process.</td><td>3.1</td></tr>
<tr><td>1.2</td><td>Visual examination and dimensional checks
Each rod.</td><td>3.1</td></tr>
<tr><td>1.3</td><td>Materials identification checks in the case of alloyed steels
Each rod: by a suitable procedure.</td><td>3.1</td></tr>
<tr><td>1.4</td><td>Check of the ID-marking
Each rod.</td><td>3.1</td></tr>
<tr><td>1.5</td><td>Ultrasonic examination
Rods with a product thickness equal to or larger than 30 mm: each rod 100 %
Procedure and evaluation as specified in Appendix B</td><td>3.1</td></tr>
<tr><td colspan="3">2. Tests and Inspections of the finished bolts and nuts:</td></tr>
<tr><td>2.1</td><td>Attestation of the heat treatment condition
Each heat treatment lot</td><td>3.1</td></tr>
<tr><td>2.2</td><td>Hardness test
On 10 % of the bolts and nuts, however, at least 15 pieces.</td><td>3.1</td></tr>
<tr><td>2.3</td><td>Destructive tests
For each melt, dimensional range and heat treatment lot:
<table>
<tr><th>Number of pieces (St) delivered</th><th>Number of specimen sets</th></tr>
<tr><td>St ≤ 300</td><td>1</td></tr>
<tr><td>300 < St ≤ 800</td><td>2</td></tr>
<tr><td>800 < St ≤ 8000</td><td>4</td></tr>
<tr><td>St > 8000</td><td>Number of specimen sets shall be agreed upon with the authorized expert.</td></tr>
</table>
Tests on each specimen set of bolts:
- one tensile test at room temperature in accordance with DIN EN ISO 6892-1
- If > M14: Notched bar impact test at room temperature: on one set (= three Charpy-V-notch specimens) in accordance with DIN EN ISO 148-1.
- If ≤ M14: one head soundness test.
Test on each specimen set of nuts:
- proof load test.</td><td>3.1</td></tr>
<tr><td>2.4</td><td>Visual examination and dimensional checks
The bolts and nuts shall be subjected to visual examinations and dimensional checks in accordance with the respective product standards. The requirements of **Tables WPB 4.6-1** and **WPB 4.6-2** shall be applied to the number of random specimens, to the acceptance numbers as well as to the characteristics to be tested.
The surface condition of the bolts shall be checked and evaluated in accordance with DIN EN 26157-3 and that of the nuts in accordance with DIN EN ISO 6157-2.</td><td>3.1</td></tr>
</table>

MATERIAL TEST SHEET – WPB 4.6, contd.

2.5	Surface inspection Bolts and nuts by the magnetic particle procedure Procedure and evaluation for the bolts shall be performed in accordance with DIN EN 26157-3 and for the nuts in accordance with DIN EN ISO 6157-2. Cracks are not allowable. The number of random specimens shall be as specified for secondary characteristics in **Table WPB 4.6-2**. The acceptance number is 0.	3.1

Marking:

- Starting material: in accordance with DIN EN 10269
- Bolts and nuts: manufacturer mark, type of steel, code-ID of the starting material

Main Characteristics	Secondary Characteristics
Dimensional thread limits (trueness of gauge) Force application surfaces for assembly Transition below the bolt head Thread base radius at transition from thread to shaft	Lengths (bolt length, thread length) Deviations of shape and position Contact surfaces Elevations (head elevation, nut elevation) Diameter
Note: Further characteristics as well as their classification may be specified in the purchase order.	

Table WPB 4.6-1: The characteristics of bolts and nuts to be inspected during the dimensional check as well as their classification as main and secondary characteristics

Number Pieces in the Test Unit	Number of Random Specimens				Acceptance Numbers	
	Main Characteristics		Secondary Characteristics		Main Characteristics	Secondary Characteristics
	bolts	nuts	bolts	nuts		
up to 150	32	20	20	13	0	0
151 to 280	32	20	80	50	0	1
281 to 500	125	80	80	50	1	1
501 to 1200	125	80	125	80	1	2
1201 to 3200	200	125	200	125	2	3
3201 to 10000	315	200	315	200	3	5

Table WPB 4.6-2: Number of random specimens to be tested dependent on the number of pieces in the test unit – for the visual examination and dimensional checks of bolts and nuts

MATERIAL TEST SHEET **WPB 5.1**

Product form:	Steel castings
Materials:	Quenched and tempered ferritic casting steels in accordance with Annex to this WPB: GS-18 NiMoCr 3 7 (1.6761) with DIN EN 10213: GP240GH (1.0619)
Requirements:	GS-18 NiMoCr 3 7 as specified in this WPB and its Annex GP240GH DIN EN 10213 and as specified in this WPB and its Annex
Specimen sampling and extent of testing:	requirements as specified in this WPB and its Annex

Note:

The points in time for performing the following tests and inspections shall be as shown in the standard flow-chart for the production of cast steel products (cf. **Figure A-1**).

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s) and information on the melting process.	3.1
2.	Product analysis Each melt: one product analysis.	3.1
3.	Attestation of the heat treatment condition including data on the heat treatment temperatures, holding times and cooling-down conditions, including possible simulated annealings of the specimens.	3.1
4.	Tensile test at room temperature in accordance with DIN EN ISO 6892-1 On each tensile test specimen per sampling location. The values to be determined and certified are: $R_{p0,2}$, R_m, A and Z.	3.2 / 3.1 1)
5.	Tensile test at 350 °C in accordance with DIN EN ISO 6892-2 On the tensile test specimen for one sampling location, if the design temperature is higher than 250 °C. The values to be determined and certified are: $R_{p0,2}$, R_m and A.	3.2 / 3.1 1)
6.	Notched bar impact test at ±0 °C in accordance with DIN EN ISO 148-1 Performed for each tensile test under No. 5 of this WPB: one set (= three Charpy-V-notch specimens). The value to be determined and certified is: KV_2.	3.2 / 3.1 1)
7.	Visual examination and dimensional checks Each casting.	3.2 / 3.1 1)
8.	Surface inspection Each product: 100 % by in accordance with DIN EN 1369 Quality class for the magnetic particle test as specified under Section 3.1 of the Annex to this WPB.	3.1
9.	Volume examination Ultrasonic examination in accordance with DIN EN 12680-2 Radiographic testing in accordance with DIN EN 12681 If wall thickness is equal to or larger than 100 mm: each casting 100 % (including production weldings). Quality class for the ultrasonic examination and the radiographic testing as specified under Section 3.1 of the Annex to this WPB. If the wall thickness is smaller than 100 mm: the extent of volume examination as well as the quality class shall be specified by the purchaser.	3.1
10.	Materials identification checks Each steel casting made of GS-18 NiMoCr 3 7	3.1

Marking – type of casting steel, melt number, specimen number, identification marking of manufacturer and, additionally for GS-18 NiMoCr 3 7, marking of authorized expert

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1) In the case of GP240GH an Inspection Certificate 3.1 is sufficient.

Annex to Material Test Sheet WPB 5.1

1 Materials Data and Requirements

1.1 Chemical Composition for the Casting Steel GS-18 NiMoCr 3 7

Elements	**Ladle (cast) Analysis** (mass ratios in %)		**Product Analysis** (mass ratios in %)	
	min.	max.	min.	max.
C	0.17	0.23	0.16	0.23
Si	0.30	0.50	0.25	0.50
Mn	0.70	1.10	0.70	1.20
P	–	0.012	–	0.012
S	–	0.012	–	0.012
Cr	0.30	0.50	0.30	0.50
Mo	0.40	0.60	0.40	0.60
Ni	0.60	1.10	0.60	1.10
Al_{ges}	0.02	0.05	0.02	0.05
Cu	–	0.12	–	0.12
V	–	0.02	–	0.02
Sn	–	0.011	–	0.011
N_{ges}	–	0.015	–	0.015
As	–	0.025	–	0.025

1.2 Mechanical Properties of the Material

The requirements regarding mechanical properties apply to the final heat treatment condition of the component parts. The following table lists the minimum values or ranges of these properties.

Material	Wall thickness in mm	$R_{p0,2}$ in MPa at		R_m in MPa at		A in % at		Z in % at	Absorbed impact energy KV_2 in J at +20 °C	
		RT	350 °C	RT	350 °C	RT	350 °C	RT	EW	MW
GP240GH	≤ 100	240	135	420 to 600	(375)[1]	22	(20)[1]	–	28	40
GS-18 NiMoCr 3 7	≤ 300	390	343	570 to 735	490	16	12	–	34	41

[1] The values in brackets require further statistical validation

RT – room temperature, EW – single value, MW – average value of 3 specimens

1.3 Internal and External Condition

(1) The external condition shall be verified by magnetic particle testing. The internal condition may be verified by an ultrasonic examination or by radiographic testing.

(2) Requirements for the internal and external condition shall be in accordance with DIN EN 1369 and DIN EN 12680-2; the severity level to be verified for the magnetic particle test and for the ultrasonic examination are listed in the following table. For the respective materials

Materials	Indicators for Magnetic Particle Test in accordance with DIN EN 1369	Severity Level for Ultrasonic Test in accordance with DIN EN 12680-2
GS-20 NiMoCr 3 7	SM 2, LM 2, AM 2 [1] SM 3, LM 3, AM 3	2 [1] 3
GP240GH	SM 2, LM 2, AM 2 [1] SM 4, LM 4, AM 4	2 [1] 4

[1] Only those areas where the surface was created by machining procedures.

The radiographic testing shall be performed in accordance with DIN EN 12681.

(3) The surfaces prepared for non-destructive testing shall be assessed by BNIF-visual-tactile comparators in accordance with DIN EN 1370:

a) limit acceptance level for sand-blasted surfaces: at least 3 S1,

b) limit acceptance level for manually ground or swing-ground surfaces: at least 4 S2.

1.4 Processing Guidelines

1.4.1 General requirements

The casting technique shall be designed on the principles of a controlled solidification. For each type of casting the casting technique used shall be recorded and this record shall be added to the internal documentation.

1.4.2 Standard fabrication scheme for steel castings

The fabrication and testing sequence shown in **Figure WPB 5.1-1** shall be adhered to. In the case of deviations, the manufacturer shall establish a test and inspection sequence plan and submit it to the purchaser for design review.

1.4.3 Heat treatment

(1) The steel GP240GH shall be quenched and tempered in accordance with DIN EN 10213

The steel GS-18 NiMoCr 3 7 shall be used in a doubly quenched and tempered condition.

Austenitising:	800 °C to 950 °C with subsequent hardening in water.
Tempering:	650 °C to 700 °C.
Stress-relief heat treatment:	580 °C to 620 °C for the last heat treatment. Intermediate annealings may be performed at about 550 °C

(2) Dependent on the dimensions and chemical composition of the component parts the material manufacturer together with the component manufacturer shall specify the heat-up and cooling rates, the temperatures as well as the holding times such that, under consideration of subsequent heat treatments, the mechanical properties specified under Section 1.2 of this Annex to WPB 5.1 are ensured for the final condition of the entire component.

1.4.4 Production welding

The following requirements shall be met in addition to those in accordance with DIN EN 1559-2:

(1) The fabrication of production welds requires prior welding procedure qualification tests in accordance with DIN EN ISO 11970. The following shall be submitted to the authorized expert for review:

a) welding procedure specification,

b) heat treatment plan,

c) material test plan and test specimen taking plan.

(2) The manufacturer shall write a report on the welding procedure qualification test that shall contain the limits of application and the conditions for fabricating the test coupons. The test results shall be recorded.

(3) Weld filler metals and welding consumables shall have been suitability tested in accordance with VdTÜV-Merkblatt 1153.

(4) The use of a filling piece in production welds is subject to an agreement by the purchaser.

(5) Where inacceptable indications are found by surface crack examinations or volumetric testing, production welds shall be carried out following the standard flow-chart for the production of cast steel products (**Figure WPB 5.1-1**).

(6) Any location prepared for production welding, the depth of which exceeds 40% of the wall thickness, is considered to be a major production weld which shall be documented as shown in **Figure WPB 5.1-1**.

2 Sampling

2.1 Heat Treatment Condition of the Test Coupons

(1) The integrally cast test coupons shall not be cut-in or cut-off before the last quenching and tempering treatment and stamping have been performed. A deviation from this requirement shall be subject to a special agreement.

(2) Test coupons from parts of castings which are to be stress-relief heat treated during further processing shall be subjected to a simulation stress-relief heat treatment prior to preparing the samples. In this case, any stress-relief heat treatment to be performed in the course of further processing of the casting shall be accounted for, including possibly required repair annealing.

Annex to WPB 5.1, contd.

(3) Test coupons from parts of castings for which the number, temperature and time of stress-relief heat treatments cannot be predicted shall be annealed in accordance with the following requirements:

Heating rate:	≤ 100 °C/h beginning at 300 °C
Holding temperature:	620 °C ± 20 K

Holding time upon reaching holding temperature: 15 h ± 1 h

Cooling conditions:	furnace or still air, down to 300 °C

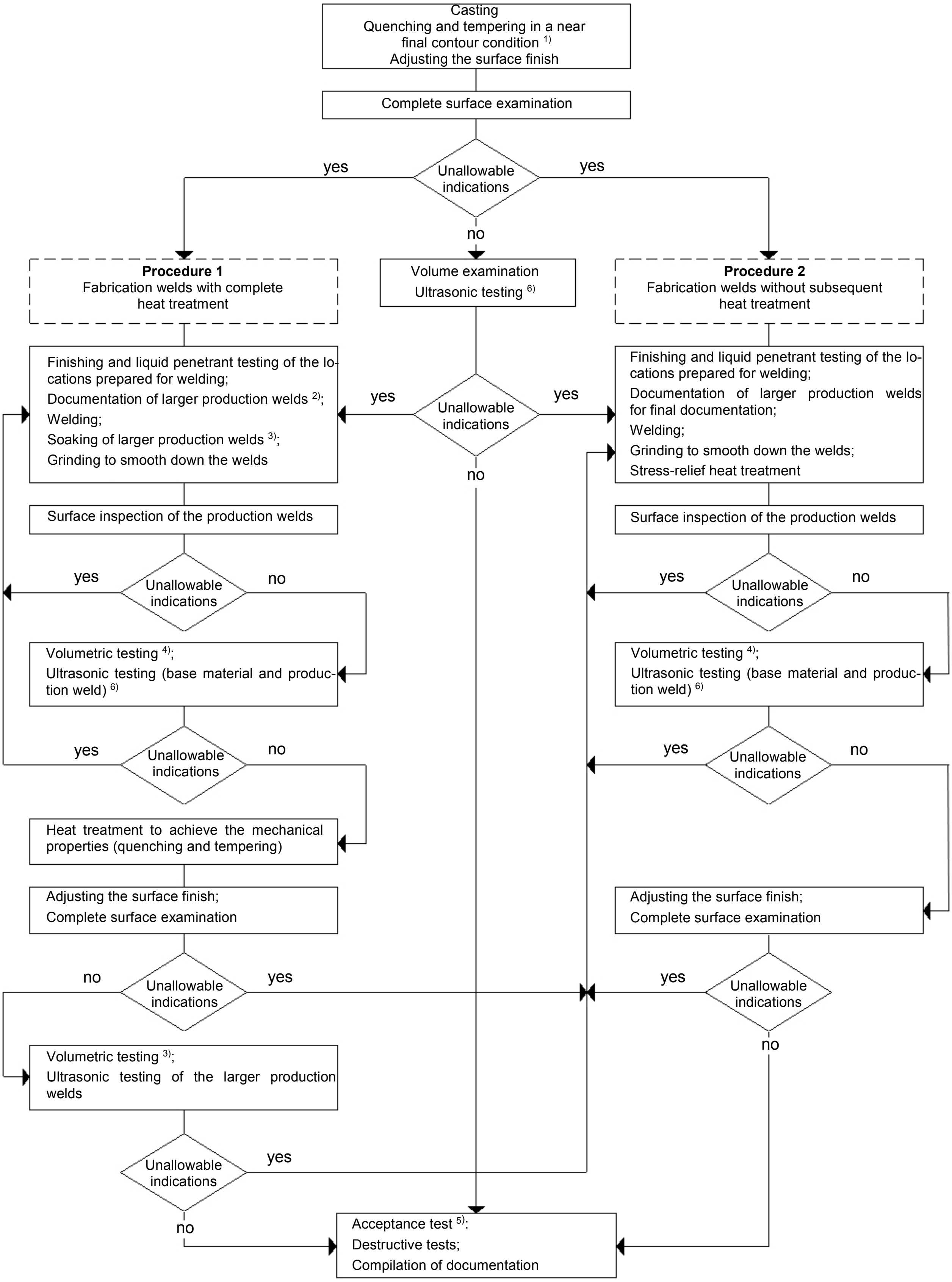
2.2 Number and Sampling Locations of the Test Coupons and the Coupon Orientation

(1) The cast-integral coupons shall be cast integrally with the casting meeting the casting technique requirements or shall be taken from excess lengths. They shall be cast integrally in such number and with such a volume that the specified samples including reserve material for substitute specimens, where necessary, can be removed.

(2) The test coupons for determining the mechanical properties shall be taken from the cast-integral coupons as close as possible to the casting.

(3) The location of the cast-integral coupons shall be documented by photography or sketches which shall be included in the Inspection Certificate. In the case of further cast-integral coupons of the same model with the same specimen location, a copy of the formerly submitted photography or sketch shall be added to the Inspection Certificate.

Annex to WPB 5.1, contd.



[1] When using Procedure 2, the steel casting made from GS-18 NiMoCr 3 7 shall be twice quenched and tempered prior to production welding.

[2] See Annex to WPB 5.1, Section 1.4.4, para. (6).

[3] Applies only to the casting steel GS-18 NiMoCr 3 7.

[4] Note: Previously tested production welds and casting areas with allowable indications do not need to be re-tested.

[5] In exceptional cases, if the manufacturer of the component performs production weldings on a far advanced processing condition of the component, these shall be agreed upon by the purchaser.

[6] In case of a wall thickness (s) smaller than 100 mm, the method for the volumetric testing shall be agreed upon by the purchaser.

Figure WPB 5.1-1: Standard flow-chart for the production welds on cast steel products

MATERIAL TEST SHEET **WPB 5.2**

Product form: Steel castings

Materials: Stainless austenitic and martensitic casting steels in accordance with DIN EN 10213:
GX5CrNiNb19-11 (1.4552)
GX4CrNi13-4 (1.4317)

Requirements: DIN EN 10213 and as specified in this WPB

Specimen sampling and extent of testing: DIN EN 10213 and as specified in this WPB

	Tests and Inspections	Certification in accordance with DIN EN 10204
1.	Chemical composition Chemical analysis of the melt(s).	3.1
2.	Attestation of the heat treatment condition.	3.1
3.	Tensile test at room temperature	3.1
4.	Notched bar impact test at room temperature Performed for each tensile test under No. 3 of this WPB: one set (= three Charpy-V-notch specimens).	3.1
5.	Visual examination and dimensional checks Each casting.	3.1
6.	Surface inspection Each casting: 100 % by liquid penetrant testing in accordance with DIN EN 1371-1 or DIN EN 1371-2 Unless the purchase order specifies an agreed upon quality class, these minimum requirements shall be applied: a) for sand-molding castings: SP 3, CP 3, LP 3, AP 3 in accordance with DIN EN 1371-1 b) for precision castings or ceramic mold castings: SP 1, CP 1, LP 1, AP 1 in accordance with DIN EN 1371-1.	3.1
7.	Volume examination Requirements and extent of testing shall be specified by the purchaser.	3.1
8.	Materials identification checks Each casting: by a suitable procedure.	3.1

Marking – type of steel casting, melt number, specimen number, identification marking of manufacturer

Appendix B

Non-destructive Testing

Contents

B 1 Scope of Appendix B

(1) Appendix B applies to performing non-destructive tests. It contains the procedural requirements and evaluation criteria for non-destructive testing.

(2) Deviations are allowable in well-justified individual cases.

Note:

The procedure, extent and point in time of non-destructive tests are specified in the material test sheets (Appendix A) and the final inspection plans.

B 2 General Requirements

B 2.1 Personnel

(1) The test supervisors shall have the knowledge required for performing their tasks and shall know the application possibilities and limits of the test procedures. It is required that,

a) for the tests to be performed during fabrication, the test supervisors have basic knowledge of the fabrication processes involved and of the characteristic appearance of irregularities caused by fabricating procedures; the test supervisors shall normally be organizationally independent of fabrication and the authorized expert shall be notified of their names.

b) for the tests to be performed during inservice inspection, the test supervisors shall be familiar with the characteristic manifestations of defects caused by operating procedures.

The test supervisors shall be responsible for ensuring both that the test procedures are applied and that the details of testing are carried out in accordance with the relevant specifications. They shall be responsible for the deployment of qualified and certified testers. This also applies to the deployment of external personnel. The test supervisors shall put their signature to the respective test reports.

(2) The test supervisors shall have at least a Level 2 qualification and certification in accordance with DIN EN ISO 9712 for the test procedures to be applied in the respective product or industrial sectors. The test procedures RT (radiological tests) and UT (ultrasonic tests) require a Level 3 qualification and certification.

(3) The testers shall have been qualified and certified in accordance with DIN EN ISO 9712 for the test procedures to be applied in the respective product and industrial sectors. The test procedures RT (radiological tests) and UT (ultrasonic tests) require a Level 2 qualification and certification.

B 2.2 Test Equipment and Test Media

The test equipment and test media to be deployed shall be regularly inspected. Type and interval of the inspections shall be specified by the manufacturer with regard to the required accuracy of the test equipment and test media. The inspections of the test equipment and test media shall be documented by certifications.

B 2.3 Surface Texture Requirements

(1) The surfaces shall be free of scale, weld spatter and other surface contaminants. Any grooves or notches affecting the test results shall be removed.

(2) The arithmetical mean deviation of the section ordinates (average roughness), Ra, for the surfaces to be inspected may not, in accordance with DIN EN ISO 4287, exceed the following values:

a) 10 µm – for the surface inspection with magnetic particle or liquid penetrant testing procedures,

b) 20 µm – for the ultrasonic testing of the contact surface and also for the opposing surface if the latter is used as reflecting surface.

(3) With regard to ultrasonic testing, the waviness of the contact surface shall be small enough for the probe shoe surface to have sufficient contact. This is normally the case if the distance between the probe shoe surface and contact surface does not exceed 0.5 mm at any point.

(4) A coating with a thickness of up to 50 µm is allowable for all non-destructive tests, except for the case of the surface inspection by the liquid penetrant testing procedure.

(5) Residues of the detection media shall be properly removed from the component parts at the end of the tests.

B 2.4 Point in Time of the Fabrication Tests

The product forms shall be tested in the as-delivered condition and the welds in the final-heat treatment condition and before applying a possible coating.

B 3 Procedural Requirements

B 3.1 Surface Inspections by Magnetic Particle and Liquid Penetrant Testing Procedures

B 3.1.1 Viewing conditions

(1) The viewing conditions shall be as required in accordance with DIN EN ISO 3059. In addition, the requirements under paragraphs (2) through (5) shall be observed.

(2) The eyes of the tester shall be given at least 5 minutes to get accustomed to the lighting conditions. It is not allowed to wear photochromatic glasses when inspecting with ultraviolet (UVA) light.

(3) To optimize the detectability of discontinuities for the magnetic particle testing, suitable media (e.g., fluorescing test media, or the application of a thin, barely covering layer of color to the surface) shall be used to provide a sufficient contrast. To improve the contrast for the liquid penetrant testing with fluorescent penetrants, ultraviolet (type UV-A) light may additionally be used.

(4) During the inspection, the angle of vision shall normally not deviate by more than 30° from the surface normal. The viewing distance to the examined surface shall normally be approximately 300 mm.

(5) Auxiliary tools (e.g., magnifying glasses, contrast-increasing eyeglasses, mirrors) are allowed for the inspections.

B 3.1.2 Magnetic particle testing

B 3.1.2.1 Procedure and execution

The magnetic particle testing shall be performed as wet process in accordance with DIN EN ISO 9934-1 and, additionally, observing the requirements specified in the following paragraphs.

B 3.1.2.1.1 Procedure

(1) If partial areas are magnetized by the current flow or the yoke magnetization procedure, alternating-current magnetization shall normally be used.

(2) Unless a lower value is specified, a residual field strength of 800 A/m shall not be exceeded. If the specified value is exceeded, demagnetization is required and the value of the residual field strength reached shall be documented.

(3) The following code letters shall be used for referencing magnetic particle test procedures:

Magnetization Procedure		Code
Yoke magnetization	by permanent magnet	JD
	by electro-magnet	JE
Current conduit magnetization	by coil	LS
	by other conductors (cable)	LK
Current flow magnetization	by direct contact	SS
	by induction	SI

B 3.1.2.1.2 Contact points with current flow magnetization

(1) In the case of current flow magnetization, melting electrodes shall normally be used (e.g., lead-tin alloys), if possible. It shall be ensured that in the contact areas any overheating of the inspected material is avoided.

(2) However, where overheating has occurred, these areas shall be marked and at the end of testing re-ground and subjected to a surface inspection, preferably, by magnetic particle testing by yoke magnetization.

B 3.1.2.1.3 Direction of magnetization

Each location of the surface shall be tested using two different directions of magnetization which shall be offset by approximately 90°.

B 3.1.2.1.4 Magnetic field strength

In the case of alternating-current magnetization, the tangential field strength at the surface shall normally be at least 2 kA/m but may not exceed 6.5 kA/m.

Notes:

a) In low-alloyed and low-carbon non-alloy steels with a high relative permeability the minimum required magnetic flow density of 1 Tesla in the surface of the test object is already achieved at a tangential field strength of 2 kA/m.

b) Other steels with a higher permeability may require a higher field strength.

c) Too strong a magnetization may lead to indications from structural discontinuities (pseudo indications) that can overshadow the relevant indications.

(2) Measurements shall be performed to monitor the adherence to these values, or the test conditions shall be determined under which these values are achieved.

B 3.1.2.1.5 Duration of magnetization

The following reference values apply to the durations of magnetization and application of the test fluid:

a) Magnetization and wetting:	at least 3 seconds
b) Re-magnetization:	at least 5 seconds

B 3.1.2.2 Detection media

(1) The detection media to be applied shall be type tested in accordance with DIN EN ISO 9934-2. The test certificate shall be submitted to the authorized expert.

(2) The particles of the magnetic powder to be applied shall have an average grain diameter less than or equal to 8 µm. Depending on the particular case, black, fluorescent or colored powders may be used.

(3) Immediately prior to wetting the surface, it shall be ensured that the magnetic powder is evenly distributed and kept suspended in the carrier liquid. The powder suspension shall be spot-checked before and during testing using suitable premagnetized test blocks (e.g., No. 1 test blocks in accordance with DIN EN ISO 9934-2).

B 3.1.2.3 Testing equipment

The testing equipment shall meet the requirements in accordance with DIN EN ISO 9934-3.

B 3.1.3 Liquid penetrant testing

B 3.1.3.1 Testing system

(1) Preferably, dye penetrants shall be used. Fluorescent penetrants or fluorescent dye penetrants may also be used.

(2) The intermediate penetrant removers used may either be a solvent or water or a combination of both.

(3) Only those wet developers may be used that use solvents as the carrier fluid. Dry developers may only be applied on the testing surface by electrostatic charging.

(4) The testing system shall meet at least the requirements of the sensitivity class “highly sensitive” in accordance with DIN EN ISO 3452-2.

(5) The suitability of the testing system (penetrant, intermediate penetrant remover and developer) shall be verified by a type test in accordance with DIN EN ISO 3452-2. The test certificate shall be submitted to the authorized expert.

(6) The penetrants in testing facilities and in partly used up open containers (with the exception of aerosol cans) shall be checked by the user with the Control Block 2 in accordance with DIN EN ISO 3452-3. In these checks, the values for the penetration time and developing time specified for the actual test may not be exceeded. The testing sensitivity achieved shall be documented.

B 3.1.3.2 Test procedure

(1) The liquid penetrant test shall be executed in accordance with DIN EN ISO 3452-1 and, additionally, by observing the requirements specified in the following paragraphs.

(2) The penetration time shall normally be at least half an hour.

(3) The first inspection shall normally take place immediately after the developer has dried. An additional inspection should be performed at the earliest half an hour after the first inspection.

(4) Inspection at further points in time are required if indications are detected by one of the first two inspections or if essential changes of indications compared to previous inspections or additional indications are detected.

(5) The evaluation shall be carried out under consideration of all inspection results.

B 3.2 Radiographic Testing

(1) The radiographic testing of weld seams shall be performed in accordance with DIN EN ISO 17636-1, Class B.

(2) Only image quality indicators in accordance with DIN EN ISO 19232-1 shall be used.

B 3.3 Ultrasonic Testing

B 3.3.1 Requirements for test frequencies, crystal size and scanning positions

The test frequencies, crystal sizes and scanning positions shall be as specified under Sections B 4 through B 6. These specifications shall be considered as guide values which may be deviated from in well-justified cases.

B 3.3.2 Test procedure

B 3.3.2.1 Basic test requirements

(1) The product forms shall be tested dependent on the design and material and in accordance with DIN EN 10228-3, DIN EN 10228-4 or DIN EN 10308.

(2) Welds shall be tested as specified under Section B 6.

B 3.3.2.2 Test instruction

Details for performing the ultrasonic testing shall be specified in a test instruction

a) if this is required by the applicable technical standards,

b) if geometries are encountered, the testing of which is not specified under Sections B 4 and B 5, or

c) if attachment welds need to be tested.

B 3.3.2.3 Adjusting the testing sensitivity

(1) The testing sensitivity shall be adjusted using the test object, the Calibration Block No. 1 in accordance with DIN EN ISO 2400 or the Calibration Block No. 2 in accordance with DIN EN ISO 7963 or on other reference blocks with suitable reference reflectors.

(2) The test-relevant characteristics of the reference blocks (material, structural design, shape, wall thickness, heat treatment) shall correspond to those of the test object. The wall thickness of the reference block shall not deviate by more than 10 % from that of the test coupon wall thickness.

(3) Reference reflectors may be back walls, grooves and boreholes.

(4) The testing sensitivity shall be adjusted in accordance with DIN EN ISO 16811.

B 4 Performing and Evaluating the Tests on Product Forms made from Ferritic Steels

B 4.1 Rods and Bars

B 4.1.1 Surface inspection

(1) The entire surface shall be tested in its finished condition. Magnetic particle testing shall, preferably, be used.

(2) The magnetic particle testing shall be performed and evaluated in accordance with DIN EN 10228-1, Quality Class 4. In addition, the requirements specified under Section B 3.1.2 shall be met. The evaluation shall occur during the re-magnetization.

(3) The liquid penetrant testing shall be performed and evaluated in accordance with DIN EN 10228-2, Quality Class 4. In addition, the requirements specified under Section B 3.1.3 shall be met.

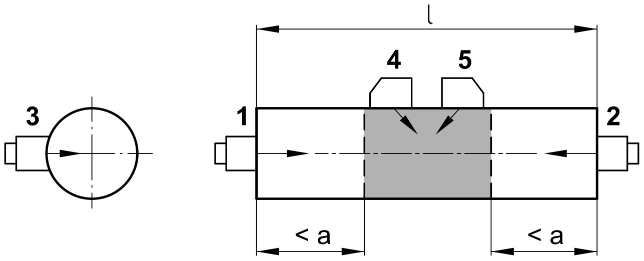
B 4.1.2 Ultrasonic testing

B 4.1.2.1 Performing ultrasonic tests

The ultrasonic testing shall be performed as specified under Section B 3.3.

B 4.1.2.2 Scanning positions, beam entry conditions and evaluation

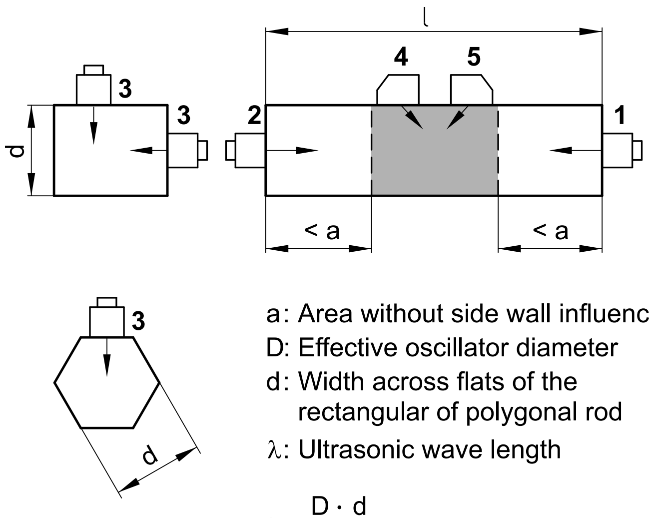
(1) The scanning positions for round bars are shown in **Figure B-1** and for rectangular or polygonal bars in **Figure B-2**.



$$a = \frac{D \cdot d}{2 \cdot \lambda}$$

a : Area without side wall influence
D: Effective oscillator diameter
d : Diameter of round rod
λ: Ultrasonic wave length

Figure B-1: Scanning positions for round rods



a: Area without side wall influence
D: Effective oscillator diameter
d: Width across flats of the rectangular of polygonal rod
λ: Ultrasonic wave length

$$a = \frac{D \cdot d}{2 \cdot \lambda}$$

Figure B-2: Scanning positions for rectangular or polygonal bars

(2) Rods or bars with diameters or edge lengths, respectively, larger than 30 mm shall be subjected 100 % to ultrasonic testing in accordance with DIN EN 10228-3; the requirements specified under paragraphs (3) and (4) shall additionally be observed.

Note:

In case of straight-beam scanning, the requirements in accordance with DIN EN 10228-3 are also met by observing those in accordance with DIN EN 10308.

(3) In case of diameters and edge lengths larger than 60 mm, additional straight-beam scanning is required in axial direction (scanning positions 1 and 2); in this case, if the distance between recording level and noise level of at least 6 dB cannot be achieved over the entire length of the rod or bar, the test shall be performed either on the cut-to-length test object or with angle-beam scanning under 45° in both axial directions (scanning positions 4 and 5).

(4) A testing frequency of 4 MHz shall normally be used.

(5) The test results shall be evaluated corresponding to the following quality classes and the respective recording levels and acceptance criteria in accordance with DIN EN 10228-3:

a) Quality Class 3 – for straight-beam scanning on rods or bars with diameters or edge lengths smaller than or equal to 60 mm,

b) Quality Class 2 – for straight-beam scanning on rods or bars with diameters or edge lengths larger than 60 mm,

c) Quality Class 3 – for angle-beam scanning.

B 4.2 Forgings

B 4.2.1 Surface inspection

B 4.2.1.1 Performance

(1) Magnetic particle testing shall be performed on the product on its finished surface condition as specified under Section B 3.1.2. The results shall be evaluated during the re-magnetization.

(2) Liquid penetrant testing shall be performed on the product on its finished surface condition as specified under Section B 3.1.3.

B 4.2.1.2 Evaluation

The results shall be evaluated as specified under Section B 4.1.1.

B 4.2.2 Ultrasonic testing

B 4.2.2.1 Performing ultrasonic tests

The ultrasonic testing shall be performed as specified under Section B 3.3.

B 4.2.2.2 Extent and point in time of testing

The entire volume of the product shall be subjected to ultrasonic testing at a time when the product is in its most simple geometric condition.

B 4.2.2.3 Scanning positions, beam entry conditions and evaluation for plates and sheets

(1) The scanning positions are shown in **Figure B-3**. The scanning position 2 is required only for wall thicknesses larger than 60 mm.

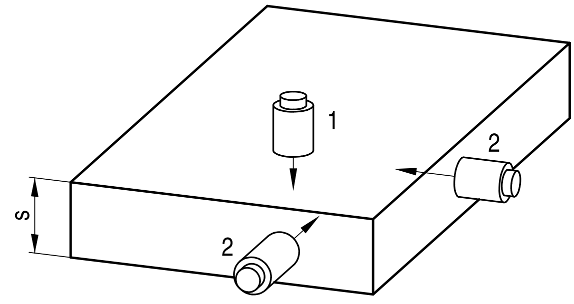


Figure B-3: Scanning positions for plates and sheets

(2) A testing frequency of 4 MHz shall normally be used.

(3) 100 % of the product shall be subjected to ultrasonic testing in accordance with DIN EN 10228-3.

(4) The results shall be evaluated corresponding to the following quality classes and the respective recording levels and acceptance criteria in accordance with DIN EN 10228-3:

a) Quality Class 3 – if wall thickness is smaller than or equal to 60 mm,

b) Quality Class 2 – if wall thicknesses larger than 60 mm.

B 4.2.2.4 Scanning positions, beam entry conditions and evaluation for open-die forgings

(1) The forgings shall be tested such that each volumetric region is tested from at least two scanning positions offset by about 90 degrees. If this cannot be achieved by straight-beam scanning, then angle-beam scanning shall be used. The details for performing the ultrasonic testing shall be specified in a test instruction.

(2) A testing frequency of 4 MHz shall normally be used.

(3) The product shall be subjected 100 % to ultrasonic testing in accordance with DIN EN 10228-3.

(4) The test results shall be evaluated corresponding to the following quality classes and the respective recording levels and acceptance criteria in accordance with DIN EN 10228-3:

a) Quality Class 2 – for straight-beam scanning,

b) Quality Class 3 – for angle-beam scanning.

B 5 Performing and Evaluating the Tests on Product Forms (Rolled or Forged Products) made from Austenitic Steels

B 5.1 Surface Inspection

(1) The entire surface shall be tested in its finished condition.

(2) The tests shall be performed and evaluated in accordance with DIN EN 10228-2, Quality Class 4. In addition, the requirements specified under Section B 3.1.3 shall be met.

B 5.2 Ultrasonic Testing

B 5.2.1 Extent and point in time of testing

The entire volume of the product shall be subjected to ultrasonic testing at a time when the product is in its most simple geometric condition (plane-parallel or cylindrical surfaces, if necessary pre-machined).

B 5.2.2 Determining the testability

(1) To determine the testability, each test object shall be examined by grid-wise straight-beam scanning in direction of wall thickness in order to measure the back-wall echo amplitudes. Reference echoes (e.g., available bore holes, edges, straight-through beaming) shall be used for these tests in regions with non-parallel or non-concentric walls.

(2) For the region with the highest sonic attenuation it shall be verified that the required recording levels are achievable.

B 5.2.3 Beam entry conditions and test frequencies

The beam entry conditions shall be as specified under Section B 4. The test frequencies may range from 2 MHz to 4 MHz.

B 5.2.4 Performing and evaluating the ultrasonic tests

(1) The tests shall be performed as specified under Section B 4, however, not in accordance with DIN EN 10228-3 but in accordance with DIN EN 10228-4.

(2) The results shall be evaluated corresponding to the following quality classes and the respective recording levels and acceptance criteria in accordance with DIN EN 10228-4:

a) Quality Class 2 – for the straight-beam scanning on rods or bars with diameters or edge lengths smaller than or equal to 250 mm,

b) Quality Class 3 – for the straight-beam scanning on rods or bars with diameters or edge lengths larger than 250 mm.

B 6 Performing and Evaluating the Tests on Weld Connections

B 6.1 General Requirements

The region to be tested includes the weld metal and the weld-adjoining base material for a width of

a) 10 mm on both sides of the weld in case of wall thicknesses equal to or smaller than 30 mm,

b) 20 mm on both sides of the weld in case of wall thicknesses larger than 30 mm.

B 6.2 Ultrasonic Testing of the Weld-Adjoining Regions of Metal Sheets

(1) The ultrasonic testing of the weld-adjoining regions shall be performed in accordance with

a) DIN EN 10160 in case of ferritic metal sheets,

b) DIN EN 10307 in case of austenitic metal sheets.

(2) The tests shall be performed with a recording level equal to a disc-shaped reflector KSR 3.

(3) The weld-adjoining regions shall meet the requirements of Quality Class E_4.

B 6.3 Non-destructive Testing of Butt Welds and Attachment Welds

(1) The examinations shall be performed and evaluated meeting the requirements of the respective execution class in accordance with DIN EN 1090-2

(2) Double bevel butt welds on steels with $R_{p0.2} > 355$ N/mm^2 shall, additionally, be checked for under-bead cracks. Here, the creeping wave technique shall be used. The recording level shall be equal to the echo amplitude of a flat-bottom bore hole with the diameter equal to 3 mm. No indications are allowable that reach or exceed the recording level.

Note:

The creeping wave technique is described in safety standard KTA 3201.3, App. C, Sec. C 6.

Appendix C

Nomenclature of the Equations

d, D	nominal thread diameter of the threaded part or hole diameter
Δd	bore hole tolerance
E	distance from the edge
F_{Rd}	design value for the load capacity
f_u	nominal value of tensile strength at room temperature (RT)
f_{uT}	nominal value of tensile strength at temperature (T)
F_V	pre-load force
f_y	nominal value of yield strength at room temperature (RT)
f_{yT}	nominal value of yield strength at temperature (T)
GV	slip resistant bolted connection
GVP	slip resistant bolted connection with fit bolts
K	Reduction factor for determining the yield strength at elevated temperatures and the tensile strength in dependence of the temperature
L	decay length
L	effective length
P_b	bending stress
P_l	local primary membrane stress
P_m	general primary membrane stress
Q	secondary stress
R	mean radius for shell-type support structures (e.g., frames, tubular nozzles) or – for other shapes – one-half the largest dimension of a flange, T-section, round section or plate, or one-half the maximum leg width of an angle section
R_{eH}	yield strength at room temperature (RT)
R_{eHT}	yield strength at temperature (T)
R_m	tensile strength at room temperature (RT)
R_{mT}	tensile strength at temperature (T)
$R_{p0,2}$	0.2 % proof stress at room temperature (RT)
$R_{p0,2T}$	0.2 % proof stress at temperature (T)
$R_{p1,0T}$	1.0 % proof stress at temperature (T)
$R_{v0,2}$	equivalent yield stress
S	wall thickness of plates, or web thickness of girders (beams), or thickness of shell-type support structures
S_m	design stress intensity
SL	shear bearing bolted connection
SLP	shear bearing bolted connection with fit bolts
T	smallest plate thickness
Z	tensile force of the bolt
zul.Q	allowable lateral force
zul.Z	allowable tensile force of the bolt
$\text{zul.}Q_{GV,Z}$	allowable transferrable shear force of slip resistant bolted connections
$\text{zul.}Q_{GVP,Z}$	allowable transferrable shear force of slip resistant bolted connections with fit bolts
γ_F	partial safety factor for actions
γ_M	safety factors for load combinations
γ_{M0}	partial safety factor for resistance of cross-sections
γ_{M1}	partial safety factor for the resistance in case of loss of stability
γ_{M2}	for the resistance in case of loss of stability due to tensile loading
ΔT	temperature increase
$\sigma_H(T)$	allowable Hertzian contact stress at temperature (T)
σ_V	reference stress/reference values (for welds)
σ_x	normal stress in the decisive cross-section of the girder (beam)
μ	friction coefficient
ψ	safety factors for load combinations

Appendix D

Pip-Whip Restraints

Contents

D 1 General Requirements

(1) Wherever a pipe rupture is possible, technical measures shall be installed to prevent unacceptable damaging effects from whipping or column-buckling pipe ends. One such measure limiting pipe movements is the installation of pipe-whip restraints.

(2) Pipe movements shall not impair the function or integrity of safety-related components and systems needed to mitigate the consequences of design basis accidents.

(3) Pipe-whip restraints will be necessary if the requirements specified under items a) through d) are not fulfilled:

a) It is certified that a postulated pipe rupture will cause only allowable pipe movements considering the energy stored in the piping.

b) Sufficient spatial separation is provided between the ruptured pipe run and the safety-related components and systems.

c) Any possible effects from a pipe rupture are limited by building or structural parts (e.g., ceilings, walls, platforms, platform supports).

d) A supercritical failure (cf. safety standard KTA 3211.3, Sec. 14) of pipe welds can be excluded.

(4) If anchors and supports of pipelines, or vibration dampers and shock absorbers can function as pipe-whip restraints then these items shall meet the requirements of this Appendix in case of the load case “Pipe rupture”.

D 2 Design Principles

Note:

The design procedure described below is based on the σ_{zul}-procedure. It is also possible to apply the procedure using partial safety factors.

(1) When applying the procedure using partial safety factors, an increased resistance due to the short duration of the load may be considered, however, only in agreement with the authorized expert.

(2) The principal design feature of a pipe-whip restraint is the load transfer of a one-time short impact loading – caused by time-varying jet thrust reaction forces during pipe rupture – and to limit the various deformations. The design measures shall be such that operation of the overall plant is ensured, e.g.:

a) no unallowed restraint of the pipeline during specified normal operation,

b) no unallowed development of thermal bridges.

(3) The design shall strive to achieve a simple geometry of the pipe-whip restraints and sufficient accessibility regarding inspections of the pipelines.

(4) Pipe-whip restraints shall be designed one single mitigation of a design basis accident. Therefore, under the conditions of section D 4.5 plastic deformations of pipe-whip restraints are allowed. Also, the damping elements between the piping and the pipe-whip restraint may be designed to absorb energy. All components of a pipe-whip restraint designed to undergo plastic deformation shall be replaced after they were subjected to a design specific loading.

(5) The functioning of pipe-whip restraints shall be ensured as follows:

a) by a loose enclosure of the piping, or

b) by frictional connections (integral or non-integral connections).

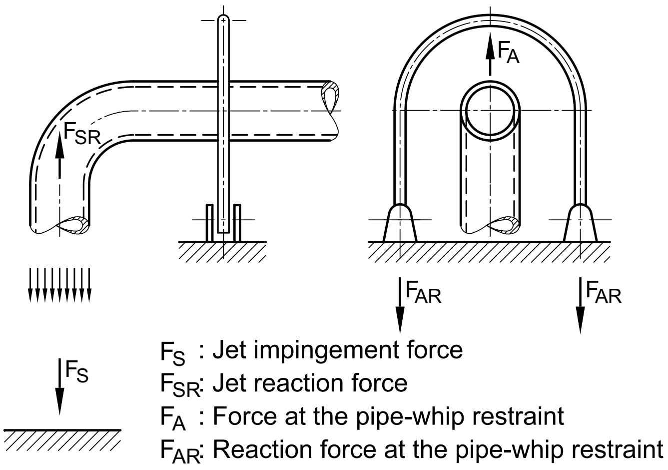
(6) A deformation limit certification is normally required to assure proper functioning.

(7) If deformation limitation of the pipe-whip restraint is required, this shall be specified in the design data sheet. Depending on the protective goal the pipe-whip restraint shall be classified under load case HS1, HS2 or HS3.

D 3 Design Loads

D 3.1 General Requirements

The designations of the forces occurring during pipe rupture are shown in **Figure D-1** for the example of a crack.



F_S : Jet impingement force
F_{SR}: Jet reaction force
F_A : Force at the pipe-whip restraint
F_{AR}: Reaction force at the pipe-whip restraint

Figure D-1: Notation of forces caused by leaking fluid due to cracking

D 3.2 Boundary Conditions for the Analysis

(1) The arrangement and design of pipe-whip restraints shall be subject to the effects of rupture occurring.

(2) The determining quantities governing the loading of pipe-whip restraints are:

a) jet reaction force,

b) pipe stiffness,

c) pipe mass (including fluid, insulation),

d) pipe guidance,

e) maximum unimpeded movement (free whip) of pipe until limitation by pipe-whip restraint,

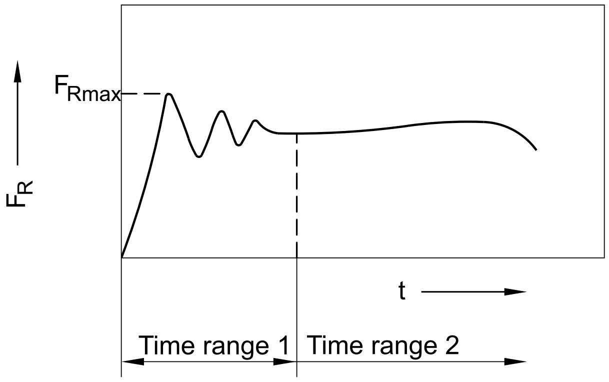
f) stiffness of pipe-whip restraint,

g) plastic deformability of piping and pipe-whip restraint.

(3) For the analysis of the pipe-whip restraint behaviour (load as function of time) due to pipe rupture the loading function (qualitative course in **Figure D-2**) can be divided into two time ranges.

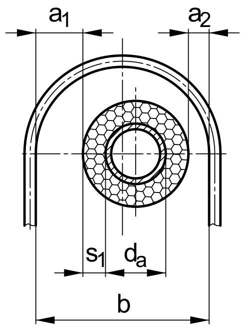
(4) The pipe-whip restraint loading within Time Range 1 shall be verified by a dynamic analysis or a suitable approximation method ("Biggs" method). The possibility of rebound due to the elastic energy store in the pipe/pipe-whip restraint shall be taken into account.

(5) For the determination of the thrust loading the maximum possible free movement s of the piping shall be used, if required by adding the elastic deformation. In the case of loose enclosures s may be determined by means of **Figure D-3**.



Time range 1: Dynamic loading
Time range 2: Quasi-stationary loading from jet impingment force

Figure D-2: Loading of the pipe-whip restraint



$s = b - d_a - s_1 - a_1$ (if thermal insulation is completely deformed)

b : clear width of whipping direction
d_a: outside diameter of pipe
s_1: thickness of thermal insulation
a_1, a_2: distance between thermal insulation and pipe-whip restraint, depending on direction of movement

Figure D-3: Maximum free whipping path s

D 4 Design Models and Design Limits

D 4.1 Design Models

(1) Well-suited design models are energy balance models, e.g., the spring/mass model.

(2) A static certification of the thrust-loaded pipe-whip restraint on the basis of load factors derived from the dynamic analysis of a similar structure is allowable. The transfer of these load factors shall take the conditions specified under Section D 3 into account.

(3) The consideration of plastic behavior of the load supporting structure of pipe-whip restraints shall be based on a load deformation diagram. The load deformation diagram may be determined from an acknowledged analysis procedure or from representative experiments.

(4) The determination of the load deformation characteristic used in the analysis shall consider the following:

a) The maximum stiffness and strength values shall be assumed in the calculation of the transferred loadings and in the stress analysis,

b) The minimum stiffness and strength values shall be assumed for the deformation certification.

D 4.2 Analysis and Design Principles

(1) An elastic analysis of case of pipe-whip restraints shall be based on the principles specified under Section 4.3.

(2) The design principles specified under Section 5 shall be observed.

D 4.3 Allowable Stresses

D 4.3.1 Base material of the load-supporting structure

The allowable stress values to be applied for the base material of the load-supporting structure shall be as listed in **Table D-1**.

D 4.3.2 Welded connections

The allowable stress values to be applied for the welded connections shall be those listed for load case HS3 in **Table 4-7**.

D 4.3.3 Bolted connections

The allowable stress values to be applied for bolts shall be those listed for load case HS3 in **Table 4-8** and **Table 4-10**.

D 4.4 Certification of Stability

The stability shall be verified (against column buckling, lateral tilting, buckling) as specified for load case HS3 under Section 4.3.

D 4.5 Plastification of the Structure due to Dynamic Loading

A plastification of the load-supporting structure and the energy-absorbing elements is allowable, provided, it can be analytically substantiated that for the material of tension members the uniform strain does not exceed 50 %. In the case of special pressure-loaded damping elements, e.g., shock pipes, higher values are allowable upon agreement with the authorized expert.

D 5 Materials

(1) The materials listed in Section 6 are allowed to be used for pipe-whip restraints. Other materials may be used upon agreement with the authorized inspector.

(2) For component parts strained into the plastic range only those materials may be used for which pronounced deformation properties are certified (e.g., elongation at fracture larger than 20 %, Quality Class Z25 or Z35 in accordance with DIN EN 10164).

D 6 Manufacturing and Assembly

The requirements specified under Section 7 shall be applied.

D 7 Tests and Inspections

D 7.1 General Requirements

The requirements specified under Section 7 and Section 8 shall be applied.

D 7.2 Final and Acceptance Inspection at the Manufacturing Plant and at the Building Site

The tests and inspections shall be based on the respective documents with affixed marks of approval by the authorized expert. The tests and inspections of component parts made from materials specified under Section D 5, para. (1) shall be performed as listed in **Table D-2**.

D 7.3 Tests and Inspections to be Performed During Commissioning and Inservice Inspections

(1) Within putting into operation and periodic inspections, tests and inspections shall be performed on pipe-whip restraints of the respective pipelines in accordance with **Table D-3**.

(2) The extent of, and requirements for the tests and inspections shall be specified bases of the individual power plant.

(3) The licensee shall keep test records on all inservice inspections.

D 8 Documentation

The requirements specified under Section 3 shall be applied.

Ser. No.	Type of Loading		Allowable Stress (in relation to $R_{v0,2)}$
1	Bending tension and bending compression if no certification of stability is required		1.26
2	Tension		1.10
3	Pressure and bending compression (certification of stability) 1)		0.90
4	Shear		0.73
5	Reference stress		1.26
6	Bearing pressure at connection 2) due to	SL without pre-tensioning 3)	1.90
7		SL unplanned pre-tensioning	2.56
8		SLP without pre-tensioning	2.20
9		SLP unplanned pre-tensioning	2.73
10		GV pre-tensioned 4) GVP	3.00

1) For austenitic materials 1.5 times the value of load case H listed in **Table 4-6** shall be applied.

2) The bolts and bore hole tolerance shall be specified as listed in **Table 4-6**.

3) For slotted holes 100 % of the listed values apply in the longitudinal direction and 70 % in the transverse direction.

4) For austenites: see Section 4.1.6, paragraph (5) .

SL : shear bearing bolted connection
SLP : shear bearing bolted connection with fit bolts
GV : slip-resistant bolted connection
GVP : slip-resistant bolted connection with fit bolts

Table D-1: Allowable stresses (in relation to $R_{v0,2}$) for the component parts of pipe-whip restraints

Ser. No.	Type of test or Inspection	Manufacturing Plant	Building Site
1	Manufacturer qualification regarding product forms, shop fabrication, assembly as specified under Section 7	S	S
2	Welder qualification as specified under Section 7	S	S
3	Checking product form markings with comparison of the certificates prior to fabrication	H, (S) 2)	H 1), (S)
4	Checking weld filler metals and consumables including their storage	H, (S)	H, (S)
5	Checking weld seam preparation and adaptation	H, (S)	H, (S)
6	Checking welding task for conformance with welding procedure specification	H, (S)	H, (S)
7	Checking of heat treatment	H, (S) 3)	H 1), (S) 3)
8	Visual inspection and dimensional check in accordance with design review documents	H, (S)	H, (S)
9	Checking control data sheets	S	S
10	Checking for transportation damage	—	H, S
11	Check of assembly and installation	—	H, S
12	Check for completeness of documentation	H, S	H, S
13	Visual inspection of welds in accordance with DIN EN ISO 5817, Quality Class D	H, S	H 1), S 1)
14	Checking the accessibility regarding periodic inspection of pipelines	—	H, S
15	Checking the specified gaps between piping and pipe-whip restraint	—	H, S
16	Checking the anti-corrosive coating	—	H
17	Surface inspection as detailed in Appendix B of welds certified for a specific weld quality; Checking tack and attachment weld locations after removal of temporary welds for arc strikes and contact points as detailed in Appendix B	H (100 %) S (10 %)	H (100 %) S (10 %)
18	Ultrasonic testing or radiography as specified in Appendix B on full-penetration welds (certification of quality as listed in **Table 4-7**)	H (100 %) S (10 %)	H (100 %) S (10 %)

1) Unless performed at the manufacturing plant.

2) In the case of earl final inspection at the manufacturing plant.

3) Shall be specified during design review.

S : Authorized expert H : Manufacturer

Table D-2: Tests and inspections for pipe-whip restraints

Ser. No.	Type of test/inspection	Performed during	
		Commissioning	Inservice Inspections
1	Checking of specified distances between piping and pipe-whip restraint in the hot condition 1)	H, S	G, S
2	Checking bolted connections for firm tightening	—	G, S
3	Visual inspection	—	G, S

1) If, since commissioning, exact knowledge on pipe movements was attained by measurement at representative locations, inservice inspections on pipe-whip restraints may be waived even in the hot condition.

G : Licensee H : Manufacturer S : Authorized expert

Table D-3: Tests and inspections during commissioning, and inservice inspections

Appendix E

Dimensioning and Stress Determination Method

Contents

E 1 Scope of Application

The following requirements apply to the general stress analysis by the procedure of allowable stresses.

E 2 Determination of Stresses for Bar-Type Component Parts

E 2.1 Nomenclature

The nomenclature used in equations (E 2-1) through (E 2-19) and in **Figure E 2-1** is as follows:

Coordinates:

x	centroidal axis
y, z	major axes of cross-section

Stress resultants:

N	longitudinal force in the x-direction
Q_y, Q_z	transverse forces
M_y, M_z	bending moments (moment vectors)
M_T (M_X)	torsional moments in the x-direction
S	1st order moment of area (static moment) of the unperforated parts of the cross-section, in relation to the centroidal axis of the unperforated cross-section
S_y, S_z	static moments
I	moment of inertia (2nd order moment of area) of the unperforated cross-section
I_y, I_z	moments of inertia
W	section modulus
W_y, W_z	section moduli
W_D, W_Z	determining section moduli for the edge compressive stress and edge tensile stress
A	area of the unperforated cross-section
ΔA	sum of all hole areas lying on that crack line that results in the smallest value of $A-\Delta A$
A_{Qy}, A_{Qz}	transverse force area capable of withstanding the analytically approximated shear forces acting on it due to a transverse force
t	thickness of partial cross-section capable of withstanding the transverse force

Stresses:

σ_x	normal stress due to N, M_y and M_z
σ_D	compressive stress
σ_Z	tensile stress
σ_y, σ_z	normal stresses due to a local force transfer
τ_{xy}, τ_{xz}	shear stress in cross-section (surface-normal x) in the directions y or z due to Q_y, Q_z and M_T
τ_m	average value of shear stress in the cross-section to be verified
τ_Q	shear stress due to transverse force

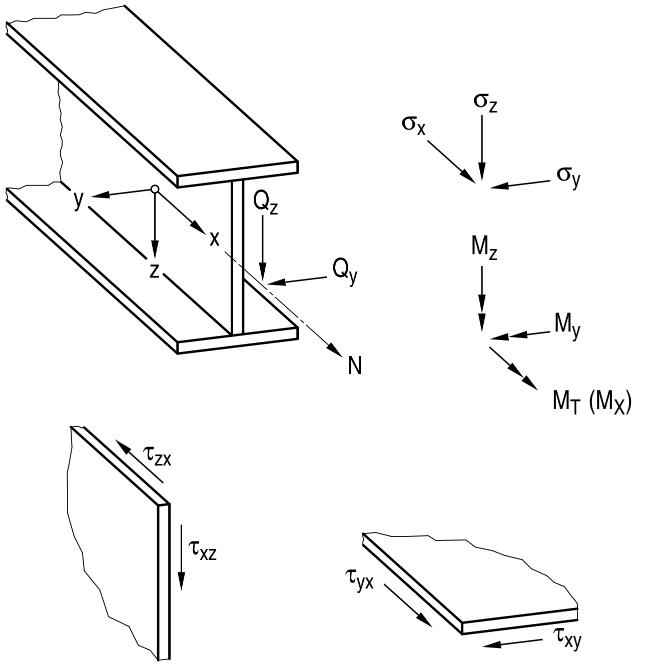


Figure E 2-1: Coordinate system for stress resultants and loadings

E 2.2 Loading by Longitudinal Force, N

(1) For a component part subject to a longitudinal (axial) force the verification shall be performed based on equations (E 2-1) and (E 2-2).

Compression, N < 0; $\sigma_D = \left|\frac{N}{A}\right| \le \sigma_{zul}$ (E 2-1)

Tension, N > 0; $\sigma_Z = \frac{N}{A - \Delta A} \le \sigma_{zul}$ (E 2-2)

(2) In the case of tension bars with an asymmetric connection by only one bolt, the verification shall be performed for the weaker portion of the net cross-section with one half of the force to be transmitted.

E 2.3 Loading by a Transverse Force Q_y or Q_z

(1) For a component part subjected to a transverse force Q_y or Q_z the shear stress shall be verified based on equation (E 2-3):

$$\left.\begin{aligned}\tau_{Q_y\,\max} &= \frac{Q_y \cdot S_{z\,\max}}{I_z \cdot t}\\ &\text{or}\\ \tau_{Q_z\,\max} &= \frac{Q_z \cdot S_{y\,\max}}{I_y \cdot t}\end{aligned}\right\} \le \tau_{zul} \qquad \text{(E 2-3)}$$

(2) The maximum shear load τ_{max} may exceed the allowable shear stress τ_{zul} by up to 10 % (equation (E 2-4)), provided, the average shear stress τ_m of one portion of the cross-section does not exceed the allowable shear stress τ_{zul} (equation (E 2-5)).

$$\left.\begin{aligned}\tau_{Q_y\,\max} &= \frac{Q_y \cdot S_{z\,\max}}{I_z \cdot t}\\ &\text{or}\\ \tau_{Q_z\,\max} &= \frac{Q_z \cdot S_{y\,\max}}{I_y \cdot t}\end{aligned}\right\} \le 1.1 \cdot \tau_{zul} \qquad \text{(E 2-4)}$$

$$\left.\begin{aligned}\tau_{Q_y,m} &= \frac{Q_y}{A_{Q_y}}\\ &\text{or}\\ \tau_{Q_z,m} &= \frac{Q_z}{A_{Q_z}}\end{aligned}\right\} \le \tau_{zul} \qquad \text{(E 2-5)}$$

(3) If shear stress components caused by the transverse forces Q_y and Q_z as well torsion occur simultaneously, the sum of the shear stresses shall be calculated according to equations (E 2-6) or (E 2-7) and equation (E 2-8):

$$\max\left(\tau_{Q_y} + \tau_{Q_z} + \tau_T\right) \le \tau_{zul} \qquad \text{(E 2-6)}$$

$$\max\left(\tau_{Q_y} + \tau_{Q_z} + \tau_T\right) \le 1.1 \cdot \tau_{zul} \qquad \text{(E 2-7)}$$

$$\left.\begin{aligned}&\tau_{Q_y} + \tau_{Q_z,m} + \tau_T\\ &\tau_{Q_y,m} + \tau_{Q_z} + \tau_T\end{aligned}\right\} \le \tau_{zul} \qquad \text{(E 2-8)}$$

E 2.4 Loading by a Bending Moment, M_y or M_z

For a component part subjected to a bending moment M_y or M_z, the verification shall be performed based on equations (E 2-9) and (E 2-10):

Bending compression:

$$\sigma_D = \max\left\{\left|\frac{M_y}{W_{D,y}}\right|;\ \left|\frac{M_z}{W_{D,z}}\right|\right\} \le \sigma_{zul} \qquad \text{(E 2-9)}$$

Bending tension:

$$\sigma_Z = \max\left\{\left|\frac{M_y}{W_{Z,y}}\right|\ ;\ \left|\frac{M_z}{W_{Z,z}}\right|\right\} \le \sigma_{zul} \qquad \text{(E 2-10)}$$

E 2.5 Loading by a Torsional Moment, M_T

For a component part subjected to a torsional moment M_T the resulting shear stresses τ shall be determined following the St. Venant method; the warping stresses shall also be determined where necessary.

E 2.6 Simultaneous Loading by a Longitudinal Force, N, and by Bending Moments, M_y and M_z

Where a component part is subjected to a longitudinal force, N (σ_N), and bending moments, M_y and M_z (σ_{My}, σ_{Mz}), the individual stress portions calculated for the parts of the forces and moments as specified under Sections E 2.1 and E 2.3 shall be combined for the determining edge or corner points. The verifications shall be performed based on equations (E 2-11), (E 2-12) or (E 2-14):

Longitudinal force and uniaxial bending (N and M_y or N and M_z):

$$\left.\begin{array}{l}\left|\sigma_N + \sigma_{M_y}\right| \\ \\ \left|\sigma_N + \sigma_{M_z}\right|\end{array}\right\} \leq \sigma_{zul} \qquad \text{(E 2-11)}$$

Longitudinal force and biaxial bending (N and M_y and M_z):

$$\left|\sigma_N + \sigma_{M_y} + \sigma_{M_z}\right| \leq \sigma_{zul} \qquad \text{(E 2-12)}$$

If each of the following expressions is satisfied

$$\left.\begin{array}{l}\left|\sigma_N + \sigma_{M_y}\right| \\ \\ \left|\sigma_N + \sigma_{M_z}\right|\end{array}\right\} \leq 0.8 \cdot \sigma_{zul} \qquad \text{(E 2-13)}$$

the maximum edge stress may be calculated as

$$\left|\sigma_N + \sigma_{M_y} + \sigma_{M_z}\right| \leq 1.1 \cdot \sigma_{zul} \qquad \text{(E 2-14)}$$

E 2.7 Biaxial Stress Conditions

(1) In the case of biaxial stress conditions, the combined action of the individual stresses (e.g., σ_x, σ_y and τ) shall be verified based on a reference stress calculated using equation (E 2-15):

$$\sigma_V = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3 \cdot \tau^2} \leq \sigma_{zul} \qquad \text{(E 2-15)}$$

(2) In the case of bending girders (beams) which are loaded exclusively by transverse forces and uniaxial bending, the verification may, instead of (E 2-15), be based on equation (E 2-16).

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} \leq 1.1 \cdot \sigma_{zul} \qquad \text{(E 2-16)}$$

(3) Regarding the certifications by equations (E 2-15) or (E 2-16), the average shear stress, τ_m, specified under Sections E 2.3 and E 2.5 may be used instead of τ.

E 2.8 Loading of Connections

(1) The loading of the connecting cross-sectional parts shall be calculated from the relative stress resultants of this cross-sectional part.

(2) In the case of doubly symmetric **I**-shaped bending girders (beams) with the stress resultants N, M_y and Q_z, the certification of the connection loads may be simplified by using the following relative stress resultants:

Tensile flange: $$N_Z = \frac{N}{2} + \frac{M_y}{h_F} \qquad \text{(E 2-17)}$$

Pressure flange: $$N_D = \frac{N}{2} - \frac{M_y}{h_F} \qquad \text{(E 2-18)}$$

Web: $$Q_{St} = Q_Z \qquad \text{(E 2-19)}$$

where h_F is the distance between the centers of gravity of the flanges. This assumes that the allowable stresses in the flanges and the web will not be exceeded.

E 3 Calculation of Stresses for Welded Connections

E 3.1 Arc-Welded Connections

The nomenclature used in equations (E 3-1) through (E 3-5) and in the following figures is as follows:

A_w	mathematical weld seam area The calculation shall consider only areas of those weld seams which, due to their location, are predominately in a position to transfer the stress resultants of the connection.
F	transferred stress resultant (longitudinal force N, transverse force Q)
I_w	2nd order moment of area (moment of inertia) of the weld seam cross-section
$z_{1....4}$	distance of welds from the centroidal axes of the connected surfaces (cf. **Figure E 3-1**)
a	weld thickness
Σa	sum of the respective weld thicknesses for the connected cross-sectional areas
$a_{F1...4}$	weld thicknesses for the connection of flanges
a_{St}	weld thickness for connection of the webs
e	non-welded length in the case of intermittent welds
ℓ	weld seam length
$\sigma_\perp$	normal stress transverse to direction of weld
$\tau_\perp$	shear stress transverse to direction of weld
σ_{II}	normal stress in direction of weld
τ_{II}	shear stress in direction of weld
t	thickness of the component parts to be welded

cf. **Figure E 3-2**

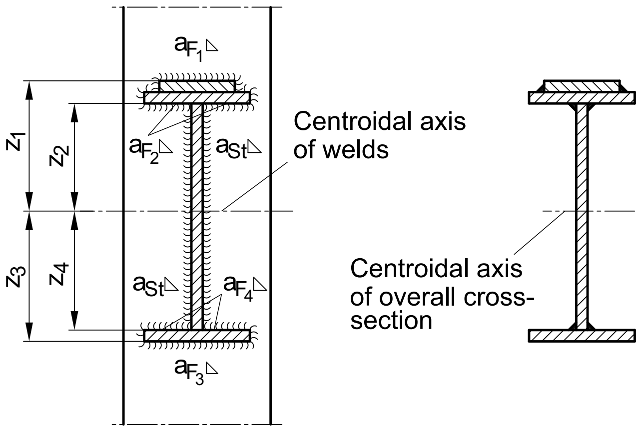


Figure E 3-1: Bending resistant girder (beam) connection

Note

The position of the centroidal axis of the overall cross-section and the centroidal axis of the connected areas (welds) are not identical.

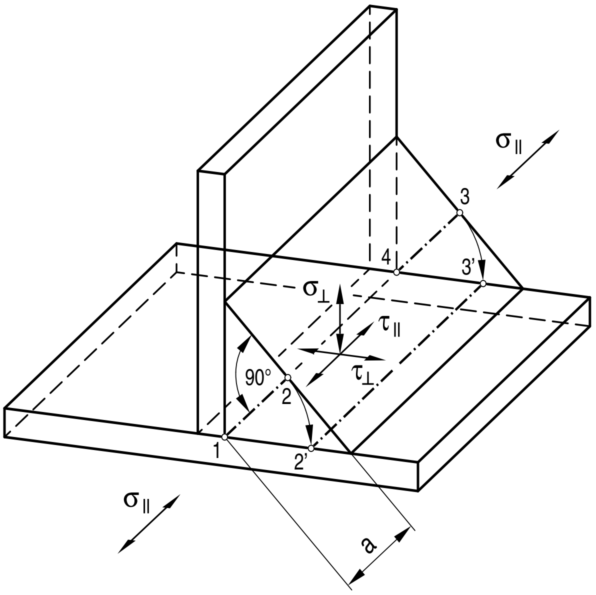


Figure E 3-2: Possible directions of stresses in the fillet weld

E 3.1.1 Dimensions and cross-sections

(1) The dimensions and cross-sections of welded connections shall be calculated as follows:

The mathematical weld seam thickness (a) shall be chosen as listed for the various weld types in **Table E 3-1**. Other than the weld types listed shall be analogously dealt with.

The mathematical weld seam length (ℓ) of a weld seam is its geometrical length. In case of fillet welds, ℓ is equal to the length of the root weld. Fillet welds may be considered in the verification, provided, $\ell \geq 6.0$ a, however, not less than 30 mm.

The mathematical weld seam area, A_w, shall be calculated as follows:

$$A_W = \Sigma\ a \cdot \ell.$$

(2) Only those weld seam areas shall be considered in the calculation which, due to their location, are predominately in a position to transfer the stress resultants of the connection.

(3) In the case of fillet welds the weld seam area shall be assumed as being concentrated in the root weld.

(4) In the immediate vicinity of bracket and bar attachments, the weld seam length, ℓ, of the individual longitudinal fillet welds may not be assumed to be larger than 150 a.

(5) If the mathematical weld seam length is determined as listed in **Table E 3-2,** the moments from eccentricities of the center of gravity of the weld seam around the bar axis may be neglected. This also applies if other than angel sections are attached.

(6) In the case of a continuous force transfer through the weld seam no upper limitation is required.

(7) In the case of composite cross-sections, the weld seam between indirectly and directly connected cross-sections shall also be verified.

(8) If parts of the cross-sections in the vicinity of connected bars are not required for the transfer of stress resultants, their connections, normally, do not need to be certified.

(9) **Figure E 3-3** shows an example of a welded connection between the directly connected (flange) and the indirectly connected (web) partial cross-section. The weld seam of this case is called "indirect connection". The mathematical weld seam length (ℓ) of an indirect connection shall be the seam length between the starting point of the direct connection and the end point of the indirect connection.

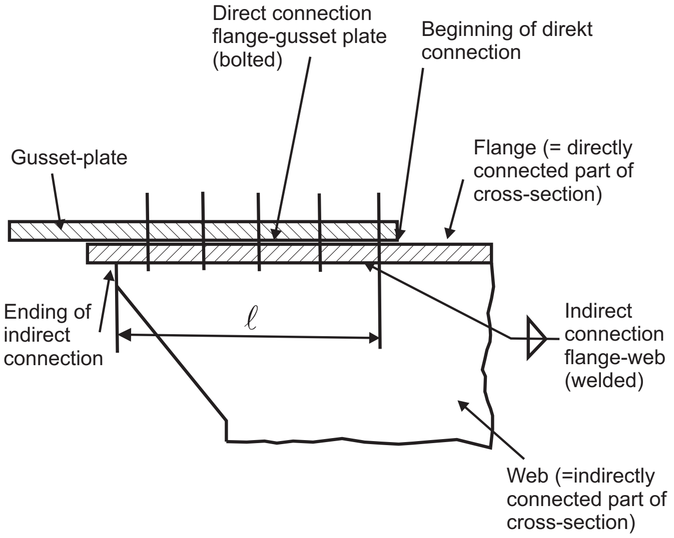


Figure E 3-3: Indirect connection in the case of composite cross-sections (based on historic standard DIN 18800-1)

(10) On account of welding considerations, the following limit values are recommended for fillet welds:

$$a_{min} \geq \max\ \{2; \sqrt{t_{max}} - 0.5\} \qquad \text{(E 3-1)}$$

$$a_{max} \leq 0.7\ \cdot\ t_{min} \qquad \text{(E 3-2)}$$

(a and t in mm)

(11) The design of welded connections shall fulfill the requirements specified under Section 5 in addition to those of the acknowledged technical standards (in particular, requirements in accordance with DIN EN 1090 and with DIN EN 1993-1-8).

E 3.1.2 Stresses in weld seams

(1) The normal and shear stresses in a welded connection that id subjected to either a longitudinal force (N) or a transverse force (Q) shall be calculated as:

$$\left.\begin{matrix}\sigma_{\perp}\\ \tau_{\perp}\\ \tau_{II}\end{matrix}\right\} = \frac{F}{A_w} = \frac{F}{\Sigma(a \cdot \ell)} \qquad \text{(E 3-3)}$$

(2) The normal stress for a welded connection that is subjected to a bending moment (M) shall be calculated as:

$$\sigma_{\perp} = \frac{M}{I_w} \cdot z \qquad \text{(E 3-4)}$$

Observing the requirements of Section E 2.8 and satisfying σ_{zul} in the flanges, the bending moment (M) may be exclusively assigned only to welds connecting the flanges.

(3) For a longitudinal weld of a bending girder (beam) loaded by a transverse force (Q) the shear stress shall be calculated as

$$\tau_{II} = \frac{Q \cdot S}{I \cdot \Sigma\ a} \qquad \text{(E 3-5)}$$

and for intermittent welds (cf. **Figure E 3-4**) as

$$\tau_{II} = \frac{Q \cdot S}{I \cdot \Sigma\ a} \cdot \frac{e + \ell}{\ell} \qquad \text{(E 3-6)}$$

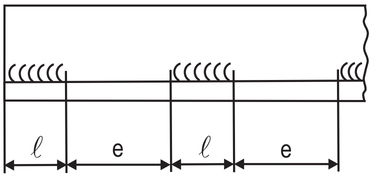


Figure E 3-4: For the analysis of weld seam shear stresses, τ_{II}, in intermittent welds

(4) In the case of girder (beam) connections and in transversal web plate welds, equation (E 3-3) may be used to calculate the shear stress, provided, the component part was dimensioned as specified under Section E 2.3, equations (E 2-4) and (E 2-5).

(5) If the welded connection is loaded by a torsional moment, M_T, the resulting shear stresses shall be considered and, where necessary, also the warping stresses.

(6) In the case of additive loadings in the fillet welds or single-bevel welds (K-type web welds) shown in **Table E 3-1**, Ser. Nos. 2 through 4, from more than one of the stresses determined by equations (E 3-3) through (E 3-6) – e.g., for the bending resistant girder (beam) connection – the value of the reference stress (σ_V) may be calculated using equation (3-7):

$$\sigma_V = \sqrt{\sigma_\perp^2 + \tau_\perp^2 + \tau_{II}^2} \qquad \text{(E 3-7)}$$

Here, the maximum value of an individual stress shall be inserted into the equation together with the corresponding values of the other stresses. In equation (E 3-7) the normal stress, σ_{II}, is neglected.

(7) The value of the reference stress for the stress resultants from bending moments, transverse and longitudinal forces need not be determined for fillet welds and single-bevel butt welds (K-type web welds) of a bending-resistant connection, provided, it is verified that the flange welds will withstand the maximum normal force (see paragraph (2)) and that the web welds will withstand the maximum transverse force calculated using equation (E 3-3).

E 3.2 Other Welding Procedures, e.g., Resistance Flash Butt Welding, Frictional Welding

If the resistance flash butt welding or frictional welding processes are applied, an expert opinion and analysis report issued by an accredited body (in agreement with the authorized expert) shall be submitted, this report specifying the resistance of the welded connection.

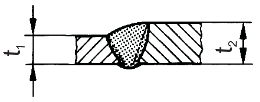
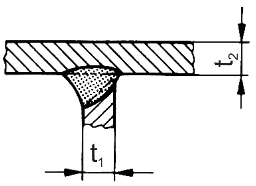
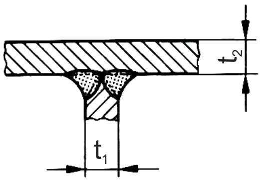
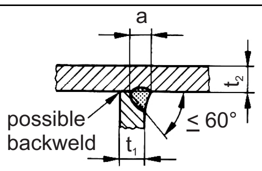
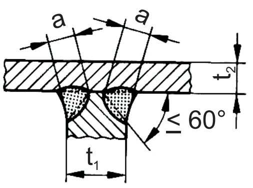
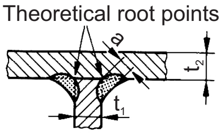
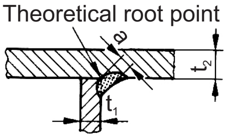
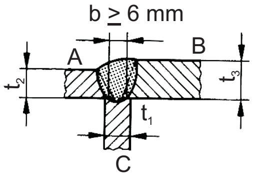
<table>
<tr><th>Ser. No.</th><th colspan="2">Type of Weld</th><th>Figure</th><th colspan="3">Mathematical Weld Seam Thickness, a</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Full penetration welds</td><td>Butt welds</td><td> </td><td colspan="3" rowspan="3">a = min {t_1; t_2}</td></tr>
<tr><td>High-strength welds (Half-V welds)
Single bevel groove welds</td><td> </td></tr>
<tr><td>Double-bevel groove welds (Double-half-V welds)</td><td> </td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Partial penetrating welds</td><td>Half-Y weld</td><td> </td><td colspan="3" rowspan="2">The weld seam thickness, a, is equal to the distance between the theoretical root point and the weld seam surface.</td></tr>
<tr><td>Double-half-Y weld</td><td> </td></tr>
<tr><td rowspan="2">3</td><td colspan="2" rowspan="2">Fillet welds</td><td> </td><td colspan="3" rowspan="2">The weld seam thickness, a, is equal to the distance between the theoretical root point and the height of the inscribable isosceles triangle.</td></tr>
<tr><td> </td></tr>
<tr><td>4a</td><td colspan="2" rowspan="2">Three-plate weld</td><td rowspan="2"> </td><td rowspan="2">Force trans-mission</td><td>from A to B</td><td>a = min {t_2; t_3}</td></tr>
<tr><td>4b</td><td>from C to A and B</td><td>a = b</td></tr>
</table>

Table E 3-1: Mathematical weld seam thickness, a (based on historic standard DIN 18800-1)

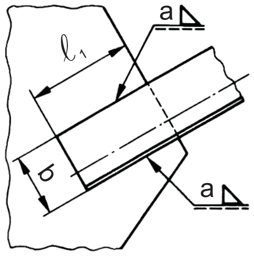
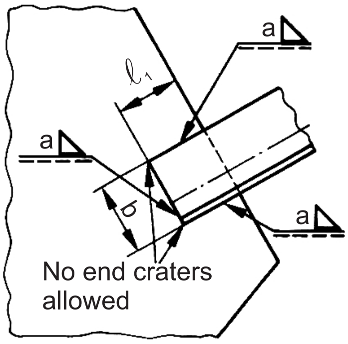
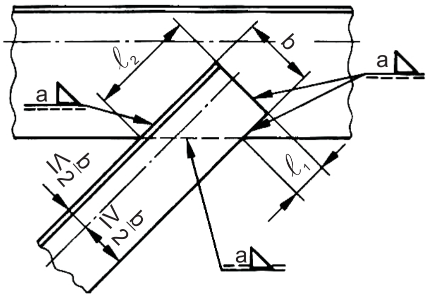
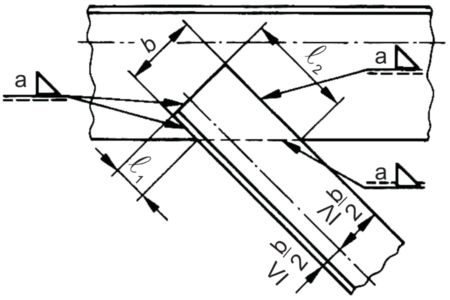
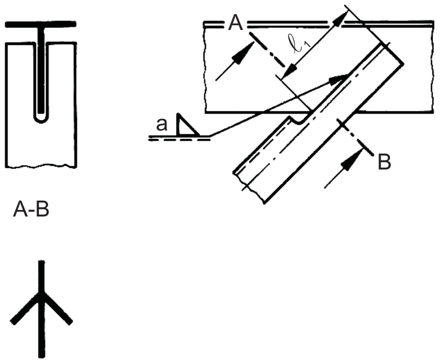
Ser. No.	Type of Weld	Figure	Mathematical Weld Seam Length, $\Sigma \ell$
1	Side fillet welds		$\Sigma \ell = 2 \ell_1$
2	End fillet welds and side fillet welds	 No end craters allowed	$\Sigma \ell = b + 2 \ell_1$
3	Ring fillet welds – centroidal axis closer to the longer weld		$\Sigma \ell = \ell_1 + \ell_2 + 2 b$
4	Ring fillet welds – centroidal axis closer to the shorter weld		$\Sigma \ell = 2 \ell_1 + 2 b$
5	Fillet weld or butt weld with slotted angle		$\Sigma \ell = 2 \ell_1$

Table E 3-2: Mathematical weld seam length, $\Sigma \ell$, for directly connected bars (based on historic standard DIN 18800-1)

E 4 Calculation of Stresses for Bolted Connections

E 4.1 Shear Bearing Bolted Connection (SL and SLP Bolted Connection)

E 4.1.1 Mode of operation

(1) In bolted connections for shear or bearing pressure, the loading of the bolts is perpendicular to their axis. The analysis of forces to be transmitted is based exclusively on the shear loading in the bolt as well as on the bearing pressure between bolt and bearing surface of the component part to be connected. High-strength bolts (Property Class 10.9) may be used without pre-tensioning or with a partial pre-tensioning equal to or greater than 0.5 · F_v (preload force in the bolt, F_v, as listed in **Tables 4-12** and **4-13** or in accordance with VDI 2230, hereinafter termed as „unplanned pre-tensioning”).

(2) The deformation behavior due to the bearing pressure can be improved by utilizing the three-dimensional stress state caused by the unplanned pre-tensioning of the bolts under load. This may be achieved for by increasing the allowable bearing pressure (see **Table 4-6**, Ser. Nos. 6 and 8).

(3) Bolted connections for shear or bearing pressure may be used with a bore hole tolerance, Δd, less than or equal to 2 mm (without fit bolts) and Δd less than or equal to 0.3 mm (with fit bolts). In the case of junctures and joints in frames that may be subject to lateral movement the bore hole tolerance shall not exceed 1 mm.

(4) Countersunk head bolts may be used. In the case of countersunk head bolt connections, the bore hole tolerance Δd shall not exceed 1 mm.

E 4.1.2 Verifications

(1) The nomenclature used in equations (E 4-1) through (E 4-3) is as follows:

A_a	cross-sectional area of the bolt shank
A_S	stress cross-section
F	internal forces (longitudinal force N, transverse force Q) to be transmitted
$Q_{SL\ zul}$	allowed transmittable force for a bolt per shear area perpendicular to the bolt axis in a bolted SL connection
$Q_{SLP\ zul}$	allowed transmittable force for a bolt per shear area perpendicular to the bolt axis in a bolted SLP connection
d	bolt shank diameter
d_2	nominal pitch diameter
d_3	nominal core (root) diameter
n	number of bolts in the connection
m	number of shear planes
$\Sigma\ t_{min}$	smallest sum of plate thicknesses where bearing pressure acts in the same direction
σ_L	bearing pressure between bolt and bore hole wall of the component part to be connected
τ_a	shear stress in the bolt

Note:
See DIN EN ISO 898-1 regarding A_S and d_2.

(2) The following equations apply to single-shear connections as well as to multiple-shear symmetrical connections. The bearing pressure, σ_L, and the shearing-off stress, τ_a, shall be calculated as follows:

$$\sigma_L = \frac{F}{d \cdot n \cdot \Sigma\ t_{min}} \qquad \text{(E 4-1)}$$

The values of $\sigma_{L\ zul}$ for the component part and for the bolt are listed in **Table 4-6**. In the case of differing materials for the component and the fastener, the dimensioning shall be based on the smaller value of the respective parts.

$$\tau_a = \frac{F}{n \cdot m \cdot A_a} \quad \text{with} \quad A_a = \frac{\pi \cdot d^2}{4} \qquad \text{(E 4-2)}$$

$$\left.\begin{matrix} Q_{SL\ zul} \\ \\ Q_{SLP\ zul} \end{matrix}\right\} = \tau_{a\ zul} \cdot \frac{\pi \cdot d^2}{4} \qquad \text{(E 4-3)}$$

The values for $\tau_{a\ zul}$ are listed in **Tables 4-8** and **4-10.**

(3) Countersunk head bolts may be verified as specified in the present section, provided, the mathematical stress of the bearing pressure between the outer component part and the unthreaded shank (Region II as shown in **Figure E 4-1**) does not exceed the allowable value. Otherwise the allowable forces shall be reduced to 80 %. In connections with countersunk head bolts, larger strains than in other connecting elements with comparable dimensions are to be expected; especially in the case of a decreasing Region II , there is a tendency that the countersunk bolt head is loosened by the wedge effect caused by the force transmission in Region I.

(4) In the case of hinge pins additionally the bending stress and reference stress shall normally be verified.

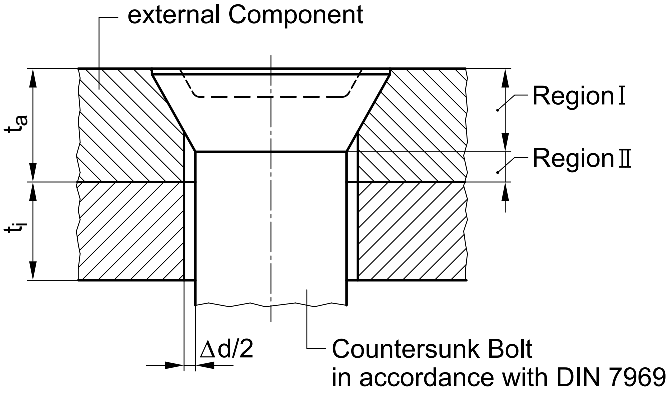


Figure E 4-1: Countersunk head bolted connection in accordance with DIN 7969

E 4.2 Slip Resistant Bolted Connection with High-Strength Bolts (GV and GVP Connection)

E 4.2.1 Mode of operation

(1) In slip-resistant bolted connections the bolts are pre-tensioned as listed in **Table 4-12** and **Table 4-13** or in accordance with VDI 2230. This allows the transmission of forces perpendicular to the bolt axis by friction in the specially treated surfaces of the component parts to be connected (slip-resistant bolted connections). In connections with high-strength fit bolts the forces are simultaneously transmitted by shear and bearing pressure (slip-resistant bolted connections with fit bolts).

(2) Slip-resistant bolted connections may be used with a bore hole tolerance, Δd, less than or equal to 2 mm or 3 mm (slip-resistant bolted connections without fit bolts) and with a bore

hole tolerance, Δd, less than or equal to 0.3 mm (friction-type connections with fit bolts).

E 4.2.2 Verifications

(1) The nomenclature used in equations (E 4-4) through (E 4-5) is as follows:

F_V	preload force in the bolt as shown in **Table 4-12** and **Table 4-13** or in accordance with VDI 2230
$Q_{GV\ zul}$	allowed transmittable force for a bolt per friction surface perpendicular to the bolt axis in a slip-resistant bolted connection
$Q_{GVP\ zul}$	allowed transmittable force for a bolt per friction surface (shear plane) normal to the bolt axis in a friction-type connection with fit bolts
$Q_{SLP\ zul}$	allowed transmittable force for a bolt per shear area perpendicular to the bolt axis in a bolted connection for shear or bearing pressure with fit bolts
$\mu = 0.5$	friction factor of contact surfaces in case of one of the following surface treatments a) steel shot peening, b) 2 x flame descaling, or c) sand blasting
ν_G	safety factor of slippage

(2) In slip-resistant bolted connections with high-strength bolts that are not covered by **Tables 4-12** and **4-13** and that have a bore hole tolerance, Δd, less than or equal to 2 mm (slip-resistant bolted connections without fit bolts) the following applies:

$$Q_{GV\ zul} = \frac{\mu \cdot F_V}{\nu_G} \qquad \text{(E 4-4)}$$

where, dependent on the load case, $\nu_{G,H}$ = 1.25 or $\nu_{G,\ HZ}$ = 1.10 or $\nu_{G,\ HS}$ = 1.05.

In case of a bore hole tolerance of 2.0 mm < $\Delta d \leq$ 3.0 mm these values shall be reduced to 80 %.

(3) In slip-resistant bolted connections with high-strength fit bolts that are not covered by **Tables 4-12** and **4-13** and that have a bore hole tolerance, Δd , less than or equal to 0.3 mm (slip-resistant bolted connections with fit bolts) the following applies:

$$Q_{GVPzul} = \frac{1}{2} \cdot Q_{SLPzul} + Q_{GVzul} \qquad \text{(E 4-5)}$$

(4) The bearing pressure, σ_l, in the component parts to be connected shall be analytically verified by applying equation (E 4-1); in this case the effects of frictional forces need not be considered. The values for $\sigma_{l,\ zul}$ shall be as listed in **Table 4-6,** Ser. No. 9. The shear stress, τ_a, does not need to be verified.

(5) For component parts under tensile loading that are connected by slip-resistant bolted connections with or without fit bolts, the general stress analysis may be based on the assumption that 40 % of the transmittable force, $Q_{GV\ zul}$, calculated by equation (E 4-4), allowed for those high-strength bolts located within the considered cross-section for which a deduction of the bore hole area has been introduced, has been connected by friction prior to the bore-hole weakening (anticipated reduction of force). In addition, the entire cross-section shall be verified by applying the total force.

(6) Where slip-resistant bolted connections with fit bolts are subjected to internal forces in alternating directions, the transmission of the force with the greater value shall be verified by means of $Q_{GVP\ zul}$ and the transmission of the force with the smaller value shall be verified by means of $Q_{GV\ zul}$.

E 4.3 Connections Subjected to Tensile Loading in Direction of the Bolt Axis due to External Loading

(1) It shall be considered that prying forces may be created in the bolted connections which will influence the loading in the connection.

(2) One example for the influence of loading in a connection is the T-joint of tensile bars as shown in **Figure E 4-2**. Depending on the dimensions of the bolts and of the end plate, prying forces (K) may occur in the region of the endplate edges. The prying forces (K) and the tensile force (F) are in equilibrium with the tensile forces of the bolts.

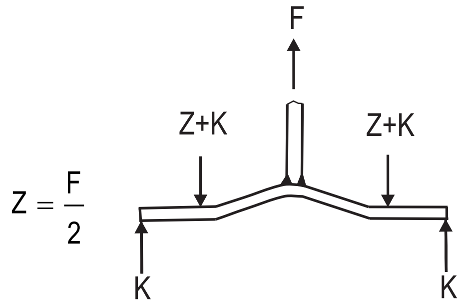


Figure E 4-2: T-joint (based on historic standard DIN 18800-1)

E 4.3.1 Unplanned pre-tensioned connections

(1) The nomenclature of equation (E 4-6) is as follows:

Z_{zul}	allowed transmittable tensile force by a bolt in direction of bolt axis
$\sigma_{z\ zul}$	allowable tensile stress within the bolt

The following applies:

$$Z_{zul} = \sigma_{z\ zul} \cdot A_s \ \text{ where } \ A_S = \frac{\pi}{4} \cdot \left(\frac{d_2 + d_3}{2}\right)^2 \qquad \text{(E 4-6)}$$

The values for $\sigma_{z\ zul}$ are listed in **Table 4-8**.

(2) High-strength bolts without pre-tensioning or with unplanned pre-tensioning where the bolt is tensile-loaded due to external loading are allowed, provided, the expected number of load cycles (N) of the non-permanent loads meets one of the following conditions:

a) $N \leq 10^4$

b) $N \leq 10^5$; however, the number of load cycles in case of stresses exceeding 40 % of the allowable values for load case H listed in **Table 4-8** may not exceed 10^4.

Here, the allowed transmittable tensile force, Z_{zul} , may be calculated by using equation (E 4-6). The respective values of allowable stresses ($\sigma_{z\ zul}$) are listed in **Table 4-8**.

(3) In the case of shear bearing bolted connections with or without fit bolts, the individual verifications (Q, σ_L, Z) shall be performed independently of each other if the shear area is located within the shaft cross-section. In this case, the allowable values for the individual of stress types listed in **Tables 4-8** and **4-10** and as calculated using equation (E 4-3) may be fully utilized without a verification of the reference stress. If the shear surface is located within the threaded region the reference stress (σ_V) shall be verified as follows:

$$\sigma_V = \sqrt{\sigma^2 + 3\,\tau^2} \qquad \text{(E 4-7)}$$

(4) Regarding the allowable bearing pressure, σ_L, for unplanned pre-tensioned connections ($\geq 0.5 \cdot F_V$) the values of **Table 4-6**, Ser. No. 6 (shear bearing bolted connections), or Ser. No. 8 (shear bearing bolted connections with fit bolts) shall be considered.

E 4.3.2 Planned pre-tensioned connections

(1) The tensile loading due to external loading shall be mathematically verified and exclusively allocated to the bolts, i.e., the actual reduction of the clamping force at the contact faces of the component parts to be connected as well as the increase in pressure on the bearing surfaces of bolt head and nut will not be considered. The mathematical tensile force (Z) acting on an individual bolt or fit bolt shall not exceed Z_{zul} calculated according to equation (E 4-6).

(2) In slip-resistant bolted connections with and without fit bolts the allowed transmittable force $Q_{GV\ zul}$ or $Q_{GVP\ zul}$ shall be reduced as follows if the connection is subjected simultaneously to external loading in axial direction and perpendicular to the bolt axis:

$$Q_{GV,Zzul} = \left(0.2 + 0.8 \cdot \frac{Z_{zul}-Z}{Z_{zul}}\right) \cdot Q_{GVzul} \qquad \text{(E 4-8)}$$

$$Q_{GVP,Zzul} = 0.5 \cdot Q_{SLPzul} + \left(0.2 + 0.8 \cdot \frac{Z_{zul}-Z}{Z_{zul}}\right) \cdot Q_{GVzul} \qquad \text{(E 4-9)}$$

(3) Regarding the allowable bearing pressure, σ_L, the values listed in **Table 4-6**, Ser. No. 9 shall be considered.

E 5 Certification of Positional Stability

The certification of positional stability for load-bearing steel structures comprises the certification of safety against lifting off, safety against lateral tilting (reaching the critical compressive force) and safety against slippage.

E 5.1 Safety Against Lifting-off and Reaching the Critical Compressive Force, β_{cr}

For the safety against lifting-off and against attaining the critical compressive force the most unfavorable loading shall be calculated from the determining main, additional and special loads, whereby the individual portions shall be multiplied by the load intensification factor, γ_{cr}, listed in **Table E 5-1**.

E 5.1.1 Safety against lifting-off

(1) The safety against lifting off shall be verified for individual support bases if it has not been established with certainty that they are stable. Sufficient stability is achieved if the following condition is satisfied:

$$N_D \geq N_Z \qquad \text{(E 5-1)}$$

The nomenclature of equation (E 5-1) is as follows:

N_D	perpendicular component of the resultant force of all compressive force portions acting on the support base, calculated from the γ_{cr}-times loadings
N_Z	perpendicular component of the resultant force of all lifting force portions acting on the support base, calculated from the γ_{cr}-times loadings

Ser. No.	**Loadings**	γ_{cr}
1	Favorably acting portions of all loads applied	1.0
2	Unfavorably acting portions of the dead load	1.1
3	Unfavorably acting portions of all loads except for the loads under lines 2 and 5	1.3
4	Unfavorably acting portions of loads in the building conditions	1.5
5	Unfavorably acting portions of equivalent loads in the case of impacts	1.1
6	Displacements and rotation loads	1.0
Unplanned eccentricities and the deformations of the system under a γ_{cr}-times loading shall be considered, where required.		

Table E 5-1: Load intensification factors, γ_{cr} , to determine the safety against lifting off and overturning

(2) Where anchors are provided for securing against lifting off, the anchor tensile force, Z_A , may be considered as follows:

$$N_D + 1.3 \cdot Z_{A_{zul}} \geq N_Z \qquad \text{(E 5-2)}$$

The nomenclature of equation (E 5-2) is as follows:

$Z_{A\ zul}$	is the allowable tensile force of the anchor at load case H
$\sigma_{Z\ zul}$	see **Table 4.8**

(3) It shall be verified that the anchor is sufficiently anchored.

E 5.1.2 Attainment of the critical compressive force, β_{cr} (lateral tilting)

The security of component parts against lateral tilting shall be verified if it has not been established with certainty that they are secure. Sufficient security is achieved if the following condition is satisfied under a γ_{cr}-times loading:

$$\sigma_{cr} = \frac{D_{cr}}{A_{cr}} \leq \beta_{cr} \qquad \text{(E 5-3)}$$

The nomenclature of equation (E 5-3) is as follows:

σ_{cr}	compression under the γ_{cr}-times loadings, based on the assumption that the stresses are evenly distributed over the compressed part of the structural bearing joint surface area and the state of equilibrium is maintained; it may be assumed that the part of the compressed surface area is rectangular,

D_{cr}	reaction force at structural bearing joint (see **Figure E 5-1**),
N_{cr}	perpendicular component of the resultant force of all forces acting on the structural bearing joint under a γ_{cr} -times loading,
A_{cr}	partial area of the overall structural bearing joint surface area, the center of gravity of which lies on the line of action of D_{cr} (assuming that σ is constant),
β_{cr}	critical compression on structural bearing joint under the γ_{cr}-times loading (β_{cr} for concrete - see DIN 1054; β_{cr} for steels: 1.5 times the Hertzian compression for load case H); see **Table 4-9** for allowable stress values.

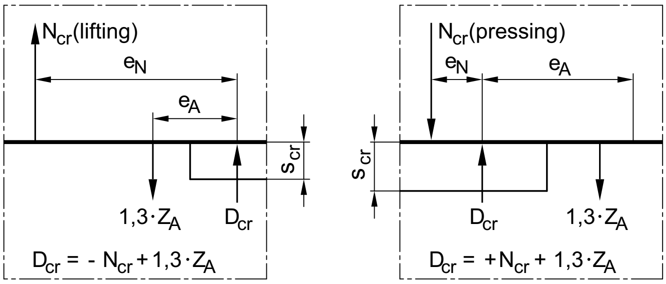


Figure E 5-1: Determination of anchor tensile force

$$Z_A = \frac{N_{cr}}{1,3} \cdot \frac{e_N}{e_A}$$

E 5.2 Safety Against Slippage

(1) The safety against slippage parallel to the structural bearing joint shall be verified as follows, unless specified otherwise in technical standards:

$$1.5 \times H \leq \mu_N \cdot N \qquad \text{(E 5-4)}$$

(2) If the frictional force is not considered in the calculation, the following simple verification is sufficient:

$$H \leq D \qquad \text{(E 5-5)}$$

Nomenclature of equations (E 5-4) and (E-5) is as follows:

μ_N	friction coefficients steel on steel: $\mu_N = 0.10$ steel on concrete: $\mu_N = 0.30$
N	compressive force perpendicular to the structural bearing joint due to external loads
H	force acting parallel to the structural bearing joint due to external loads N and H apply to the same determining load combination
D	allowed transmittable force by possibly provided mechanical shearing protections in the sliding direction, to be calculated along with the allowable stresses for the respective load case as specified under Section 4.3.3.2.

(3) In the case of impact loads the factor 1.5 in equation (E 5-4) shall be replaced by the factor 1.0.

E 5.3 Certification of Deformations

(1) The proper functioning of a structure may require that, depending on the range of application, deformations must be limited. Limit values of allowable deformations are specified in technical standards for individual cases; otherwise, they shall be specified in agreement with the purchaser prior to preparing the design documents.

(2) To determine the deformations, the cross-section values shall normally be used without a deduction for the bore hole area.

Note:

Further details regarding the certification of deformations, e.g., consideration of bolt slippage, are specified in the technical standards.

Appendix F

Regulations Referred to in the Present Safety Standard

(Regulations referred to in the present safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the latter regulations were established or issued.)

AtG		Act on the peaceful utilization of atomic energy and the protection against its hazards (Atomic Energy Act – AtG) of December 23, 1959, revised version of July 15, 1985 (BGBl. I, p. 1565), most recently changed by Article 1 of the Act of July 10, 2018 (BGBl. I 2015, p. 1122, 1124)
StrlSchV		Ordinance on the protection from damage by ionizing radiation (Radiological Protection Ordinance – StrlSchV) of July 20, 2001 (BGBl. I, p. 1714; 2002 I, p. 1459), most recently changed by Article 10 of the Act of January 27, 2017 (BGBl. I, p. 114, 1222)
SiAnf	(2015-03)	Safety requirements for nuclear power plants of November 22, 2012, revised version of March 3, 2015 (BAnz AT of March 30, 2015 B2)
SiAnf-Interpretations	(2015-03)	Interpretations of the safety requirements for nuclear power plants of November 22, 2012, revised version of March 3, 2015 (BAnz AT of March 30, 2015 B3)
KTA 1401	(2017-11)	General Requirements Regarding Quality Assurance
KTA 2201.1	(2011-11)	Design of Nuclear Power Plants against Seismic Events; Part 1: Principles
KTA 3201.1	(2017-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 1: Materials and Product Forms
KTA 3201.2	(2017-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 2: Design and Analysis
KTA 3201.3	(2017-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 3: Manufacture
KTA 3201.4	(2016-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 4: Inservice Inspections and Operational Monitoring
KTA 3205.2	(2018-10)	Component Support Structures with Non-integral Connections; Part 2: Component Support Structures with Non-Integral Connections for Pressure and Activity-Retaining Components in Systems Outside the Primary Circuit
KTA 3205.3	(2018-10)	Component Support Structures with Non-integral Connections; Part 3: Series-Production Standard Supports
KTA 3211.2	(2013-11)	Pressure and Activity Retaining Components of Systems Outside the Primary Circuit; Part 2: Design and Analysis
KTA 3211.3	(2017-11)	Pressure and Activity Retaining Components of Systems Outside the Primary Circuit; Part 3: Manufacture
KTA 3401.2	(2016-11)	Steel Containment Vessels; Part 2: Analysis and Design
DIN 13-1	(1999-11)	ISO general purpose metric screw threads - Part 1: Nominal sizes for coarse pitch threads; nominal diameter from 1 mm to 68 mm
DIN 1054	(2010-12)	Subsoil - Verification of the safety of earthworks and foundations - Supplementary rules to DIN EN 1997-1
DIN 1054/A1	(2012-08)	Subsoil - Verification of the safety of earthworks and foundations - Supplementary rules to DIN EN 1997-1:2010; Amendment A1:2012
DIN 1054/A2	(2015-11)	Subsoil - Verification of the safety of earthworks and foundations - Supplementary rules to DIN EN 1997-1; Amendment 2
DIN 7968	(2017-08)	Hexagon fit bolts with hexagon nut for steel structures
DIN 7969	(2017-08)	Slotted countersunk head bolts with hexagon nut for steel structures
DIN 7990	(2017-08)	Hexagon head bolts with hexagon nut for steel structures

DIN 25449	(2016-04)	Reinforced and prestressed concrete components in nuclear facilities - Safety concept, actions, design and construction
DIN EN 1011-1	(2009-07)	Welding - Recommendations for welding of metallic materials - Part 1: General guidance for arc welding; German version EN 1011-1:2009
DIN EN 1011-2	(2001-05)	Welding - Recommendation for welding of metallic materials - Part 2: Arc welding of ferritic steels; German version EN 1011-2:2001
DIN EN 1011-3	(2001-01)	Welding - Recommendations for welding of metallic materials - Part 3: Arc welding of stainless steels; German version EN 1011-3:2018
DIN EN 1090-1	(2012-02)	Execution of steel structures and aluminium structures - Part 1: Assessment and verification of constancy of performance of steel components and aluminium components for structural use; German version EN 1090-1:2009+A1:2011
DIN EN 1090-2	(2011-10)	Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures; German version EN 1090-2:2008+A1:2011
DIN EN 1369	(2013-01)	Founding - Magnetic particle testing; German version EN 1369:2012
DIN EN 1370	(2012-03)	Founding - Examination of surface condition; German version EN 1370:2011
DIN EN 1371-1	(2012-02)	Founding - Liquid penetrant testing - Part 1: Sand, gravity die and low pressure die castings; German version EN 1371-1:2011
DIN EN 1371-2	(2015-04)	Founding - Liquid penetrant testing - Part 2: Investment castings; German version EN 1371-2:2015
DIN EN 1559-2	(2014-12)	Founding - Technical conditions of delivery - Part 2: Additional requirements for steel castings; German version EN 1559-2:2014
DIN EN 1990	(2010-12)	Eurocode: Basis of structural design; German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010
DIN EN 1990/NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode: Basis of structural design
DIN EN 1990/NA/A1	(2012-08)	National Annex - Nationally determined parameters - Eurocode: Basis of structural design; Amendment A1
DIN EN 1991-1-1	(2010-12)	Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings; German version EN 1991-1-1:2002 + AC:2009 in conjunction with
DIN EN 1991-1-1 /NA	(2010-12)	National Annex - Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings
DIN EN 1991-1-1 /NA/A1	(2015-05)	Nationally determined parameters - Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings; Amendment A1
DIN EN 1991-1-2	(2010-12)	Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire; German version EN 1991-1-2:2002 + AC:2009 in conjunction with
DIN EN 1991-1-2 /NA	(2015-09)	Nationaler Anhang - National festgelegte Parameter - Eurocode 1: Einwirkungen auf Tragwerke - Teil 1-2: Allgemeine Einwirkungen - Brandeinwirkungen auf Tragwerke National Annex - Nationally determined parameters - Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire
DIN EN 1991-1-2 Corrigendum 1	(2013-08)	Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire; German version EN 1991-1-2:2002 + AC:2009, Amendment 1
DIN EN 1991-1-3	(2010-12)	Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads; German version EN 1991-1-3:2003 + AC:2009 in conjunction with
DIN EN 1991-1-3/A1	(2015-12)	Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads; German version EN 1991-1-3:2003/A1:2015
DIN EN 1991-1-3 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads
DIN EN 1991-1-4	(2010-12)	Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions; German version EN 1991-1-4:2005 + A1:2010 + AC:2010 in conjunction with
DIN EN 1991-1-4 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions
DIN EN 1991-1-5	(2010-12)	Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions; German version EN 1991-1-5:2003 + AC:2009 in conjunction with
DIN EN 1991-1-5 /NA	(2010-12)	Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions; German version EN 1991-1-5:2003 + AC:2009

DIN EN 1991-1-6	(2010-12)	Eurocode 1: Actions on structures - Part 1-6: General actions, Actions during execution; German version EN 1991-1-6:2005 + AC:2008 in conjunction with
DIN EN 1991-1-6 Corrigendum 1	(2013-08)	Eurocode 1: Actions on structures - Part 1-6: General actions, Actions during execution; German version EN 1991-1-6:2005, Corrigendum to DIN EN 1991-1-6:2010-12; German version EN 1991-1-6:2005/AC:2012
DIN EN 1991-1-6 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 1: Actions on structures - Part 1-6: General actions, Actions during execution
DIN EN 1991-1-7	(2010-12)	Eurocode 1: Actions on structures - Part 1-7: General actions - Accidental actions; German version EN 1991-1-7:2006 + AC:2010 in conjunction with
DIN EN 1991-1-7/A1	(2014-08)	Eurocode 1 - Actions on structures - Part 1-7: General actions - Accidental actions; German version EN 1991-1-7:2006/A1:2014
DIN EN 1991-1-7 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 1: Actions on structures - Part 1-7: General actions - Accidental actions
DIN EN 1993-1-1	(2010-12)	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings; German version EN 1993-1-1:2005 + AC:2009 in conjunction with
DIN EN 1993-1-1 /A1	(2014-07)	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings; German version EN 1993-1-1:2005/A1:2014
DIN EN 1993-1-1 /NA	(2015-08)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
DIN EN 1993-1-3	(2010-12)	Eurocode 3: Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting; German version EN 1993-1-3:2006 + AC:2009 in conjunction with
DIN EN 1993-1-3 /NA	(2017-05)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting
DIN EN 1993-1-4	(2015-10)	Eurocode 3: Design of steel structures - Part 1-4: General rules - Supplementary rules for stainless steels; German version EN 1993-1-4:2006 + A1:2015 in conjunction with
DIN EN 1993-1-4 /NA	(2017-01)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-4: General rules - Supplementary rules for stainless steels
DIN EN 1993-1-5	(2017-07)	Eurocode 3 - Design of steel structures - Part 1-5: Plated structural elements; German version EN 1993-1-5:2006 + AC:2009 + A1:2017in conjunction with
DIN EN 1993-1-5 /NA	(2016-04)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-5: Plated structural elements
DIN EN 1993-1-6	(2017-07)	Eurocode 3 - Design of steel structures - Part 1-6: Strength and Stability of Shell Structures; German version EN 1993-1-6:2007 + AC:2009 + A1:2017in conjunction with
DIN EN 1993-1-6 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-6: Strength and stability of shell structures
DIN EN 1993-1-7	(2010-12)	Eurocode 3: Design of steel structures - Part 1-7: Plated structures subject to out of plane loading; German version EN 1993-1-7:2007 + AC:2009 in conjunction with
DIN EN 1993-1-7 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-7: Plated structures subject to out of plane loading;
DIN EN 1993-1-8	(2010-12)	Eurocode 3: Design of steel structures - Part 1-8: Design of joints; German version EN 1993-1-8:2005 + AC:2009 in conjunction with
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 1993-1-9	(2010-12)	Eurocode 3: Design of steel structures - Part 1-9: Fatigue; German version EN 1993-1-9:2005 + AC:2009 in conjunction with
DIN EN 1993-1-9 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-9: Fatigue
DIN EN 1993-1-10	(2010-12)	Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through-thickness properties; German version EN 1993-1-10:2005 + AC:2009 in conjunction with
DIN EN 1993-1-10 /NA	(2016-04)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through-thickness properties

DIN EN 1993-1-12	(2010-12)	Eurocode 3: Design of steel structures - Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S700; German version EN 1993-1-12:2007 + AC:2009
DIN EN 1993-1-12 /NA	(2011-08)	National Annex - Nationally determined parameters - Eurocode 3: Design of steel structures - Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S700
DIN EN 10025-1	(2005-02)	Hot rolled products of structural steels - Part 1: General technical delivery conditions; German version EN 10025-1:2004
DIN EN 10025-2	(2005-04)	Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels; German and English version EN 10025-2:2004
DIN EN 10025-3	(2005-02)	Hot rolled products of structural steels - Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels; German and English version EN 10025-3:2004
DIN EN 10025-4	(2005-04)	Hot rolled products of structural steels - Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels; German and English version EN 10025-4:2004
DIN EN 10028-1	(2009-07)	Flat products made of steels for pressure purposes - Part 1: General requirements; German version EN 10028-1:2017
DIN EN 10028-2	(2009-09)	Flat products made of steels for pressure purposes - Part 2: Non-alloy and alloy steels with specified elevated temperature properties; German version EN 10028-2:2017
DIN EN 10028-3	(2009-09)	Flat products made of steels for pressure purposes - Part 3: Weldable fine grain steels, normalized; German version EN 10028-3:2017
DIN EN 10028-7	(2016-07)	Flat products made of steels for pressure purposes - Part 7: Stainless steels; German version EN 10028-7:2016
DIN EN 10029	(2011-02)	Hot-rolled steel plates 3 mm thick or above - Tolerances on dimensions and shape; German version EN 10029:2010
DIN EN 10083-1	(2006-10)	Quenched and tempered steels – Part 1: General technical delivery conditions German version EN 10083-1:2006
DIN EN 10083-2	(2006-10)	Quenched and tempered steels – Part 2: Technical delivery conditions for unalloyed steels; German version EN 10083-2:2006
DIN EN 10083-3	(2007-01)	Quenched and tempered steels – Part 3: Technical delivery conditions for alloyed steels; German version EN 10083-3:2006 in conjunction with
DIN EN 10083-3 Amendment 1	(2009-01)	Quenched and tempered steels – Part 3: Technical delivery conditions for alloyed steels; Amendment 1, German version EN 10083-3:2006/AC:2008
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 10160	(1999-09)	Ultrasonic testing of steel flat product of thickness equal to or greater than 6 mm (reflection method); German version EN 10160:1999
DIN EN 10163-1	(2005-03)	Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections - Part 1: General requirements; German version EN 10163-1:2004 in conjunction with
DIN EN 10163-1 Amendment 1	(2007-05)	Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections - Part 1: General requirements; German version EN 10163-1:2004, Corrigenda to DIN EN 10163-1:2005-03; German version EN 10163-1:2004/AC:2007
DIN EN 10163-2	(2005-03)	Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections - Part 2: Plate and wide flats; German version EN 10163-2:2004
DIN EN 10164	(2005-03)	Steel products with improved deformation properties perpendicular to the surface of the product - Technical delivery conditions; German version EN 10164:2018
DIN EN 10204	(2005-01)	Metallic products - Types of inspection documents; German version EN 10204:2004
DIN EN 10210-1	(2006-07)	Hot finished structural steel hollow sections - Part 1: General; German and English version EN 10210-1:2006
DIN EN 10210-2	(2006-07)	Hot finished steel structural hollow sections - Part 2: Tolerances, dimensions and sectional properties; German version EN 10210-2:2019
DIN EN 10213	(2016-10)	Steel castings for pressure purposes; German version EN 10213:2007+A1:2016

DIN EN 10216-2	(2014-03)	Seamless steel pipes for pressure purposes - Technical delivery conditions - Part 2: Non-alloy and alloy steel pipes with specified elevated temperature properties; German version EN 10216-2:2013
DIN EN 10216-3	(2014-03)	Seamless steel pipes for pressure purposes - Technical delivery conditions - Part 3: Alloy fine grain steel pipes; German version EN 10216-3:2013
DIN EN 10216-5	(2014-03)	Seamless steel pipes for pressure purposes - Technical delivery conditions - Part 5: Stainless steel pipes; German and English version EN 10216-5:2013 in conjunction with
DIN EN 10216-5 Amendment 1	(2015-01)	Seamless steel pipes for pressure purposes - Technical delivery conditions - Part 5: Stainless steel pipes; German version EN 10216-5:2013, Corrigendum to DIN EN 10216-5:2014-03
DIN EN 10217-3	(2005-04)	Welded steel pipes for pressure purposes - Technical delivery conditions - Part 3: Electric welded and submerged arc welded alloy fine grain steel pipes with specified room, elevated and low temperature properties; German version EN 10217-3:2019
DIN EN 10217-7	(2015-01)	Welded steel pipes for pressure purposes - Technical delivery conditions - Part 7: Stainless steel pipes; German and English version EN 10217-7:2014
DIN EN 10219-1	(2006-07)	Cold formed welded structural steel hollow sections - Part 1: General; German and English version EN 10219-1:2006
DIN EN 10219-2	(2006-07)	Cold formed welded steel structural hollow sections - Part 2: Tolerances, dimensions and sectional properties; German version EN 10219-2:2019 in conjunction with
DIN EN 10219-2 Amendment 1	(2007-01)	Cold formed welded steel structural hollow sections - Part 2: Tolerances, dimensions and sectional properties; German version EN 10219-2:2019, Amendment 1
DIN EN 10222-1	(2017-06)	Steel forgings for pressure purposes - Part 1: General requirements for open die forgings; German version EN 10222-1:2017
DIN EN 10222-2	(2017-06)	Steel forgings for pressure purposes - Part 2: Ferritic and martensitic steels with specified elevated temperatures properties; German version EN 10222-2:2017
DIN EN 10222-5	(2017-06)	Steel forgings for pressure purposes - Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels; German version EN 10222-5:2017
DIN EN 10228-1	(2016-10)	Non-destructive testing of steel forgings - Part 1: Magnetic particle inspection; German version EN 10228-1:2016
DIN EN 10228-2	(2016-10)	Non-destructive testing of steel forgings - Part 2: Penetrant testing; German version EN 10228-2:2016
DIN EN 10228-3	(2016-10)	Non-destructive testing of steel forgings - Part 3: Ultrasonic testing of ferritic or martensitic steel forgings; German version EN 10228-3:2016
DIN EN 10228-4	(2016-10)	Non-destructive testing of steel forgings - Part 4: Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings; German version EN 10228-4:2016
DIN EN 10250-1	(1999-12)	Open die steel forgings for general engineering purposes - Part 1: General requirements; German version EN 10250-1:1999
DIN EN 10250-2	(1999-12)	Open die steel forgings for general engineering purposes - Part 2: Non-alloy quality and special steels; German version EN 10250-2:1999
DIN EN 10250-4	(2000-02)	Open die steel forgings for general engineering purposes - Part 4: Stainless steels; German and English version EN 10250-4:1999
DIN EN 10250-4 Amendment 1	(2008-12)	Open die steel forgings for general engineering purposes - Part 4: Stainless steels; German version EN 10250-4:1999, Corrigendum to DIN EN 10250-4:2000-02
DIN EN 10269	(2014-02)	Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties; German version EN 10269:2013
DIN EN 10272	(2016-10)	Stainless steel bars for pressure purposes; German version EN 10272:2016
DIN EN 10273	(2016-10)	Hot rolled weldable steel bars for pressure purposes with specified elevated temperature properties; German version EN 10273:2016
DIN EN 10296-2	(2006-02)	Welded circular steel pipes for mechanical and general engineering purposes - Technical delivery conditions - Part 2: Stainless steel; German version EN 10296-2:2005 in conjunction with
DIN EN 10296-2 Amendment 1	(2007-06)	Welded circular steel pipes for mechanical and general engineering purposes - Technical delivery conditions - Part 2: Stainless steel; German version EN 10296-2:2005, Corrigenda to DIN EN 10296-2:2006-02; German version EN 10296-2:2005/AC:2007

DIN EN 10297-2	(2006-02)	Seamless steel pipes for mechanical and general engineering purposes - Technical delivery conditions - Part 2: Stainless steel; German version EN 10297-2:2005 in conjunction with
DIN EN 10297-2 Amendment 1	(2007-06)	Seamless steel pipes for mechanical and general engineering purposes - Technical delivery conditions - Part 2: Stainless steel; German version EN 10297-2:2005, Corrigenda to DIN EN 10297-2:2006-02; German version EN 10297-2:2005/AC:2007
DIN EN 10307	(2002-03)	Non-destructive testing - Ultrasonic testing of austenitic and austenitic-ferritic stainless steels flat products of thickness equal to or greater than 6 mm (reflection method); German version EN 10307:2001
DIN EN 10308	(2002-03)	Non-destructive testing - Ultrasonic testing of steel bars; German version EN 10308:2001
DIN EN 12680-2	(2003-06)	Founding - Ultrasonic examination - Part 2: Steel castings for highly stressed components; German version EN 12680-2:2003
DIN EN 12681	(2003-06)	Founding - Radiographic testing
DIN EN 14399-1	(2015-04)	High-strength structural bolting assemblies for preloading - Part 1: General requirements; German version EN 14399-1:2015
DIN EN 14399-2	(2015-04)	High-strength structural bolting assemblies for preloading - Part 2: Suitability for preloading; German version EN 14399-2:2015
DIN EN 14399-4	(2015-04)	High-strength structural bolting assemblies for preloading - Part 4: System HV - Hexagon bolt and nut assemblies; German version EN 14399-4:2015
DIN EN 26157-3	(1991-12)	Fasteners; surface discontinuities; bolts, screws and studs subject to special requirements (ISO 6157-3:1988); German version EN 26157-3:1991
DIN EN ISO 148-1	(2017-05)	Metallic materials - Charpy pendulum impact test - Part 1: Test method (ISO 148-1:2016); German version EN ISO 148-1:2016
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 ISO 2400	(2013-01)	Non-destructive testing - Ultrasonic testing - Specification for calibration block No. 1 (ISO 2400:2012); German version EN ISO 2400:2012
DIN EN ISO 3059	(2013-03)	Non-destructive testing - Penetrant testing and magnetic particle testing - Viewing conditions (ISO 3059:2012); German version EN ISO 3059:2012
DIN EN ISO 3269	(2000-11)	Fasteners - Acceptance inspection (ISO/DIS 3269:2018); German and English version EN ISO 3269:2000
DIN EN ISO 3452-1	(2014-09)	Non-destructive testing - Penetrant testing - Part 1: General principles (ISO 3452-1:2013, Corrected version 2014-05-01); German version EN ISO 3452-1:2013
DIN EN ISO 3452-2	(2014-03)	Non-destructive testing - Penetrant testing - Part 2: Testing of penetrant materials (ISO 3452-2:2013); German version EN ISO 3452-2:2013
DIN EN ISO 3452-3	(2014-03)	Non-destructive testing - Penetrant testing - Part 3: Reference test blocks (ISO 3452-3:2013); German version EN ISO 3452-3:2013
DIN EN ISO 3506-1	(2010-04)	Mechanical properties of corrosion-resistant stainless steel fasteners - Part 1: Bolts, screws and studs with specified property classes - Coarse pitch thread and fine pitch thread (ISO 3506-1:2009); German and English version EN ISO 3506-1:2009
DIN EN ISO 3506-2	(2010-04)	Mechanical properties of corrosion-resistant stainless steel fasteners - Part 2: Nuts with specified property classes - Coarse pitch thread and fine pitch thread (ISO/DIS 3506-2:2009); German and English version EN ISO 3506-2:2009
DIN EN ISO 4287	(2010-07)	Geometrical Product Specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters (ISO 4287:1997 + Cor 1:1998 + Cor 2:2005 + Amd 1:2009); German version EN ISO 4287:1998 + AC:2008 + A1:2009
DIN EN ISO 5817	(2014-06)	Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality Class for imperfections (ISO 5817:2014); German version EN ISO 5817:2014
DIN EN ISO 6157-2	(2004-10)	Fasteners - Surface discontinuities - Part 2: Nuts (ISO 6157-2:1995); German version EN ISO 6157-2:2004

DIN EN ISO 6892-1	(2017-02)	Metallic materials - Tensile testing - Part 1: Method of test at room temperature (ISO 6892-1:2016); German version EN ISO 6892-1:2016
DIN EN ISO 6892-2	(2011-05)	Metallic materials - Tensile testing - Part 2: Method of test at elevated temperature (ISO 6892-2:2018); German version EN ISO 6892-2:2018
DIN EN ISO 7963	(2010-12)	Non-destructive testing - Ultrasonic testing - Specification for calibration block No. 2 (ISO 7963:2006); German version EN ISO 7963:2010
DIN EN ISO 9001	(2015-11)	Quality management systems - Requirements (ISO 9001:2015); German and English version EN ISO 9001:2015
DIN EN ISO 9606-1	(2013-12)	Qualification testing of welders - Fusion welding - Part 1: Steels (ISO 9606-1:2012 including Cor 1:2012 and Cor 2:2013); German version EN ISO 9606-1:2017
DIN EN ISO 9712	(2012-12)	Non-destructive testing - Qualification and verification of NDT personnel (ISO 9712:2012); German version EN ISO 9712:2012 in conjunction with
DIN EN ISO 9712 Supplement 1	(2014-05)	Non-destructive testing - Qualification and verification of NDT personnel; Supplement 1: Recommendations on the application of DIN EN ISO 9712:2012-12
DIN EN ISO 9934-1	(2017-03)	Non-destructive testing - Magnetic particle testing - Part 1: General principles (ISO 9934-1:2016); German version EN ISO 9934-1:2016
DIN EN ISO 9934-2	(2015-12)	Non-destructive testing - Magnetic particle testing - Part 2: Detection media (ISO 9934-2:2015); German version EN ISO 9934-2:2015
DIN EN ISO 9934-3	(2015-12)	Non-destructive testing - Magnetic particle testing - Part 3: Equipment (ISO 9934-3:2015); German version EN ISO 9934-3:2015
DIN EN ISO 11970	(2016-08)	Specification and qualification of welding procedures for production welding of steel castings (ISO 11970:2016); German version EN ISO 11970:2016
DIN EN ISO 13916	(1996-11)	Welding - Measurement of preheating temperature, interpass temperature and preheat maintenance temperature (ISO 13916:2017); German version EN ISO 13916:2017
DIN EN ISO 13920	(1996-11)	Welding - General tolerances for welded constructions - Dimensions for lengths and angles; shape and position (ISO 13920:1996); German version EN ISO 13920:1996
DIN EN ISO 14731	(2006-12)	Welding coordination - Tasks and responsibilities (ISO 14731:2019); German version EN ISO 14731:2019
DIN EN ISO 14732	(2013-12)	Welding personnel - Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials (ISO 14732:2013); German version EN ISO 14732:2013
DIN EN ISO 15607	(2004-03)	Specification and qualification of welding procedures for metallic materials - General rules (ISO/DIS 15607:2003); German and English version EN ISO 15607:2003
DIN EN ISO 15613	(2004-09)	Specification and qualification of welding procedures for metallic materials - Qualification based on pre-production welding test (ISO 15613:2004); German version EN ISO 15613:2004
DIN EN ISO 15614-1	(2012-06)	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2017); German version EN ISO 15614-1:2017
DIN EN ISO 16811	(2014-06)	Non-destructive testing - Ultrasonic testing - Sensitivity and range setting (ISO 16811:2012); German version EN ISO 16811:2014
DIN EN ISO 17636-1	(2013-05)	Non-destructive testing of welds - Radiographic testing - Part 1: X- and gamma-ray techniques with film (ISO 17636-1:2013); German version EN ISO 17636-1:2013
DIN EN ISO 17637	(2017-04)	Non-destructive testing of welds - Visual testing of fusion-welded joints (ISO 17637:2016); German version EN ISO 17637:2016
DIN EN ISO 17663	(2009-10)	Welding - Quality requirements for heat treatment in connection with welding and allied processes (ISO 17663:2009); German version EN ISO 17663:2009
DIN EN ISO 19232-1	(2013-12)	Non-destructive testing - Image quality of radiographs - Part 1: Determination of the image quality value using wire-type image quality indicators (ISO 19232-1:2013); German version EN ISO 19232-1:2013
DIN ISO 2768-1	(1991-06)	General tolerances; tolerances for linear and angular dimensions without individual tolerance indications; identical with ISO 2768-1:1989
DIN ISO 2768-2	(1991-04)	General tolerances; geometrical tolerances for features without individual tolerances indications; identical with ISO 2768-2:1989

AD 2000-Merkblatt HP 2/1	(2017-06)	Procedure testing for joining processes - Procedure testing for welded joints
SEW 088	(1993-10)	Weldable non-alloy and low-alloy steels - Recommendations for processing, in particular for fusion welding
SEW 550	(1976-08)	Steels for larger forgings; quality regulations
VDI 2230 Blatt 1	(2015-11)	Systematic calculation of highly stressed bolted connections - Joints with one cylindrical bolt
VdTÜV-Merkblatt 1153	(2012-10)	Guideline for the qualification testing of weld additives
VdTÜV-Merkblatt 1253/4	(2017-01)	Listing of the TÜV-approved bolt and nut manufacturers with a waiver of the Inspection Certificate according to DIN EN 10204
Type Approval Z-30.3-6	(2017-05)	General Type Approval Z-30.3-6 “Products, components and connecting elements made from stainless steel” of the Deutsches Institut für Bautechnik (DIBt), valid until May 1, 2022

Appendix G (informative)

Amendments Regarding Previous Version 2002-06

The safety standard was updated to reflect the current state of the art in science and technology. Likewise, all cross-references, definitions and the technical standards referenced were updated. In particular, Section 4 “Analysis” (previous Section 7) and the Appendix A “Material Test Sheets (WPS)” underwent major amendments to reflect the current state of the art in science and technology.

Re Section “General Principles”

The wording of this section was aligned with that of new safety standard KTA 3205.2. The current Radiological Protection Law (StrlSchG) as well as the Safety Requirements for Nuclear Power Plants (SiAnf) and the Interpretations of the Safety Requirements for Nuclear Power Plants (Interpretations of SiAnf) are now also referenced.

Re Section 1 “Scope”

Limiting the scope to component support structures with non-integral connection for components of the primary coolant circuit of light-water reactors is prescribed by the title of the safety standard. The standard DIN EN 1990 classifies support structures according to damaging effects (consequence class), loading (loading category) and type of manufacturing (manufacturing category). Depending on this classification, an execution class is specified that determines, e.g., the extent of the inservice inspections or the type of the welds.

Section 1, Scope, was adapted to be in accordance with the revised safety standard KTA 3205.2 (2015-11). Likewise adapted was the Table 1-1, Steel construction categories for component support structures. Table 1-2, Load case categories and associated design criteria, is a direct copy from the revised safety standard KTA 3205.2.

Re Section 2 “Definitions”

Section 2, Definitions, was revised.

Re Section 3 “Specifications, Design Data Sheets, Documents, Documentation, Design Review, Tests and Inspections”

This section was updated under consideration of the revised safety standard KTA 2201.1 (2011-11), of current steel construction standards and the revised safety standard KTA 3205.2 (2015-11).

Re Section 4 “Analysis”

The former Section 7, Analysis, of safety standard KTA 3205.1 (2002-06) is now Section 4. In line with the revised safety standard KTA 3205.2 (2015-11), its subsections were technically re-sorted (general requirements, certification procedure using partial safety factors, certification procedure using a global safety factor). The tables of Section 4 were aligned with the revised safety standard KTA 3205.2 (2015-11) and the listed values adapted to the scope of safety standard KTA 3205.1.

Re Section 5 “Design”

The former Section 8, Design, of safety standard KTA 3205.1 (2002-06) is now Section 5. Its text was aligned with the revised safety standard KTA 3205.2 (2015-11).

Re Section 6 “Materials and Product Forms”

Section 6, Materials and Product Forms, was adapted to comply with DIN EN 1090 and with the revised safety standard KTA 3205.2 (2015-11) under consideration of the requirements of the primary coolant circuit.

Re Section 7 “Manufacturing”

The former Section 9, Manufacturing, of safety standard KTA 3205.1 (2002-06) is now Section 7. It was adapted to comply with DIN EN 1090-1 and DIN EN 1090-2 (e.g., quality class of weld seam irregularities) and with the revised safety standard KTA 3205.2 (2015-11) under consideration of the requirements of the primary coolant circuit.

Re Section 8 “Inservice Inspection”

The former Section 11, Inservice Inspection, is now Section 8. It was adapted to comply with the revised safety standard KTA 3205.2 (2015-11)

Re Appendix A “Material Test Sheets (WPB)”

All of the Material Test Sheets were adapted to comply with the updated standard.

Re Appendix B “Non-destructive Testing”

Appendix B, Non-destructive Testing, was adapted to ensure uniform rules on implementing and evaluating tests and inspections taking the updated standards into account. Special emphasis was put on a consistent use of the terminology.

Re previous Appendix C “Verification of Stability for Austenitic Steels at Elevated Temperatures”

The previous Appendix C was deleted because it was based on column-buckling analyses presented in the meantime retracted standard DIN 18800. New constructions and constructions under compressive loads are dealt with in the new standard DIN EN 1993.

Re Appendix C “Nomenclature”

This Appendix C, Nomenclature, was introduced to avoid that references from the revised safety standard KTA 3205.2 (2015-11) to Appendix E of the present safety standard KTA 3205.1 do not end in nowhere. Thus, the designation of the further appendices could remain unchanged.

Re Appendix D “Pipe-whip Restraints”

Pipe-whip restraints have been designed and constructed for a very small allowable plastic deformation. This was founded in the short-term nature of the dynamic load peaks. The maximum allowed stresses for the various stress types were individually specified.

Re Appendix E “Dimensioning and Stress Determination Method”

Appendix E, Dimensioning Assumptions, was taken over from the previous version and supplemented by definitions and explanations from DIN 18800 (1981-03) which are necessary for the calculations according to Section 4.3.

Re Appendix F “Regulations Referred to in the Present Safety Standard”

Reference has been made to the new SiAnf and the SiAnf Interpretations and the referenced standards have been updated.