

# Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

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

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# KTA SAFETY STANDARD

October  
2018

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

KTA 3205.1

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

|                                                                                                            |     |
|------------------------------------------------------------------------------------------------------------|-----|
| Basic Principles .....                                                                                     | 5   |
| 1 Scope .....                                                                                              | 5   |
| 2 Definitions .....                                                                                        | 7   |
| 3 Specifications, Design Data Sheets, Documents, Documentation, Design Review, Tests and Inspections ..... | 7   |
| 3.1 Specifications .....                                                                                   | 7   |
| 3.2 Design data sheets .....                                                                               | 7   |
| 3.3 Design Review Documents .....                                                                          | 8   |
| 3.4 Documents for the Final Document File .....                                                            | 8   |
| 4 Analysis .....                                                                                           | 9   |
| 4.1 General Requirements .....                                                                             | 9   |
| 4.2 Certification Procedure Using Partial Safety Factors .....                                             | 10  |
| 4.3 Procedures Using Allowable Stresses .....                                                              | 11  |
| 5 Design .....                                                                                             | 23  |
| 5.1 General Requirements .....                                                                             | 23  |
| 5.2 Requirements .....                                                                                     | 23  |
| 6 Materials and Product Forms .....                                                                        | 23  |
| 6.1 Allowable materials and product forms .....                                                            | 23  |
| 7 Manufacturing .....                                                                                      | 27  |
| 7.1 General Requirements .....                                                                             | 27  |
| 7.2 Suitability of the Manufacturer .....                                                                  | 27  |
| 7.3 Personnel Requirements .....                                                                           | 27  |
| 7.4 Welding of Component Parts .....                                                                       | 27  |
| 7.4.1 General requirements .....                                                                           | 27  |
| 7.5 Forming or Shaping of Component Parts .....                                                            | 29  |
| 7.6 Heat Treatment .....                                                                                   | 29  |
| 7.7 Marking .....                                                                                          | 29  |
| 7.8 Corrosion Protection and Cleanliness .....                                                             | 29  |
| 7.9 Final Inspection .....                                                                                 | 29  |
| 8 Inservice Inspections .....                                                                              | 31  |
| Appendix A Material Test Sheets (WPB) .....                                                                | 34  |
| Appendix B Non-destructive Testing .....                                                                   | 77  |
| Appendix C Nomenclature of the Equations .....                                                             | 82  |
| Appendix D Pip-Whip Restraints .....                                                                       | 83  |
| Appendix E Dimensioning and Stress Determination Method .....                                              | 88  |
| Appendix F Regulations Referred to in the Present Safety Standard .....                                    | 99  |
| Appendix G (informative) Amendments Regarding Previous Version 2002-06 .....                               | 107 |

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](http://www.kta-gs.de)

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#### Comments by the Editor:

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

|                        |                                                                                                                                                                                                                                                                                      |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>shall</b>           | indicates a mandatory requirement,                                                                                                                                                                                                                                                   |
| <b>shall basically</b> | 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 <b>shall normally</b> - are specified in the text of the present safety standard, |
| <b>shall normally</b>  | indicates a requirement to which exceptions are allowed. However, exceptions used shall be substantiated during the licensing procedure,                                                                                                                                             |
| <b>should</b>          | indicates a recommendation or an example of good practice,                                                                                                                                                                                                                           |
| <b>may</b>             | 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 support 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):

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

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.

Component Support Structure

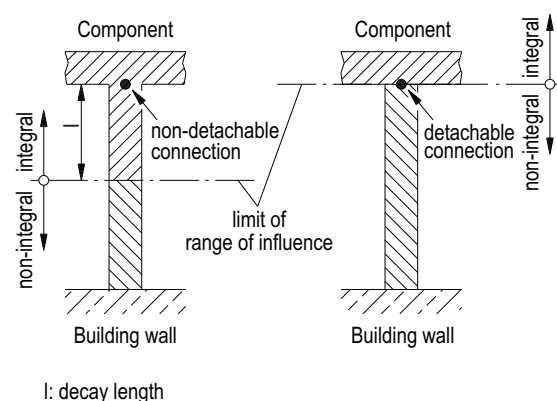


**Figure 1-1:** Attachment types of the component support structure and range of influence of the component

| Ser<br>·<br>No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Specifications for non-integral<br>component support structures are contained in:                               |                                                                           | KTA 3205.1                                | KTA 3205.2                                | Technical<br>standards other<br>than KTA <sup>1)</sup> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------------------------|-------------------------------------------|--------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                 |                                                                           | KTA 3205.3                                |                                           |                                                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Steel structure types:                                                                                          |                                                                           | Components as<br>specified in<br>KTA 3201 | Components as<br>specified in<br>KTA 3211 | Other<br>components                                    |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Steel platforms with supporting function                                                                        |                                                                           | S1                                        | S3 <sup>2)</sup>                          |                                                        |
| 2a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Pipeline and valve supports,<br>pump supports <sup>3)</sup>                                                     | > DN 100                                                                  | S1                                        | S2 <sup>5)</sup>                          | S3 <sup>2), 5)</sup>                                   |
| 2b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                 | ≤ DN 100                                                                  | S2 <sup>4), 5)</sup>                      | S3 <sup>2), 5)</sup>                      |                                                        |
| 3a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Pressure vessel supports                                                                                        | Weight force ≥ 50 kN<br>or pressure-times-liter<br>value ≥ 1000 [bar · l] | S1                                        | S2                                        | S3 <sup>2)</sup>                                       |
| 3b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                 | Weight force < 50 kN<br>or pressure-times-liter<br>value < 1000 [bar · l] | S1                                        | S3 <sup>2)</sup>                          |                                                        |
| 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Protective and special constructions (without Ser. No. 5)<br>including storage facility for new fuel assemblies |                                                                           | S2                                        |                                           | S3 <sup>2)</sup>                                       |
| 5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Pipe-whip restraints                                                                                            |                                                                           | Requirements as specified in Appendix D   |                                           | –                                                      |
| <sup>1)</sup> In accordance with acknowledged technical standards.<br><sup>2)</sup> 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).<br><sup>3)</sup> The determining nominal diameter (DN) for a pump is that of its discharge nozzle.<br><sup>4)</sup> Falls within the scope of the present safety standard; however, the certification process shall be as specified in safety standard KTA 3205.2.<br><sup>5)</sup> 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)<br>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 <sup>1)</sup> and bill of materials <sup>1)</sup> 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) <sup>1)</sup>                                                                                                                                                                                                                                       |
| 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 <sup>1)</sup><br>All test certificates shall be compiled in a list of certificates                                                                                                                                                                                                          |
| <sup>1)</sup> 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 ( $\sigma_{zul}$ -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 ( $\sigma_{zul}$ -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 be 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.

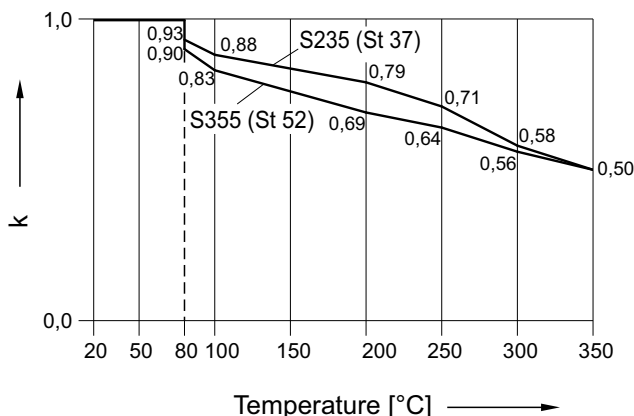


**Figure 4-1:** Reduction factor,  $k$ , for determining the yield strength at elevated temperatures and the tensile strength in dependence of the temperature

The following equations shall be applied:

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

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

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

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

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,  $\mu$ , 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): Dead-weight 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,  $\gamma_M$ , in accordance with DIN EN 1993-1 and the associated national annexes, e.g.:

- a)  $\gamma_{M0}$  for the resistance of cross-sections,
- b)  $\gamma_{M1}$  for the resistance in case of loss of stability,

c)  $\gamma_{M2}$  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.

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

(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.

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

##### 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<sup>2</sup>, 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:

- 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
- 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.
- 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).
- 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

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

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

- Bolted connections shall be verified as specified in Appendix E, Section E 4.
- 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**.
- 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**.
- 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).
- 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**.

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

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} \quad (4-7)$$

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

- 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

- 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,  $\sigma_V$  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  $\sigma_x$  and  $\sigma_z$  are different and

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

then

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

- in all other cases

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

Nomenclature:

- $\sigma_x$  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**

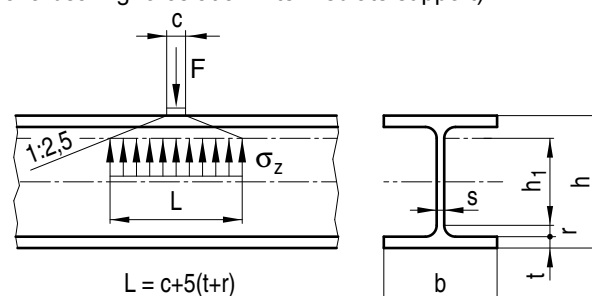
(4) In case of a slenderness ratio of the web (ratio of web height to web thickness) that is larger than 60, the safety against buckling shall be verified for the web.

#### 4.3.3.6 Certification of stability

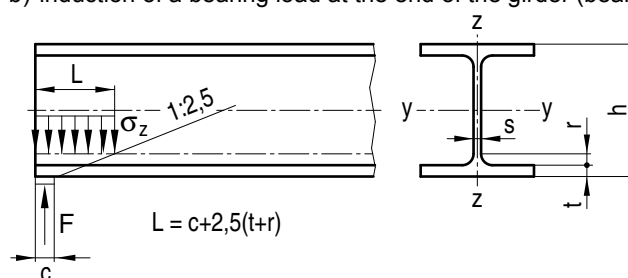
Simple certifications of stability (column buckling) for compression struts of ferritic steels shall be performed as specified in safety standard KTA 3205.2, Appendix A. A reduction of the

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):

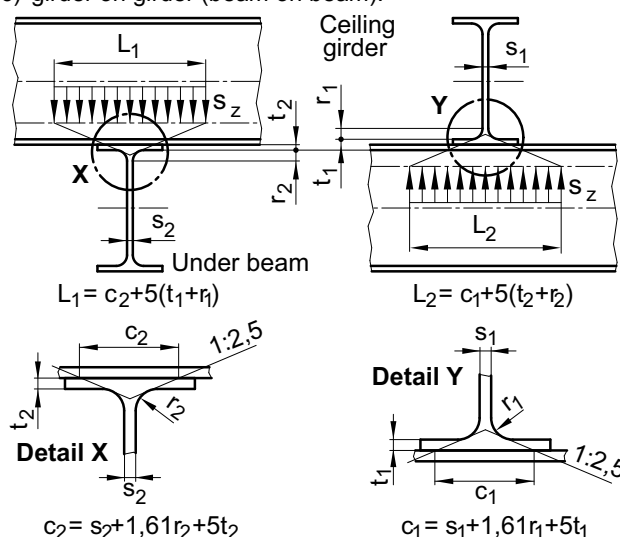


**Figure 4-2:** Load introduction without stiffeners in case of rolled sections with an H-type cross-section (based on historic standard DIN 18800-1)

#### 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:

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

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

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

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:

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

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 through 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, $\gamma_F$ , 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 <sup>3)</sup> | 1.0 <sup>3)</sup> | 1.0 <sup>3)</sup> | 1,0 <sup>3)</sup> | 1,0 <sup>4)</sup> |
| 3        |                                                |                                                                                                       | B2 |                                                             | 1.5                | 1.5                |                   |                   |                   |                   |                   |
| 4        |                                                | Component loads P <sup>1)</sup>                                                                       |    | 1.35                                                        |                    |                    |                   |                   |                   |                   |                   |
| 5        |                                                | Component loads A <sup>1)</sup>                                                                       |    |                                                             | 1.5 <sup>11)</sup> |                    |                   |                   |                   |                   |                   |
| 6        |                                                | Component loads B <sup>1) 6)</sup>                                                                    |    |                                                             |                    | 1.5 <sup>13)</sup> |                   |                   |                   |                   |                   |
| 7        | Accidental actions <sup>2)</sup>               | Component loads C <sup>1) 6) 7)</sup>                                                                 |    |                                                             |                    |                    | 1.17              |                   |                   |                   |                   |
| 8        |                                                | Component loads D <sup>1)</sup>                                                                       |    |                                                             |                    |                    |                   | 1.0               |                   | 1.0               | 1,0 <sup>4)</sup> |
| 9        |                                                | Temperatures during design basis accidents                                                            |    |                                                             |                    |                    |                   |                   |                   |                   | 1,0               |
| 10       |                                                | Pipe rupture loads, jet impingement forces <sup>5) 10)</sup>                                          |    |                                                             |                    |                    |                   |                   | 1.0               |                   |                   |
| 11       |                                                | Additional loads from external events <sup>8)</sup> from the component structure itself <sup>9)</sup> |    |                                                             |                    |                    |                   |                   |                   | 1.0               |                   |
| 12       |                                                |                                                                                                       |    | Safety factors for load combinations, $\psi$ <sup>12)</sup> |                    |                    |                   |                   |                   |                   |                   |
|          |                                                |                                                                                                       |    | 1,0                                                         | 1.0                | 1.0                | 1.0               | 1.0               | 1.0               | 1.0               | 1.0               |

<sup>1)</sup> 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.

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

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

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

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

<sup>6)</sup> Including loads from restrained thermal expansion and boundary displacements.

<sup>7)</sup> Including loads from restrained thermal expansion of the support structure.

<sup>8)</sup> Design basis earthquake and burst-pressure wave, airplane crash, blast-pressure wave.

<sup>9)</sup> 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.

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

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

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

<sup>13)</sup> 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,  $\gamma_F$ , for actions, and safety factors for load combinations,  $\psi$

| Ser. No. | Actions                                        |                                                                                                       | Load combinations<br>(Superposition of the actions) |   |    |                 |                        |                 |                 |                 |
|----------|------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------|---|----|-----------------|------------------------|-----------------|-----------------|-----------------|
|          |                                                |                                                                                                       | 0                                                   | 1 | 2  | 3               | 4                      | 5               | 6               | 7               |
|          |                                                |                                                                                                       | Load case categories (service limit levels)         |   |    |                 |                        |                 |                 |                 |
|          | Design categories in accordance with DIN 25449 |                                                                                                       | HZ                                                  | H | HZ | HS1             | HS2/HS3 <sup>11)</sup> |                 |                 |                 |
|          |                                                |                                                                                                       | 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                                                                              |                                                     | X | X  | X <sup>3)</sup> | X <sup>3)</sup>        | X <sup>3)</sup> | X <sup>3)</sup> | X <sup>4)</sup> |
| 3        |                                                |                                                                                                       |                                                     | X | X  |                 |                        |                 |                 |                 |
| 4        |                                                | Component loads P <sup>1)</sup>                                                                       | X                                                   |   |    |                 |                        |                 |                 |                 |
| 5        |                                                | Component loads A <sup>1)</sup>                                                                       |                                                     | X |    |                 |                        |                 |                 |                 |
| 6        |                                                | Component loads B <sup>1) 6)</sup>                                                                    |                                                     |   | X  |                 |                        |                 |                 |                 |
| 7        | Special loads <sup>2)</sup>                    | Component loads C <sup>1) 6) 7)</sup>                                                                 |                                                     |   |    | X               |                        |                 |                 |                 |
| 8        |                                                | Component loads D <sup>1)</sup>                                                                       |                                                     |   |    |                 | X                      |                 | X               | X <sup>4)</sup> |
| 9        |                                                | Temperatures during design basis accidents                                                            |                                                     |   |    |                 |                        |                 |                 | X               |
| 10       |                                                | Pipe rupture loads, jet impingement forces <sup>5) 10)</sup>                                          |                                                     |   |    |                 |                        | X               |                 |                 |
| 11       |                                                | Additional loads from external events <sup>8)</sup> from the component structure itself <sup>9)</sup> |                                                     |   |    |                 |                        |                 | X               |                 |

<sup>1)</sup> 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.  
<sup>2)</sup> The design data sheet shall include a detailed list of the special loads allocated to the various steel constructions.  
<sup>3)</sup> Only if a simultaneous occurrence of special loads must be assumed (e.g., according to probability considerations in the individual case).  
<sup>4)</sup> Only if a simultaneous occurrence with design basis accident temperatures must be assumed (e.g., according to probability considerations in the individual case).  
<sup>5)</sup> For the jet impingement area, the temperature specific yield strength shall be assumed.  
<sup>6)</sup> Including loads from restrained thermal expansion and boundary displacements.  
<sup>7)</sup> Including loads from restrained thermal expansion of the support structure.  
<sup>8)</sup> Design basis earthquake and burst-pressure wave, airplane crash, blast-pressure wave.  
<sup>9)</sup> 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.  
<sup>10)</sup> Pipe rupture loads and jet impingements forces do not need to be assumed as occurring simultaneously.  
<sup>11)</sup> 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<br>(to be allocated as listed in<br>Tables 6-1 through 6-5) | Formula symbols in<br>DIN EN 1993                                         |                                                            |
|----------|-----------------------------------|----------------------------------------------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------|
|          |                                   |                                                                      | $f_y$ (nominal value of<br>yield strength) corre-<br>sponds to $R_{v0.2}$ | $f_u$ (nominal value of<br>tensile strength) <sup>3)</sup> |
| 1        | Component parts and<br>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,<br>with the exception of<br>Ser. Nos. 1, 2 and 3    | $\min \left( R_{eHT}; \frac{2}{3} R_{mT} \right)^{1)}$                    | $R_{mT}$                                                   |
| 5        |                                   | Stainless austenitic steels                                          | $R_{p0.1T}$<br>or alternatively <sup>2)</sup><br>$1.2 \cdot R_{p0.2T}$    | $R_{mT}$                                                   |
| 6a       | Bolts                             | Property Classes 4.6, 5.6, 8.8 und 10.9                              | —                                                                         | $R_{mT}$                                                   |
| 6b       |                                   | Ferritic steels,<br>with the exception of Ser. No. 6a                | $R_{eHT}$                                                                 | $R_{mT}$                                                   |
| 6c       |                                   | Austenitic steels                                                    | $R_{p0.2T}$                                                               | $R_{mT}$                                                   |

<sup>1)</sup> 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.

<sup>2)</sup> If values for  $R_{p1.0T}$  are not available.

<sup>3)</sup> 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<br>(allocated as listed in<br>Tables 6-1 through 6-5) | Equivalent Yield Stress, $R_{v0.2}$                    |
|----------|-----------------------------------|----------------------------------------------------------------|--------------------------------------------------------|
| 1        | Component parts and<br>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,<br>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 <sup>2)</sup>      | 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.<br>cf. <b>Table 4-8</b>            |
| 7b       |                                   | Ferritic steels,<br>with the exception of Ser. No. 6a          | $R_{eHT}$                                              |
| 7c       |                                   | Austenitic steels                                              | $R_{p0.2T}$                                            |

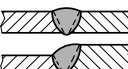
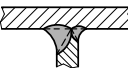
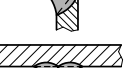
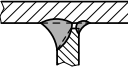
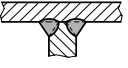
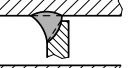
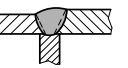
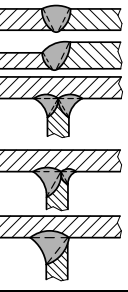
<sup>1)</sup> In case the ratio  $R_{eH} / R_m$  is equal to or greater than 0.7, the equivalent yield strength  $R_{v0.2} = \min \{R_{eHT}; 1.5 / 2.4 R_m\}$ . If the yield strength is less pronounced, the values for the 0.2 % proof stress shall be applied.

<sup>2)</sup> 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.<br>No.                                                                                                                                                                                                                                                                                                                                                                                      | Types of Stress                                                                                            |                                         |                                                                                                                                                                                                                      | Allowable Stresses<br>(in relation to $R_{v0.2}$ ) |                    |                    |             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------|--------------------|-------------|
|                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                            |                                         |                                                                                                                                                                                                                      | H                                                  | HZ                 | HS1                | HS2/<br>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 <sup>1)</sup>                                 | 0.75 <sup>1)</sup> | 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 <sup>2)</sup>                                 | 0.75 <sup>2)</sup> | 0.85 <sup>2)</sup> | 1.0         |
| 5                                                                                                                                                                                                                                                                                                                                                                                                | Allowable bearing pressure <sup>4)</sup> 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)<br>Bore hole tolerance $0.3 \text{ mm} < \Delta d \leq 2 \text{ mm}$ – without pre-loading <sup>3)</sup>                 | 1.17                                               | 1.33               | 1.50               | 1.75        |
| 6                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                            | SL                                      | High-strength bolts (DIN EN 14399-4)<br>Bore hole tolerance $0.3 \text{ mm} < \Delta d \leq 2 \text{ mm}$ – not systematic pre-loading: $\geq 0.5 \cdot F_V$                                                         | 1.58                                               | 1.80               | 2.10               | 2.4         |
| 7                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                            | SLP                                     | Fit bolts (DIN 7968)<br>Bore hole tolerance $\Delta d \leq 0.3 \text{ mm}$ – without pre-loading                                                                                                                     | 1.33                                               | 1.50               | 1.75               | 2.0         |
| 8                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                            | SLP                                     | High-strength fit bolts<br>Bore hole tolerance $\Delta d \leq 0.3 \text{ mm}$ – not systematic pre-loading: $\geq 0.5 \cdot F_V$                                                                                     | 1.75                                               | 1.96               | 2.25               | 2.6         |
| 9                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                            | GV, GVP                                 | High-strength bolts <sup>5)</sup> - bore hole tolerance $0.3 \text{ mm} < \Delta d \leq 2 \text{ mm}$<br>High-strength fit bolts - bore hole tolerance $\Delta d \leq 0.3 \text{ mm}$ with pre-load: $1.0 \cdot F_V$ | 2.00                                               | 2.25               | 2.50               | 3.0         |
| SL : shear bearing bolted connection<br>GV : slip-resistant bolted connection<br>SLP : shear bearing bolted connection with fit bolts<br>GVP : slip-resistant bolted connection with fit bolts<br>$F_V$ : pre-load force as specified in <b>Tables 4-12</b> and <b>4-13</b> for bolt sizes 8.8 and 10.9 respectively; the values, $F_V$ , for other bolt sizes are specified in VDI 2230 Sheet 1 |                                                                                                            |                                         |                                                                                                                                                                                                                      |                                                    |                    |                    |             |
| <sup>1)</sup> 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).                                                                                                                                                                                                                                  |                                                                                                            |                                         |                                                                                                                                                                                                                      |                                                    |                    |                    |             |
| <sup>2)</sup> In case of a local stress limitation, 10 % higher values are allowed.                                                                                                                                                                                                                                                                                                              |                                                                                                            |                                         |                                                                                                                                                                                                                      |                                                    |                    |                    |             |
| <sup>3)</sup> In case of slotted holes, the values shall be applied as 100 % lengthwise and as 70 % crosswise.                                                                                                                                                                                                                                                                                   |                                                                                                            |                                         |                                                                                                                                                                                                                      |                                                    |                    |                    |             |
| <sup>4)</sup> Edge distance: in direction of force $2d \leq e \leq \min\{3d; 6t\}$<br>transverse to direction of force $1.5d \leq e \leq \min\{3d; 6t\}$<br><br>Hole spacing: $3d \leq e \leq \min\{6d; 12t\}$<br>with edge distance (e), hole diameter (d) and smallest sheet thickness (t).                                                                                                    |                                                                                                            |                                         |                                                                                                                                                                                                                      |                                                    |                    |                    |             |
| <sup>5)</sup> 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)<br>[S355 (St52)] and <Others><br>(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<br>[0.66]<br><0.66><br>(0.66)<br>{0.66}                                                                                         | 0.75<br>[0.75]<br><0.75><br>(0.75)<br>{0.75}               | 0.85<br>[0.85]<br><0.85><br>(0.85)<br>{0.85}               | 1.00<br>[1.00]<br><1.00><br>(1.00)<br>{1.00}               |
| 1b       |                             | Single bevel groove weld                                                            |  | Tension, bending tension, reference value | Certified weld quality <sup>1)</sup>     | 0.66<br>[0.66]<br><0.66><br>(0.50)<br>{0.37}                                                                                         | 0.75<br>[0.75]<br><0.75><br>(0.58)<br>{0.42}               | 0.85<br>[0.85]<br><0.85><br>(0.65)<br>{0.48}               | 1.00<br>[1.00]<br><1.00><br>(0.75)<br>{0.55}               |
| 1c       |                             | Double bevel groove weld                                                            |  |                                           | Weld quality not certified               | 0.56<br>[0.47]<br><0.47><br>(0.35)<br>{0.26}                                                                                         | 0.63<br>[0.53]<br><0.53><br>(0.40)<br>{0.29}               | 0.70<br>[0.60]<br><0.57><br>(0.43)<br>{0.31}               | 0.84<br>[0.71]<br><0.63><br>(0.48)<br>{0.35}               |
| 2a       | Not fully penetrating welds | Half-Y welds                                                                        |  | Compression, bending compression          | All weld qualities                       | 0.66<br>[0.66]<br><0.66><br>(0.66)<br>{0.66}                                                                                         | 0.75<br>[0.75]<br><0.75><br>(0.75)<br>{0.75}               | 0.85<br>[0.85]<br><0.85><br>(0.85)<br>{0.85}               | 1.00<br>[1.00]<br><1.00><br>(1.00)<br>{1.00}               |
| 2b       |                             | Double-Half-Y welds                                                                 |  | Tension, bending tension, reference value | All weld qualities                       | 0.56<br>[0.47]<br><0.47><br>(0.35)<br>{0.26}                                                                                         | 0.63<br>[0.53]<br><0.53><br>(0.40)<br>{0.29}               | 0.70<br>[0.60]<br><0.57><br>(0.43)<br>{0.31}               | 0.84<br>[0.71]<br><0.63><br>(0.48)<br>{0.35}               |
| 3a       | Fillet welds                |  | All stress types (shear stress cf. Ser. No. 5)                                    | All weld qualities                        | All weld qualities                       | 0.56<br>[0.47]<br><0.47><br>(0.35)<br>{0.26}                                                                                         | 0.63<br>[0.53]<br><0.53><br>(0.40)<br>{0.29}               | 0.70<br>[0.60]<br><0.57><br>(0.43)<br>{0.31}               | 0.84<br>[0.71]<br><0.63><br>(0.48)<br>{0.35}               |
| 3b       |                             |                                                                                     |                                                                                   |                                           |                                          |                                                                                                                                      |                                                            |                                                            |                                                            |
| 3c       |                             |                                                                                     |                                                                                   |                                           |                                          |                                                                                                                                      |                                                            |                                                            |                                                            |
| 4a       | Three-plate welds           |  | Compression, bending compression                                                  | All weld qualities                        | All weld qualities                       | 0.66<br>[0.66]<br><0.66>                                                                                                             | 0.75<br>[0.75]<br><0.75>                                   | 0.85<br>[0.85]<br><0.85>                                   | 1.00<br>[1.00]<br><1.00>                                   |
| 4b       |                             |                                                                                     | Tension, bending tension, reference value                                         | Certified weld quality <sup>1)</sup>      | Certified weld quality <sup>1)</sup>     | 0.66<br>[0.66]<br><0.66>                                                                                                             | 0.75<br>[0.75]<br><0.75>                                   | 0.85<br>[0.85]<br><0.85>                                   | 1.00<br>[1.00]<br><1.00>                                   |
| 4c       |                             |                                                                                     |                                                                                   | Weld quality not certified <sup>2)</sup>  | Weld quality not certified <sup>2)</sup> | 0.56<br>[0.47]<br><0.47>                                                                                                             | 0.63<br>[0.53]<br><0.53>                                   | 0.70<br>[0.60]<br><0.60>                                   | 0.84<br>[0.71]<br><0.71>                                   |
| 5        | All welds                   |  | Shear force in seam direction                                                     | All weld qualities                        | All weld qualities                       | 0.56<br>[0.47]<br><0.37> <sup>3)</sup><br>(0.35)<br>{0.26}                                                                           | 0.63<br>[0.53]<br><0.43> <sup>3)</sup><br>(0.40)<br>{0.29} | 0.70<br>[0.60]<br><0.47> <sup>3)</sup><br>(0.43)<br>{0.31} | 0.84<br>[0.71]<br><0.50> <sup>3)</sup><br>(0.48)<br>{0.35} |

<sup>1)</sup> cf. Section 7.9.2.4.3 item b) and Section 7.9.2.4.4 item b)  
<sup>2)</sup> 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  
<sup>3)</sup> 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                 | HZ                | HS1               | HS2/HS3           |
|          |                |                |         | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> |
| 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/mm <sup>2</sup> |      |      |           |
| Compression, bending compression, bending tension, bending | S235       | 160                                     | 180  | 210  | 235       |
|                                                            | S355       | 240                                     | 270  | 310  | 355       |
| Hertzian contact pressure <sup>1)</sup>                    | S235       | 650                                     | 800  | 890  | 960       |
|                                                            | S355       | 850                                     | 1050 | 1190 | 1295      |
| Bearing pressure for hinge pins <sup>2)</sup>              | S235       | 210                                     | 240  | 275  | 320       |
|                                                            | S355       | 320                                     | 360  | 415  | 480       |
| Kind of stress                                             | Material   | Allowable Stresses in N/mm <sup>2</sup> |      |      |           |
| Compression, bending compression, bending tension, bending | all others | 0.67                                    | 0.75 | 0.85 | 1.00      |
| Hertzian contact pressure <sup>1)</sup>                    | all others | 2.40                                    | 3.00 | 3.30 | 3.60      |
| Bearing pressure for hinge pins <sup>2)</sup>              | 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 $R_{eH} \leq 450 \text{ N/mm}^2$ |                 |                 |                 |                 |
| 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 $R_{eH} > 450 \text{ N/mm}^2$    |                 |                 |                 |                 |
| 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,  $R_{v0.2}$ , listed in Table 4-5) for bolts and threaded parts not covered by Table 4-8

| Bolt Size                                                                                                          | Shear Area in $\text{mm}^2$ |                            | Core (Root) Cross-Section in $\text{mm}^2$ | Stress Cross-Section in $\text{mm}^2$ |
|--------------------------------------------------------------------------------------------------------------------|-----------------------------|----------------------------|--------------------------------------------|---------------------------------------|
|                                                                                                                    | 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<br>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<br>(10.9) | Pre-load<br>force, $F_v$ ,<br>in kN | Allowable Lateral Force<br>in kN                    |        |         |                                                                        |        |         | Allowable Tensile Force<br>in kN |        |         |
|---------------------|-------------------------------------|-----------------------------------------------------|--------|---------|------------------------------------------------------------------------|--------|---------|----------------------------------|--------|---------|
|                     |                                     | Pre-loaded slip-resistant<br>bolted connection (GV) |        |         | Pre-loaded slip-resistant<br>bolted connection with fit<br>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 | $P_m$              | $P_l, (P_m + P_b)$<br>or $(P_l + P_b)$ | $P_m + P_b + Q$<br>or $P_l + P_b + Q$ |
|------------|--------------------|----------------------------------------|---------------------------------------|
| H          | $1.00 \cdot S_m$   | $1.20 \cdot S_m$                       | $2.50 \cdot S_m$ <sup>1)</sup>        |
| HZ         | $1.15 \cdot S_m$   | $1.38 \cdot S_m$                       | $2.88 \cdot S_m$ <sup>1)</sup>        |
| HS1        | $1.30 \cdot S_m$   | $1.56 \cdot S_m$                       | –                                     |
| HS2        | $1.50 \cdot S_m$   | $1.80 \cdot S_m$                       | –                                     |
| HS3        | $0.7 \cdot R_{mT}$ | $R_{mT}$                               | –                                     |

<sup>1)</sup> 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 (1.4301)<br>X5CrNiMo17-12-2 (1.4401)<br>X6CrNiTi18-10 (1.4541)<br>X6CrNiNb18-10 (1.4550)<br>X6CrNiMoTi17-12-2 (1.4571) |
| 2        | 1.2 | Creep-resisting quenched and tempered steels in accordance with Annex to WPB 1.2                      | 20 MnMoNi 5 5 (1.6310)<br>22 NiMoCr 3 7 <sup>1)</sup> (1.6751)                                                                     |
| 3        | 1.3 | Creep-resisting steels in accordance with DIN EN 10028-2                                              | P265GH (1.0425)<br>P295GH (1.0481)<br>P355GH (1.0473)<br>16Mo3 (1.5415)<br>13CrMo4-5 (1.7335)                                      |
| 4        | 1.4 | Non-alloy structural steels in accordance with DIN EN 10025-2                                         | S235JR <sup>2)</sup> (1.0038)<br>S235J2 (1.0117)<br>S355J2 (1.0577)                                                                |
| 5        | 1.5 | Quenched and tempered steels in accordance with <sup>3)</sup><br>DIN EN 10083-2<br><br>DIN EN 10083-3 | C35E+QT (1.1181)<br>C45E+QT (1.1191)<br>42CrMo4 (1.7225)<br>34CrNiMo6 (1.6582)                                                     |
| 6        | 1.6 | Weldable fine-grain structural steels in accordance with<br>DIN EN 10025-3<br><br>DIN EN 10025-4      | S275N (1.0490)<br>S355N (1.0545)<br>S275M (1.8818)<br>S355M (1.8823)                                                               |

<sup>1)</sup> The requirements for the steel 22 NiMoCr 3 7 shall be specified within the framework of design review.  
<sup>2)</sup> 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).  
<sup>3)</sup> 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)<br>X5CrNiMo17-12-2 (1.4401)<br>X6CrNiTi18-10 (1.4541)<br>X6CrNiNb18-10 (1.4550)<br>X6CrNiMoTi17-12-2 (1.4571) |
| 2        | 2.2 | Non-alloy structural steels in accordance with DIN EN 10219-1                                     | S235JRH (1.0039)<br>S355J2H (1.0576)                                                                                               |
| 3        | 2.3 | Creep-resisting steels in accordance with DIN EN 10216-2                                          | P235GH (1.0345)<br>P265GH (1.0425)<br>16Mo3 (1.5415)<br>10CrMo9-10 (1.7380)<br>13CrMo4-5 (1.7335)                                  |
| 4        | 2.4 | Non-alloy structural steels in accordance with DIN EN 10210-1                                     | S235JRH (1.0039)<br>S275J2H (1.0138)<br>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)<br>X5CrNiMo17-12-2 (1.4401)<br>X6CrNiTi18-10 (1.4541)<br>X6CrNiNb18-10 (1.4550)<br>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)<br>22 NiMoCr 3 7 <sup>1)</sup> (1.6751)                                                                     |
| 3        | 3.3 | Non-alloy structural steels in accordance with DIN EN 10250-2                                                                                                                                   | S235JRG2 (1.0038)<br>S235J2G3 (1.0116)<br>S355J2G3 (1.0570)                                                                        |
| 4        | 3.4 | Creep-resisting steels in accordance with DIN EN 10222-2 or DIN EN 10273                                                                                                                        | P250GH (1.0460)<br>16Mo3 (1.5415)                                                                                                  |
| 5        | 3.5 | Quenched and tempered steels in accordance with <sup>2)</sup><br>DIN EN 10083-2, DIN EN 10269 or SEW 550 <sup>3)</sup><br>DIN EN 10083-3, DIN EN 10269 or SEW 550 <sup>3)</sup><br>DIN EN 10269 | C45E+QT (1.1191)<br>34CrNiMo6 (1.6582)<br>42CrMo4 (1.7225)<br>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)<br>26 NiCrMo 14 6 (1.6958)                                                                                 |

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

<sup>2)</sup> A weld-related processing of these steels is not allowed.

<sup>3)</sup> 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<br>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<br>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<br>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<br><br>Assemblies additionally in accordance with DIN EN 14399-2 | Property Classes 8.8 / 8 and 10.9 / 10 <sup>1)</sup><br><br>C45 (1.0503)<br><br>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<br>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)<br>X6CrNiNb18-10 (1.4550)<br>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<br>in accordance with DIN EN 10269, DIN EN 10083-2 or DIN EN 10083-3<br><br>in accordance with Annex to WPB 4.5                                                                                   | C35E (1.1181)<br>C45E (1.1191)<br>X19CrMoNbVN-11-1 (1.4913)<br>34CrNiMo6 (1.6582)<br>25CrMo4 (1.7218)<br>42CrMo4 (1.7225)<br>21CrMoV5-7 (1.7709)<br>40CrMoV4-6 (1.7711)<br><br>26 NiCrMo 14 6 (1.6958)<br>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)<br>25CrMo4 (1.7218)<br>21CrMoV5-7 (1.7709)<br>40CrMoV4-6 (1.7711)<br>X19CrMoNbVN-11-1 (1.4913)                                                                                                                      |

<sup>1)</sup> 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)<br>GP240GH (1.0619)   |
| 2        | 5.2 | Austenitic and martensitic steel castings in accordance with DIN EN 10213    | GX5CrNiNb19-11 (1.4552)<br>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-affecting 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 as 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 under-bead cracks is required in the case of steels with a yield strength at room temperature  $R_{p0.2}$  larger than 355 N/mm<sup>2</sup>.

### 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 examina-

tions 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: <input type="text"/> of: <input type="text"/> |                      |
| 1                                                                                                   | Power Plant / Project:<br><input type="text"/>                | Component:<br><input type="text"/>                                |                      | Subassembly:<br><input type="text"/>                |                      |
| KKS <input type="text"/> <sup>1)</sup> :                                                            |                                                               | PFP / WPP / Quality Class <sup>2)</sup> :<br><input type="text"/> |                      | Test No.:<br><input type="text"/>                   |                      |
| Manufacturer:<br><input type="text"/>                                                               |                                                               | Order No.:<br><input type="text"/>                                |                      | Marking No. <sup>3)</sup> :<br><input type="text"/> |                      |
| Welding Procedure Specification (WPS): <input type="text"/> Weld Location No.: <input type="text"/> |                                                               |                                                                   |                      |                                                     |                      |
| 2                                                                                                   | Date: <input type="text"/> Time: <input type="text"/>         | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
| 3                                                                                                   | Welder ID:                                                    | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
| 4                                                                                                   | Weld Sequence:                                                | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
| 5                                                                                                   | Dimension: <input type="text"/> [mm]                          |                                                                   |                      |                                                     |                      |
|                                                                                                     | Trademark                                                     |                                                                   |                      |                                                     |                      |
|                                                                                                     | Melt No.                                                      |                                                                   |                      |                                                     |                      |
|                                                                                                     | Powder / Batch No.                                            |                                                                   |                      |                                                     |                      |
| 6                                                                                                   | Position                                                      | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Pre-heating / Interpass Temperature <input type="text"/> [°C] | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Weld Additive No.                                             | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Current <input type="text"/> [A]                              | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Voltage <input type="text"/> [V]                              | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Welding Velocity ① <input type="text"/> [mm/min]              | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Welding Nozzle No. ①                                          | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Area (cf. Sketch) ①                                           | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Bead No. ②                                                    | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Oscillation Width ②                                           | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
| Layer No. ②                                                                                         | <input type="text"/>                                          | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                |                      |
| 7                                                                                                   | Remarks:                                                      |                                                                   |                      |                                                     |                      |
| Supervision                                                                                         | Manufacturer (H)                                              | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     | Authorized Expert (S)                                         | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |
|                                                                                                     |                                                               | <input type="text"/>                                              | <input type="text"/> | <input type="text"/>                                | <input type="text"/> |

|                                                                                                                                                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ① Only for mechanized welding      ② Only for manual welding                                                                                                                                                                       |
| 1) KKS = Identification System for Power Plants<br>2) cross out whichever does not apply<br>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)<br>and other ferritic steels |                   |                   |
|----------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|-------------------|-------------------------------------------|-------------------|-------------------|
|                                                                                                                | Plate Thickness (t) in mm  |                   |                   |                                           |                   |                   |
|                                                                                                                | ≤ 20                       | 20 < t ≤ 40       | > 40              | ≤ 20                                      | 20 < t ≤ 40       | > 40              |
| Without preheating                                                                                             | —                          | Z15 <sup>1)</sup> | Z25 <sup>1)</sup> | —                                         | Z25 <sup>1)</sup> | Z25 <sup>1)</sup> |
| With preheating at<br>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)<br>S355 (St 52)<br>P265GH (HII)<br>16Mo3 (15 Mo 3)<br>P235GH (St 35.8) | High-strength, quenched and tempered steels:<br>15 NiCuMoNb 5-6-4 (15 NiCuMoNb 5)<br>20 MnMoNi 5 5<br>22 NiMoCr 3 7 | Other Materials                                        |
|---------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| Volumetric testing with ultrasonic or radiographic procedures | Manufacturer: 10 %<br>Authorized expert: randomly                                   | Manufacturer: 100 %<br>Authorized expert: at least 25 %                                                             | Manufacturer: 25 %<br>Authorized expert: at least 10 % |
| Surface inspection                                            | Manufacturer: 10 %<br>Authorized expert: randomly                                   | Manufacturer: 100 %<br>Authorized expert: at least 25 %                                                             | Manufacturer: 25 %<br>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**