Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3211.1 (2017-11)

Pressure- and activity-retaining components of systems outside the primary circuit
Part 1: Materials

(Druck- und aktivitätsführende Komponenten von Systemen außerhalb des Primärkreises; Teil 1: Werkstoffe)

Please note:
This translation includes the correction published in BAnz of April 24th, 2019.

Previous versions of this Safety Standard were issued 1991-06, 2000-06 and 2015-11

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

Editor:

KTA-Geschaeftsstelle c/o Bundesamt fuer kerntechnische Entsorgungs-sicherheit (BfE) • Willy-Brandt-Strasse 5 • 38226 Salzgitter • Germany
Telephone +49-30-18-333-1621 • Telefax +49-30-18-333-1625

KTA SAFETY STANDARD

November 2017	Pressure- and activity-retaining components of systems outside the primary circuit; Part 1: Materials	KTA 3211.1

CONTENTS

Fundamentals 5
1 Scope 5
2 Definitions 5
3 General principles 6
3.1 Selection of materials 6
3.2 Appraisal of the materials 6
3.3 General quality-assurance requirements 6
3.4 Requirements to be met by the manufacturer 6
3.5 Design approval 7
3.6 In-process inspection by the authorized inspector to § 20 of the Atomic Energy Act 7
3.7 Verification of quality characteristics 7
3.8 Marking 7
3.9 Repairs 7
3.10 Material characteristic data for design analysis 7
4 Generally applicable stipulations for materials and material tests 7
4.1 General 7
4.2 Allowable materials 7
4.3 Requirements for the materials and their product forms 7
4.4 Testing and examination of materials and product forms 8
4.5 Re-examinations 10
5 Product forms of ferritic steels of material group W I 10
5.1 Flat products 10
5.2 Dished or pressed product forms made from flat products 12
5.3 Forgings, bars and rolled rings 13
5.4 Seamless pipes larger than DN 50 17
5.5 Seamless pipe elbows larger than DN 50 18
5.6 Seamless fittings larger than DN 50 20
5.7 Castings 21
6 Product forms of ferritic steels of material group W II 23
6.1 Flat products 23
6.2 Dished or pressed product forms made from flat products 24
6.3 Forgings, bars and rolled rings 25
6.4 Seamless pipes larger than DN 50 27
6.5 Seamless pipe elbows larger than DN 50 28
6.6 Seamless fittings larger than DN 50 29
6.7 Castings 30
7 Product forms of austenitic steels 31
7.1 Flat products 31
7.2 Dished or pressed product forms made from flat products 32
7.3 Forgings, bars and rolled rings 33
7.4 Seamless pipes larger than DN 50 34
7.5 Seamless pipe elbows larger than DN 50 35
7.6 Seamless fittings larger than DN 50 36
7.7 Castings 37
8 Bolts and nuts 39
8.1 Scope 39
8.2 Materials 39
8.3 Additional requirements for the materials 39
8.4 Bolts and nuts made by machining from quenched and tempered bars or from hot-cold work hardened austenitic bars 39
8.5 Bolts and nuts made by machining from solution-annealed and quenched austenitic bars 41
8.6 Bolts and nuts made by hot or cold forming and then quenched and tempered 41
8.7 Bolts and nuts of strength classes or steel grades 42
8.8 Marking 43
8.9 Verification of quality characteristics 43
9 Product forms of steels for special loads 44
9.1 Forgings, bars and rolled rings 44
9.2 Castings 45
10 Heat-exchanger tubes 46
10.1 Seamless straight heat-exchanger tubes of ferritic steels with wall thicknesses smaller than or equal to 4 mm and with outside diameters smaller than or equal to 38 mm 46
10.2 Seamless bent heat-exchanger tubes of ferritic steels with wall thicknesses smaller than or equal to 4 mm and with outside diameters smaller than or equal to 38 mm 46
10.3 Seamless straight heat-exchanger tubes of austenitic steels with wall thicknesses smaller than or equal to 3.6 mm and with diameters smaller than or equal to 42.4 mm 47
10.4 Seamless bent heat-exchanger tubes of austenitic steels with wall thicknesses smaller than or equal to 3.6 mm and with diameters smaller than or equal to 42.4 mm 48
10.5 Longitudinally welded straight heat-exchanger tubes of austenitic steels with wall thicknesses smaller than 2 mm and with diameters D_a smaller than or equal to 38 mm 49

(Continued next page)

PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 35-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in Bundesanzeiger of May 17th 2018. Copies of the German versions of the KTA safety standards may be mail-ordered through the Wolters Kluwer Deutschland GmbH (info@wolterskluwer.de). Downloads of the English translations are available at the KTA website (http://www.kta-gs.de).

All questions regarding this English translation should please be directed to the KTA office:
KTA-Geschaeftsstelle c/o BfE, Willy-Brandt-Strasse 5, D-38226 Salzgitter, Germany or kta-gs@bfe.bund.de

CONTENTS

(Continued)

11 Non-destructive tests and examinations 50
11.1 General requirements 50
11.2 Flat products 52
11.3 Dished or pressed product forms made from flat products 53
11.4 Forgings, bars and rings 53
11.5 Seamless pipes larger than DN 50 56
11.6 Seamless pipe elbows larger than DN 50 57
11.7 Seamless fittings larger than DN 50 57
11.8 Castings 58
11.9 Bolts and nuts 64
11.10 Product forms of steels for special loads 65
11.11 Heat-exchanger tubes 65

Annex A: Material characteristic data 69
Annex AP: Reference data on physical characteristics 94
Annex B: Production welds of steel castings 96
Annex C: Procedure for determining the delta ferrite content 100
Annex D: Performance of manual ultrasonic testing 102
Annex E: Performance of surface inspections by magnetic particle and penetrant methods 119
Annex F: Regulations and literature referred to in this Safety Standard 121

Comments by the editor:

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

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

Fundamentals

(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 and the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants as well as in the Interpretations on the Safety Requirements for Nuclear Power Plants.

(2) No. 3.1 of the Safety Requirements for Nuclear Power Plants requires the use of qualified materials as well as the assurance and maintenance of the quality features during manufacturing. The safety requirement no. 3.4 sets forth further design and fabrication requirements for the pressure-retaining walls of components outside the primary circuit. KTA safety standard 3211.1 defines provisions to be made to meet these requirements within their scope of application. For this purpose it also draws upon numerous individually cited rules from conventional engineering, especially DIN Standards. For the pressure- and activity-retaining components of systems outside the primary circuit the requirements of the aforementioned safety requirements are further concretised with the following safety standards

KTA 3211.2 Design and Analysis,

KTA 3211.3 Manufacture

KTA 3211.4 In-service Inspections and Operational Monitoring, as well as with

KTA 3206 Break Preclusion Verifications for Pressure-Retaining Components in Nuclear Power Plants.

(3) KTA 3211.1 specifically defines the requirements to be imposed on:

a) organizations involved in manufacturing,

b) manufacture of materials and product forms as well as their chemical composition, mechanical and technological characteristics, physical characteristics, heat treatment and further processing,

c) methods for testing and verifying the required quality of materials and product forms, such as destructive and non-destructive examinations,

d) provision of documents for documentation of the test and inspection results.

1 Scope

(1) This safety standard shall apply to the materials and product forms of the pressure-retaining walls of pressure- and activity-containing light-water-reactor systems and components that do not belong to the reactor-coolant pressure boundary but have relevance specifically to reactor engineered safety. This definition shall include systems and components meeting one of the following criteria:

a) The plant section is necessary for accident control by means of shutdown, maintenance of long-term subcriticality and direct residual heat removal. Requirements for components in systems involved only indirectly in residual heat removal - in other words the closed cooling-water systems and secondary cooling-water systems which do not carry activity - shall be established on a plant-specific basis with consideration of the multiple design (e.g., redundancy-type, diversity-type).

b) Considerable energy is released in the event of failure of the plant section, and the consequences of failure are not limited by structural provisions, spatial separation or other safety provisions to an extent that is acceptable for nuclear safety.

c) Failure of the plant section can lead directly or via a chain of conceivable subsequent events to an accident as defined by § 49 of the Radiation Protection Ordinance.

(2) The following components fall within the scope of application of this safety standard:

a) pressure vessels,

b) piping systems and piping-system parts,

c) pumps and

d) valves and fittings

including the integral zones of the component support structures.

(3) This safety standard shall not apply to:

a) piping systems and to valves and fittings of DN 50 size or smaller,

b) internals of components (that are not part of the pressure-containing wall) and accessories,

c) systems and plant sections that perform auxiliary functions for the systems in question here,

d) system parts in which the system pressure is determined exclusively by the geodetic pressure head in the suction zone,

e) parts for force and power transmission to pumps and to valves and fittings as well as inspections for verification of functional capability,

f) weld filler metals and welding consumables,

g) small parts.

Note:

Small parts are subject to the stipulations of Section 10 and of Table 2-3 of KTA 3211.3.

2 Definitions

(1) Loading temperature, lowest

The lower of the pressure-test temperature or lowest operating temperature is designated the lowest loading temperature.

(2) Production welding

Production welding means welding performed prior to delivery to the customer to ensure the stipulated quality of cast pieces.

(3) Construction welding

Construction welding is a welded joint between two cast pieces performed prior to delivery to the customer to produce a complete unit.

(4) Test groups A1, A2 and A3

The components in the scope of application of this safety standard shall be classified in test groups A1, A2 or A3 depending on design data and dimensions, with consideration of the planned materials and stresses. KTA 3211.2 defines the criteria for classification of a component.

Note:

The allocation to the test groups is made by the licence holder by agreement with the authorized inspector.

(5) Room temperature

The temperature range for the room temperature is (23 ± 5) °C for the mechanical tests laid down in this safety standard.

(6) Noise

Depending on the test conditions, randomly distributed additional signals in the screen image due to reflections from the structure of the material, its surface condition or the electronics.

(7) Noise level

Noise level means the 95 % value of the cumulative frequency of the echo heights of the noise in the examined volume free from defects.

(8) Authorized inspector

The authorized inspector for the tests and inspections to be conducted in accordance with this safety standard is the authorized inspector called in by the licensing or supervisory authority in accordance with Section 20 of the Atomic Energy Act. The inspections/reviews required by this safety standard shall be performed on the basis of applications made by the competent authority.

(9) Ultrasonic testing, selected

Selected ultrasonic testing means testing where the acceptance criteria refer to the finished component. To this end, it is required to know the shape and final dimensions of the components to be fabricated from the test object as well as their location in the test object.

(10) Ultrasonic testing, global

Global ultrasonic testing means testing where the acceptance criteria have been determined globally without reference to a finished component.

(11) Reference block

A reference block is a block corresponding to the test object with respect to test-relevant characteristics (e.g. material, forging direction, shape, wall thickness) and that contains reference flaws (e.g. notches, bores) adapted to the individual testing task.

(12) Material group W I or W II

The ferritic materials for manufacturing components within the scope of application of this safety standard are classified in material groups W I or W II according to their quality features, especially chemical composition and toughness characteristics. The allocation of materials to test groups is defined in KTA 3211.2.

(13) Acceptance criteria for non-destructive testing

Non-destructive testing acceptance criteria refer to the sum of all stipulations used to determine whether an indication can be evaluated to be acceptable without taking further measures (requirements of test instruction have been met) or whether further measures need be taken. The acceptance criteria contain both quantitative stipulations in form of acceptance limits (e.g. amplitude height, extension of indication, frequency, and distance between indications) and descriptive stipulations (e.g. linear or rounded indication, indication on surface or across volume, accumulation of indications).

3 General principles

3.1 Selection of materials

(1) Materials appropriate for the intended use shall be selected, with consideration of the mechanical, thermal and chemical loadings as well as the design conditions to KTA 3211.2.

(2) The materials shall safely withstand the loadings during the pressure test, during operation and all specified plant conditions. Any materials on which welding is to be performed shall be suitable for welding.

Note:

The selection of material shall be made by the purchaser, if necessary after consultation with the material manufacturer.

3.2 Appraisal of the materials

(1) The materials shall be appraised to determine whether they are suitable for the intended use and the planned processing conditions.

(2) Ferritic steels for service in material group W I shall be appraised with reference to the manufacturer and to the product form by agreement with the authorized inspector.

(3) As regards nature and scope of appraisal tests, all other steels shall be treated as steels for conventional pressure vessel plants subject to supervision. If these steels for use in conventional pressure vessel plants subject to supervision have already been approved, they shall qualify as appraised.

(4) If in individual cases a material is used outside the scope of validity of its approval, or if a different material is used, a special appraisal shall be required. The special appraisal shall be mentioned in the inspection certificate.

3.3 General quality-assurance requirements

The stipulations in KTA 1401 shall apply to the general quality-assurance requirements.

3.4 Requirements to be met by the manufacturer

(1) The manufacturer shall possess facilities that permit proper and state-of-the-art production of materials and product forms.

(2) The manufacturer shall possess test and inspection facilities that permit testing and inspection of the materials and product forms in accordance with the applicable DIN standards or other rules pertinent to the conduct of materials testing and inspection. The test equipment shall correspond to DIN 51 220 and be inspected in accordance with DIN 51 220. Within the measuring range of the test equipment, the permitted measuring inaccuracy of the forces measuring equipment shall not exceed $\pm$ 1 %. Upon request, the test reports to DIN 51 220 shall be submitted to the authorized inspector. If test facilities of other agencies are employed, they shall be subject to the same stipulations.

(3) The manufacturer shall have access in its own works or at other agencies to facilities with which the non-destructive examinations required by this safety standard can be performed.

(4) Mechanized or automated facilities to be employed for the non-destructive examinations required by this safety standard shall undergo an appraisal by the authorized inspector.

(5) Lists of necessary procedure instructions for the production and testing facilities shall be compiled.

(6) Through quality monitoring with corresponding recordings, the manufacturer shall ensure proper manufacture and processing of the materials and product forms as well as adherence to the governing technical rules.

(7) The manufacturer shall employ skilled personnel capable of performing the tests and examinations properly. Personnel performing visual inspections shall be informed on the manufacturing process and have vision to comply with the requirements of DIN EN ISO 9712, which shall be checked every 12 months. For personnel performing non-destructive tests the requirements of Section 11.1.3 apply.

(8) The manufacturer shall be entitled to issue inspection certificates only if he employs an authorized inspection representative qualified in accordance with the conditions of DIN EN 10204. The name and stamp of the manufacturer's authorized inspection representative shall be announced to the authorized inspector.

(9) If welding work is performed on the product forms in the course of manufacture, the manufacturer shall employ his own supervisory staff and welders qualified to DIN EN ISO 9606-1 in conjunction with AD-2000 Merkblatt HP 3. Only qualified welders shall be used for the welding jobs. The revalidation of

welder qualification must be acquired to clause 9.3 a) or clause 9.3 b) of DIN EN ISO 9606-1. The welding supervisor shall be a member of the staff of the manufacturer's works and be named to the authorized inspector.

(10) A procedure by which all deviations from the quality requirements observed during production are reported to the responsible agency shall be set forth in writing.

(11) The manufacturer shall have a quality department that is independent of the production department.

(12) The organizational classification and assignment of duties of the manufacturer's authorized inspection representative, test supervisory personnel, NDT operators and quality department and, if applicable, the welding supervisory personnel, shall be set forth in writing.

(13) The authorized inspector shall review whether the requirements have been met before production can be started. The review shall be repeated at intervals of about one to two years, unless the authorized inspector can be convinced by other means that the conditions are still being met.

3.5 Design approval

Subject to design approval by the authorized inspector are

a) test instructions for non-destructive testing procedures RT, UT and ET,
b) material testing and sampling plans for product forms for production of components from ferritic steels of material group WI, if sampling is not clearly defined in the Sections relating to product forms, and
c) documents for cast pieces according to the stipulations in Sections 5.7.2, 6.7.2, 7.7.2 and 9.2.2.

3.6 In-process inspection by the authorized inspector to § 20 of the Atomic Energy Act

The authorized inspector shall have the right to be present during the manufacturing processes. However, he shall not impair the manufacturing operations.

3.7 Verification of quality characteristics

(1) The quality characteristics of the materials and product forms shall be determined by tests and examinations, which shall be performed in the manufacturer's works.

(2) The quality characteristics of the materials and product forms shall be verified by inspection certificates to DIN EN 10204. The governing stipulations for the required type of quality verification shall be those in the following Sections relating to product forms. Confirmation that the requirements of this safety standard have been met shall be required in the certificates.

(3) inspection certificates 3.2 shall be confirmed or be established by the authorized inspector to § 20 of the Atomic Energy Act.

3.8 Marking

The product forms shall be clearly and durably marked, if at all possible without notching, in accordance with the stipulations in the following Sections relating to product forms. The use of code characters is permitted. The complete text of the marking shall be indicated in the inspection certificates. A clear correlation between the inspection certificates and product forms shall be possible at all times.

3.9 Repairs

(1) Any necessary repairs shall be reported to the authorized inspector. Further action shall be determined in consultation with the authorized inspector.

(2) Repairs by welding shall be subject to the stipulations of KTA 3211.3.

(3) Production weldings on cast pieces are not repairs within the meaning of this safety standard.

3.10 Material characteristic data for design analysis

The characteristic data critical to strength design analysis shall be taken from **Annex A**, from the appropriate DIN standards, VdTÜV material sheets or, in the case of special steels, from the authorized inspector's appraisal.

4 Generally applicable stipulations for materials and material tests

4.1 General

(1) The requirements for material characteristics shall apply to the final condition of the components after the in-process inspection and pressure test. On the basis of the tests and examinations to be performed on materials and product forms, the material characteristics shall be verified on sufficiently large test coupons in the heat-treatment conditions required for the particular purpose.

(2) The products shall have smooth surfaces consistent with the forming method employed. Impermissible surface irregularities shall be eliminated. The resulting depressions shall be ground flush. The wall thickness shall not be less than the allowable minimum nominal wall thickness.

(3) Finish and surface quality of the products shall be specified in the purchase order. In this regard, the surface requirements according to Section 11.1 shall be taken into account.

4.2 Allowable materials

Materials shall be allowable if they fulfill the prerequisites of Section 3.1 and their suitability has been established in accordance with Section 3.2 of this safety standard. Materials approved for the individual products are given in Sections 5 to 10.

4.3 Requirements for the materials and their product forms

4.3.1 Ferritic steels of material group W I

Ferritic steels of material group W I shall meet the following conditions:

a) In the notched-bar impact test on transverse specimens at the lowest operating temperature (including accidents) or at the temperature at which the primary membrane stress is higher than 50 N/mm^2, the smallest individual value of impact energy of the base metal, weld metal and heat-affected zone shall not be less than 68 J, and the smallest individual value of lateral expansion shall not be less than 0.9 mm.
b) The smallest individual value of upper shelf impact energy, determined on transverse specimens, shall not be less than 100 J. This only applies to the base metal.
c) The impact energy, determined on transverse specimens, shall not be less than 41 J at the test temperature of 0 °C. Only one individual value below the required mean value shall be permitted, and it shall not be smaller than 29 J. This requirement applies to the base metal, the weld metal and the heat-affected zone.

For cast steel the specimen direction is not specified.

4.3.2 Ferritic steels of material group W II

Ferritic steels of material group W II shall meet the following conditions:

a) The values of the chemical composition determined in the ladle analysis shall not exceed 0.020 % P and 0.015 % S. In addition, the processability shall be considered when defining the chemical composition, especially the permissible contents of microalloying elements.

b) In the notched-bar impact bend test on transverse specimens, the mean value shall not be less than 41 J

   ba) at the test temperature of 0 °C if the lowest loading temperature is lower than 20 °C, or

   bb) at the test temperature of 20 °C if the lowest loading temperature is higher than or equal to than 20 °C.

   Only one individual value below the required mean value shall be permitted, and it shall not be smaller than 29 J.

   The requirement applies for the base metal, the weld metal and the heat-affected zone.

   For cast steel the specimen direction is not specified.

4.3.3 Austenitic steels

Austenitic steels shall meet the following conditions:

a) The steels shall be resistant to intergranular corrosion in the production conditions in question.

b) Steels for hot (operating temperature ≥ 200 °C during continuous operation) reactor water containing product forms and components in boiling water reactor plants shall be resistant to IGSCC and have a cobalt content not exceeding 0.2 %. Details are specified in the product-form related Sections.

c) The chemical composition shall be defined such that hot cracks do not develop during welding.

d) In the case of steels for product forms with a wall thickness greater than 16 mm or DN greater than 150 mm, the impact energy value of the base metal, weld metal and heat-affected zone, determined on transverse specimens at the test temperature of 20 °C, shall not be less than 70 J (mean value of three specimens, smallest individual value not less than 60 J) in the solution-annealed and quenched condition, or 55 J (mean value of three specimens, smallest individual value not less than 40 J) in the annealed condition.

e) For parts on which welding work without weld filler metal will be performed during further processing, the deposited base metal shall have a delta ferrite content of 2 % to 10 % (ferrite number 2 to 11) to **Annex C**. For parts on which welding work with weld filler metal will be performed during further processing, the deposited base metal shall have a delta ferrite content of 1 % to 10 % (ferrite number 1 to 11) to **Annex C**. A close ferrite lattice structure is not permitted in either case. Deviations are permitted if the characteristics of the welded joint satisfy the stipulations of KTA 3211.3.

f) For rolled and forged product forms made of austenitic steels as well as parts made from such forms, the required ultrasonic examinability, the further processability and the specified mechanical and technological characteristics shall not be impaired by coarse-grained microstructural zones.

   Note:

   Based on available experience, every effort should be made to achieve a grain size corresponding to a characterizing number larger than or equal to 4 to DIN EN ISO 643.

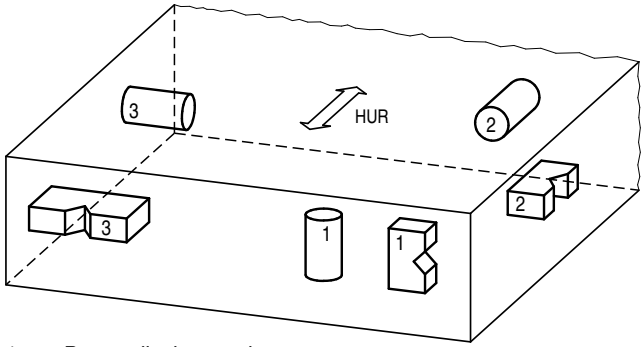
4.3.4 Steels for special loads

If special loads such as erosion, corrosion and wear are present, materials matched to the requirements of the particular application shall be employed. The conditions for such materials shall be defined on a case-by-case basis by agreement with the authorized inspector.

4.4 Testing and examination of materials and product forms

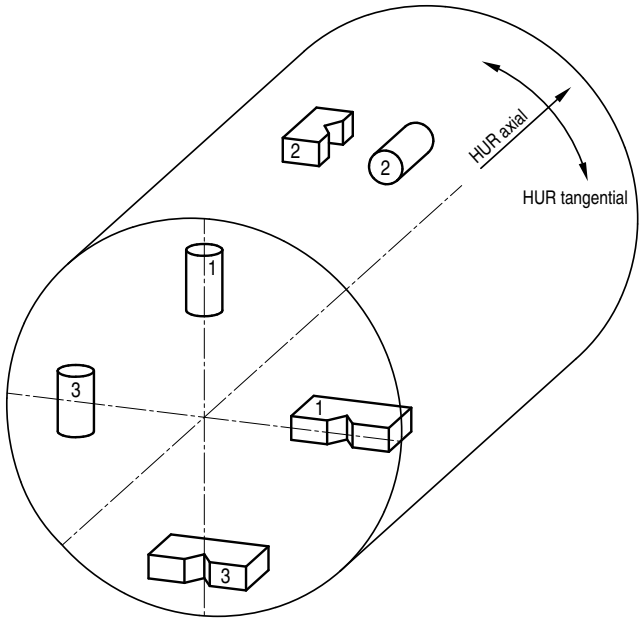
4.4.1 Designation of specimen direction in product forms

The following designations shall be used to describe the direction of specimens in product forms (see **Figures 4-1** and **4-2**):



1: Perpendicular specimen
2: Longitudinal specimen
3: Transverse specimen
HUR: Main forming direction

Figure 4-1: Designation of specimen directions for flat products



Specimen No.	Specimen direction relative to		
	Product geometry	Main forming direction (HUR)	
		tangential	axial
1	radial	perpendicular	perpendicular
2	axial	transverse	longitudinal
3	tangential	longitudinal	transverse

Figure 4-2: Designation of specimen directions for rotationally symmetric product forms

a) Designation based on direction relative to fibre:

   Longitudinal specimens (L):
   Longitudinal axis of specimen in the main forming direction; for notched-bar impact specimens, the notch axis shall be perpendicular to the plane of the transverse and longitudinal directions.

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

Perpendicular specimens (S):
Longitudinal axis of specimen perpendicular to the plane of the transverse and longitudinal directions; for notched-bar impact specimens, the notch axis shall be in the main forming direction.

b) Designation based on direction relative to product geometry:

Axial specimens (A):
Longitudinal axis of specimen parallel to the axis of rotational symmetry; for notched-bar impact specimens, the notch axis shall be perpendicular to the cylindrical surface.

Tangential specimens (T):
Longitudinal axis of specimen in the circumferential direction; for notched-bar impact specimens, the notch axis shall be perpendicular to the cylindrical surface.

Radial specimens (R):
Longitudinal axis of specimen perpendicular to the cylindrical surface; for notched-bar impact specimens, the notch axis shall be in the main forming direction.

4.4.2 Location of specimens in product forms

The specimen location shall be identified as follows: as regards depth below the surface, by the location of the specimen axis; as regards distance from the edge, by the location of the cross section to be inspected. Further particulars are defined in the following Sections relating to product forms.

4.4.3 Size of test coupons

(1) The quantity of material to be taken shall be large enough to provide an adequate quantity of material for substitute specimens in addition to the material for verification of mechanical and technological characteristics.

(2) If further specimen quantities are needed for additional tests, the number and dimensions of the additional test coupons shall be specified in the purchase order. In the case of castings, additional test plates from the heats used for these coupons shall be kept available if required.

4.4.4 Marking of test coupons and specimens

For the acceptance tests, the test coupons shall be marked legibly and clearly before removal from the product form, and the specimens shall be marked likewise before specimen removal from the test coupon. The specimen marking shall permit exact correlation with its location in the product form.

4.4.5 Heat-treatment conditions of specimens

(1) All test coupons shall be heat-treated on and together with the product form (normalizing, quenching and tempering, solution annealing and quenching).

(2) If the product forms are not delivered in the heat-treatment condition governing establishment of the characteristics, but receive this heat treatment only in the course of further processing, the material manufacturer shall perform tests on specimens from test coupons subjected to corresponding heat treatment.

Note:
Unless otherwise stipulated in the appraisal, stress-relief annealing shall not constitute the heat treatment governing establishment of the mechanical and technological characteristics.

(3) Should simulated stress-relief annealing be required in **Annex A** or in the authorized inspector's appraisal, it shall be performed in accordance with the conditions stipulated therein.

4.4.6 Tests and test methods to be employed

4.4.6.1 General

(1) The stipulations of clause 4.4.6 shall apply if performance of the tests cited in the following is required in the Sections relating to product forms and if nothing to the contrary is expressly stipulated there.

(2) The particulars needed for materials testing and taken from the classification into test and material groups per KTA 3211.2 shall be announced to the material or product-form manufacturer in the purchase order.

4.4.6.2 Chemical analysis

(1) The content by mass of elements specified for the respective material shall be determined during ladle and product analyses.

(2) DIN EN ISO 14284 shall apply to the specimen taking and preparation.

(3) In case of doubt the chemical composition shall be determined by the test method developed by the Chemists Committee of the Association of German Ferrous Metallurgists (VDEh) (see Manual for the Ferrous Metallurgy Laboratory [1]).

4.4.6.3 Hardness test

(1) Hardness tests shall be performed to DIN EN ISO 6506-1 and DIN EN ISO 6506-4 or to DIN EN ISO 6507-1 and DIN EN ISO 6507-4.

(2) Other hardness test methods may also be used, subject to approval of the authorized inspector.

4.4.6.4 Tensile test

Tensile tests shall be performed to DIN EN ISO 6892-1 and DIN EN ISO 6892-2. Where method A is used, the strain rates recommended by the standard shall be used. Tensile test specimens to DIN 50125 may also be used.

4.4.6.5 Notched-bar impact bend test

Notched-bar impact bend tests shall be performed to DIN EN ISO 148-1 on specimens with V-notch using a striker with 2 mm radius (KV_2). One set consisting of three specimens shall be tested. Where specimens with a width less than 10 mm are used, the impact energy determined shall be converted proportionally to the specimen width to the standard specimen if the test has been conducted at the upper shelf of impact energy. Otherwise, the conversion factor of impact energy to the standard specimen value shall be decided in each individual case.

4.4.6.6 Impact energy vs. temperature curves

(1) In the case of product forms belonging to test group A 1 or A 2 notched-bar impact bend tests to clause 4.4.6.5 shall be performed at a minimum of four temperatures to plot impact energy vs. temperature curves.

(2) The temperatures shall be chosen such that they encompass the upper shelf of impact energy, characterized by a dull fracture surface representing a proportion of about 100 % of the total fracture surface, as well as the transition to brittle fracture behaviour, characterized by a dull fracture surface

representing a proportion of about 50% of the total fracture surface.

(3) A set of three specimens shall be tested at each test temperature. For all notched-bar specimens of ferritic steels used to plot impact energy vs. temperature curves, the lateral expansion and the proportion of dull fracture surface as a percentage of total fracture surface shall be determined according to DIN EN ISO 148-1.

4.4.6.7 Technological tests on pipes

The technological tests on pipes shall be performed to:

DIN EN ISO 8492 - Flattening test or

DIN EN ISO 8493 - Drift test or

DIN EN ISO 8495 - Ring expanding test or

DIN EN ISO 8496 - Ring tensile test

4.4.6.8 Metallographic examinations

(1) The microstructural condition shall be determined by preparing micrographs at a magnification that permits an unequivocal evaluation.

(2) The grain-size characterizing number shall be determined to DIN EN ISO 643.

4.4.6.9 Determination of delta ferrite content

(1) If required in the Sections relating to product forms, the delta ferrite content of products of austenitic steels or austenitic cast steel shall be determined by one of the following methods:

a) metallographic determination in the as-delivered condition,

b) metallographic determination on the bead-on-plate test specimen,

c) theoretical estimation from the chemical composition, using De Long's method [2].

(2) The Sections relating to product forms specify which of the methods indicated under (1) a) to c) is to be employed.

(3) If the theoretical estimate yields ferrite numbers lower than 3, the delta ferrite content shall also be determined metallographically on the bead-on-plate test specimen.

(4) Details on how to perform the methods cited under (1) a) to c) are described in **Annex C**.

(5) The particular method to be employed shall be indicated in the inspection certificate.

4.4.6.10 Corrosion-resistance testing

The resistance to intergranular corrosion shall be verified to DIN EN ISO 3651-2.

4.4.6.11 Materials identification check

(1) The materials identification check shall be carried out using a spectrometric method.

(2) For pieces that have undergone a product analysis, it is permitted to acknowledge that analysis as the materials identification check.

4.4.6.12 Dimensional check

Before shipment of the products, the dimensions and tolerances specified in the purchase order shall be checked.

4.4.6.13 Visual inspection

During the acceptance procedure, all products shall be subjected to a visual inspection in which case the following shall be checked:

a) the compliance of the product surface with the required surface condition in due consideration of subsequent surface coating, if any,

b) the surface condition with regard to surface irregularities,

c) the compliance of the products with the number of items given and the identification marking, and

d) the product surface for compliance with the given cleanliness requirements.

4.4.6.14 Non-destructive tests and examinations

The stipulations of Section 11 shall apply.

4.5 Re-examinations

(1) Test results that are based on incorrect taking or preparation of the test specimens (test specimen sets), on incorrect performance of the test or on a random narrow flaw location in one test specimen are invalid. The examination shall be repeated.

(2) Should the results of a properly performed examination fail to meet the above requirements, the following actions shall be taken:

a) Lotwise examination

aa) The test coupon from which the unsatisfactory specimen (or specimen set) was taken shall be excluded from the lot. It shall be replaced by two further test coupons from the lot, and the required examinations shall be repeated on those coupons.

ab) The examination shall qualify as passed if the results of the re-examination meet the requirements.

ac) The lot shall be rejected if any result of the two re-examinations fails to meet the requirements. However, a check examination of the characteristic found to be out of specification is permitted on each individual piece of the lot.

b) Individual examination

ba) For each unsatisfactory specimen (or specimen set), two further specimens (or specimen sets) from the same sampling location shall be examined.

bb) The results of both examinations shall meet the requirements.

(3) Should it be impossible by appropriate heat treatment to eliminate the reason for the unsatisfactory result of an examination, a new heat treatment shall be required, after which the test unit shall be submitted again for examination.

(4) The cause of the unsatisfactory result of the first examination shall be investigated.

5 Product forms of ferritic steels of material group W I

5.1 Flat products

5.1.1 Materials

(1) The following steel grades may be used:

a) steel grades to Section A 1

b) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

5.1.2 Additional requirements for the materials

(1) Flat products with nominal thicknesses equal to or larger than 15 mm subjected to loading perpendicular to the rolled surface shall at least meet the requirements of quality class Z35 to DIN EN 10164. This shall be specified in the purchase order.

(2) For flat products with nominal thicknesses equal to or greater than 150 mm, the smallest individual value of impact energy absorbed (transverse specimens) at the middle of the flat product thickness at 80 °C shall not be less than 68 J.

(3) When flat products are used for tubesheets, the same requirements as for specimens longitudinal to or transverse to the main rolling direction shall apply for the room-temperature yield point or 0.2 % proof stress and tensile strength of standard specimens perpendicular to the flat product surface. This shall be specified in the purchase order.

(4) The surface finish shall satisfy the stipulations of DIN EN 10163-2 Class B Subgroup 3.

5.1.3 Tests and examinations

5.1.3.1 Sampling and specimen preparation

(1) The sampling locations are stipulated in Section A 1.

(2) The following specimens shall be taken for the tensile test at room temperature:

a) For flat products with nominal thicknesses not exceeding 40 mm, flat tensile-test specimens containing both rolled surfaces.

b) For flat products with nominal thicknesses larger than 40 mm, flat tensile-test specimens at least 40 mm thick containing at least one intact rolled surface.

(3) The following specimens shall be taken for the tensile test at elevated temperature:

a) for flat products with nominal thicknesses smaller than 12 mm, flat tensile-test specimens or round tensile-test specimens,

b) for flat products with nominal thicknesses equal to or larger than 12 mm up to and including 40 mm, round tensile-test specimens,

c) for flat products with nominal thicknesses larger than 40 mm, round tensile-test specimens with the specimen axis at one quarter of nominal thickness under the rolled surface (test diameter equal to or larger than 10 mm).

(4) The notched-bar impact bend test shall be subject to the following requirements:

As regards the specimens for notched-bar impact testing one side of the specimen shall be located as close as possible to the rolling surface in case of wall thicknesses ≤ 40 mm. In case of nominal thicknesses exceeding 40 mm the specimen axis shall be located at a distance of one quarter of the thickness of the product form below the rolling surface.

(5) Transverse specimens shall be used for the tensile and notched-bar impact bend tests.

(6) Specimens for determination of the reduction of area at fracture on perpendicular specimens shall be taken and be prepared in accordance with the stipulations in DIN EN 10164.

(7) Standard specimens shall be used for determination of the room-temperature yield point or 0.2 % proof stress and tensile strength on specimens perpendicular to the flat product surface.

5.1.3.2 Extent of tests and examinations

(1) The chemical composition shall be determined by performing:

a) One ladle analysis per heat.

b) One product analysis on one sampling location in each of two rolled plates per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One elevated-temperature tensile test per heat, dimensional range and a total weight of at most 30 metric tons. The test temperature is defined in Section A 1 or in the authorized inspector's appraisal.

c) Room-temperature tensile tests to DIN EN 10164 per rolled plate for flat products with nominal thicknesses equal to or larger than 15 mm, in order to determine the reduction of area at fracture, whenever the quality class Z35 is required acc. to clause 5.1.2 (1).

d) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 33 °C or at the lowest operating temperature, whichever is lower, for flat products with nominal thicknesses equal to or larger than 5 mm. Notwithstanding the foregoing, the impact energy for steel grade 15 MnNi 6 3 shall be determined at 0 °C.

e) Notched-bar impact bend tests at one sampling location for determination of the impact energy vs. temperature curve to clause 4.4.6.6 per heat, dimensional range and identical heat treatment for flat products with nominal thicknesses equal to or larger than 10 mm and not exceeding 38 mm, and per rolled plate for plates with nominal thicknesses exceeding 38 mm. At least four test temperatures shall be used, of which two shall be 0 °C and the lowest loading temperature. This test may be waived for flat products of steel grade 15 MnNi 6 3.

f) One notched-bar impact bend test to clause 4.4.6.5 at one sampling location per rolled plate, to determine the upper shelf impact energy for flat products with nominal thicknesses larger than 16 mm. This test may be performed during determination of the impact energy absorbed vs. temperature curves. In general, 80 °C shall be selected as the test temperature. The test shall be performed only in test group A 1, and may be waived if the value of impact energy absorbed determined per d) is equal to or greater than 100 J.

g) One notched-bar impact bend test to clause 4.4.6.5 at 80 °C at one sampling location in the middle of the flat product thickness of each rolled plate for plates with nominal thicknesses equal to or greater than 150 mm, unless otherwise stipulated in the appraisal.

(3) Each rolled plate shall be subjected to a materials identification check.

(4) Each flat product shall be subjected to a visual inspection of its external finish.

(5) The dimensional and shape accuracy of each rolled plate shall be measured.

(6) The Sections 11.1 and 11.2 as well as the Sections 11.1 and 11.4 in the case of flat products for tube sheets shall apply to the non-destructive tests and examinations.

5.1.4 Marking

(1) Each flat product shall be marked with the following information:

a) manufacturer's symbol,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) specimen number,

e) authorized inspector's mark.

(2) The marking shall be applied such that it appears upright when viewed in the main rolling direction of the rolled plate.

5.1.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process, the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

5.2 Dished or pressed product forms made from flat products

5.2.1 Materials

(1) The following steel grades may be used:

a) steel grades to Section A 1,

b) other steel grades that the meet the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

5.2.2 Additional requirements for the materials

The requirements of clauses 5.1.2 (1), (2) and (4) shall apply.

5.2.3 Starting products

(1) Starting products shall be subject to the stipulations in Section 5.1.

(2) If the finished parts are tested individually in accordance with clause 5.2.4.2, the tests to clause 5.1.3.2 (2) as well as the corresponding verifications can be omitted.

(3) For the tests to clauses 5.1.3.2 (3) to (5), an inspection certificate 3.1 to DIN EN 10204 will suffice.

Note:
The stipulations of KTA 3211.3 shall apply to welded joints made with the starting products and remaining in the finished parts.

5.2.4 Tests and examinations of dished or pressed product forms made from flat products

5.2.4.1 Sampling and specimen preparation

(1) For product forms with a diameter or length equal to or smaller than 3000 mm, the tests or examinations shall be performed on one part per rolled plate and heat-treatment lot. The maximum permissible lot size shall be 10 parts.

Note:
Correlation of parts with the rolled plate can be achieved, for example, through the specimen number of the starting products.

(2) For product forms with a diameter or length greater than 3000 mm, each part shall be tested.

(3) One test coupon shall be taken from each part to be examined. In the case of length or diameter exceeding 6 m an additional test coupon shall be taken at the opposite side.

(4) The test coupons shall be taken such that transverse specimens can be machined. Deviations up to 20 degrees from the theoretical transverse direction are permitted for heads (ends) and similar parts. If this is not possible, a different way of sampling shall be agreed with the authorized inspector.

(5) Round tensile-test specimens with a test diameter equal to or larger than 10 mm shall be made for both the room-temperature and elevated-temperature tensile tests. For nominal thicknesses larger than 40 mm, the specimen axis shall be located at a distance of one quarter of the product-form thickness under the rolled surface.

For product-form thicknesses that do not permit a test diameter of 10 mm, the largest possible diameter shall be chosen.

(6) For nominal wall thicknesses equal to or smaller than 40 mm, one side of the specimens for the notched-bar impact bend test shall be as close as possible to the rolled surface. For nominal wall thicknesses larger than 40 mm, the specimen axis shall be located at a distance of one quarter of the product-form thickness under the rolled surface.

5.2.4.2 Extent of tests and examinations

(1) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One elevated-temperature tensile test per heat, dimensional range and total weight of at most 30 metric tons. The test temperature is defined in Section A 1 or in the authorized inspector's appraisal.

c) Room-temperature tensile tests to DIN EN 10164 in order to determine the reduction of area at fracture in the case of product forms with nominal wall thicknesses equal to or larger than 15 mm, if as per clause 5.1.2 (1) quality class Z35 is required. This test may be waived if it has already been performed on the rolled plate and documented with an inspection certificate 3.2 to DIN EN 10204.

Note:
Correlation of parts with the rolled plate can be achieved, for example, through the specimen number of the starting products.

d) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 33 °C or at the lowest operating temperature, whichever is lower, for nominal wall thicknesses equal to or larger than 5 mm. Notwithstanding the foregoing, the impact energy for steel grade 15 MnNi 6 3 shall be determined at 0 °C.

e) Notched-bar impact bend tests at one sampling location for determination of the impact energy vs. temperature curve to clause 4.4.6.6 per heat, dimensional range and heat-treatment lot for product forms with nominal wall thicknesses equal to or larger than 10 mm and not exceeding 38 mm, and per rolled plate for product forms with nominal wall thicknesses exceeding 38 mm. At least four test temperatures shall be used, of which two shall be 0 °C and the lowest loading temperature. This test may be waived for product forms of steel grade 15 MnNi 6 3.

f) One notched-bar impact bend test to clause 4.4.6.5 at one sampling location of each part to be tested to determine the upper shelf impact energy for product forms with nominal wall thicknesses larger than 16 mm. This test may be performed during determination of the impact energy vs. temperature curve.

In general, 80 °C shall be selected as the test temperature. The test shall be performed only in test group A 1, and may be waived if the value of impact energy determined per d) is equal to or greater than 100 J.

g) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 80 °C in the middle of the product-form thickness for product forms with nominal wall thicknesses equal to or greater than 150 mm, unless otherwise stipulated in the appraisal.

(2) Each product form shall be subjected to a materials identification check.

(3) Each product form shall be subjected to a visual inspection of its external finish.

(4) The dimensional and shape accuracy of each product form shall be measured.

(5) The Sections 11.1 and 11.3 shall apply to the non-destructive tests and examinations.

5.2.5 Marking

(1) Each product form shall be marked with the following information:

a) symbol of the manufacturer of the product form,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) specimen number and

e) authorized inspector's mark.

(2) In the case of lotwise examination, the product form from which the specimens were taken shall additionally be marked.

(3) The marking shall be applied such that it appears upright when viewed in the main rolling direction of the rolled plate.

5.2.6 Verification of quality characteristics

(1) The results of the materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons shall be indicated in the inspection certificate 3.1.

(2) The forming method shall be indicated in inspection certificate 3.1 to DIN EN 10204.

(3) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with the inspection certificate 3.1 as an inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

5.3 Forgings, bars and rolled rings

5.3.1 Materials

(1) The following steel grades may be used:

a) steel grades to Section A 2,

b) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

5.3.2 Additional requirements for the materials

For products with heat-treatment thicknesses greater than 150 mm and heat-treatment weights heavier than 500 kg, the smallest individual value of impact energy (transverse specimens) at the middle of the wall thickness at 80 °C shall not be less than 68 J.

Note:
Heat-treatment thickness and heat-treatment weight designate the wall thickness and piece weight of the product forms in the condition in which the heat treatment governing establishment of the mechanical and technological characteristics is performed.

5.3.3 Tests and examinations

5.3.3.1 Sampling and specimen preparation

5.3.3.1.1 Test units

(1) Unless otherwise required in clause 5.3.3.2, the following is required:

a) Pieces with heat-treatment weights lighter than or equal to 100 kg may be grouped as test units of 1000 kg each.

b) Pieces with heat-treatment weights heavier than 100 kg and equal to or lighter than 500 kg from the same heat, with similar dimensions and from the same heat-treatment lot shall be grouped as test units containing at most 10 parts.

c) Pieces with heat-treatment weights heavier than 500 kg shall be tested individually.

5.3.3.1.2 Sampling locations

(1) For forged hollow parts, e.g., for shell courses, nozzles or valve bodies, specimens shall be taken from one end as a function of inside diameter D_i as follows: from one sampling location for D_i equal to or smaller than 500 mm; from two sampling locations separated by 180 degrees for D_i between 500 mm and 2000 mm; and from three sampling locations separated by 120 degrees for D_i larger than 2000 mm.

(2) At the opposite end, specimens shall be taken from one sampling location for normalized or air quenched and tempered forgings having a finished length longer than 5000 mm and for liquid quenched and tempered forgings having a finished length longer than 2000 mm. For pieces with inside diameters smaller than or equal to 500 mm, this sampling location shall be offset by 180 degrees relative to that at the other end (see **Figures 5.3-1** and **5.3-2**).

Note:
Finished length designates the length of the product form during the governing heat treatment, less the length of the test coupons.

(3) For seamless rolled or forged rings or flanges, specimens shall be taken from the circumference or end of the flange. They may also be taken from the end of the welding end, if the heat-treatment wall thickness of the welding end is equal to that of the flange. Specimens shall be taken as follows: from one sampling location for inside diameters D_i smaller than or equal to 1000 mm; from two sampling locations separated by 180 degrees for D_i between 1000 mm and 2000 mm; and from three locations separated by 120 degrees for D_i larger than 2000 mm (see **Figure 5.3-3**).

(4) For plates such as tubesheets, tube plates or blanking-off covers with heat-treatment weights lighter than 1000 kg, specimens shall be taken from one sampling location. If permitted by the forging method employed, this location shall be in the top or bottom zone (see **Figure 5.3-4**).

(5) For plates with heat-treatment weights equal to or heavier than 1000 kg, specimens shall be taken from two sampling locations. If permitted by the forging method employed, these locations shall be in the top and bottom zones (see **Figure 5.3-4**).

(6) For bars, specimens shall be taken at one end as a function of the diameter D of the bars: from one sampling location for D smaller than or equal to 500 mm; and from two sampling locations separated by 180 degrees for D larger than 500 mm.

(7) In the case of

a) normalized or air quenched and tempered bars having a finished length longer than 5000 mm

b) liquid quenched and tempered bars having a finished length longer than 2000 mm

specimens shall be taken from one sampling location at the opposite end. For bars having diameters smaller than or equal to 500 mm, this location shall be offset by 180 degrees relative to that at the other end.

5.3.3.1.3 Sampling depth

(1) For normalized and air quenched and tempered parts, the specimens shall be taken from at least one quarter of the governing heat-treatment thickness but at most 80 mm under the heat-treatment surfaces.

(2) For liquid quenched and tempered parts, except for plates with heat-treatment thicknesses larger than 320 mm, the specimens shall be taken from at least one quarter of the governing heat-treatment thickness but at most 80 mm under the governing heat-treatment surface and at least from the middle of the governing heat-treatment thickness (s/2) and at most 160 mm under the other surfaces.

(3) For liquid quenched and tempered plates with heat-treatment thicknesses larger than 320 mm, the specimens shall be taken from at least 80 mm under the heat-treatment surfaces.

(4) For parts with a governing heat-treatment thickness larger than 150 mm and a heat-treatment weight heavier than 500 kg, samples shall be taken additionally at one location from the middle of the governing heat-treatment thickness (s/2).

Note:

In the case of plates for tubesheets, the question of whether this requirement is met shall be verified in the appraisal by the impact energy at the middle of the wall thickness.

5.3.3.1.4 Specimen direction

(1) Transverse specimens shall be taken for tensile tests and notched-bar impact bend tests if geometrically possible and nothing to the contrary is stipulated in Section A 2 or in the authorized inspector's appraisal.

(2) Notwithstanding the foregoing, longitudinal specimens or axial specimens may be taken from bars, specifically for tensile tests if the diameter or greatest length of a cross-sectional edge is smaller than 160 mm, or for notched-bar impact bend tests if the diameter or the greatest length of a cross-sectional edge is smaller than 68 mm.

5.3.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis on one sampling location in each of two separately manufactured pieces per heat.

c) One product analysis on each piece for piece weights equal to or heavier than 5000 kg.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One hardness test per piece to verify uniformity for pieces grouped together in test units.

Note:

Verification of uniformity shall be acknowledged if the difference between the highest and lowest hardness values in a test unit does not exceed 30 HB units.

b) One room-temperature tensile test per sampling location.

c) For pieces of similar dimension, one elevated-temperature tensile test per heat and heat-treatment lot. The test temperature is defined in Section A 2 or in the authorized inspector's appraisal.

d) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 33 °C or at the lowest operating temperature, whichever is lower. Notwithstanding the foregoing, the impact energy absorbed for steel grade 15 MnNi 6 3 shall be determined at 0 °C.

e) Notched-bar impact bend tests for determination of the impact energy vs. temperature curve to clause 4.4.6.6.

ea) per heat and heat-treatment lot for pieces with heat-treatment weights equal to or lighter than 500 kg

eb) per piece, at one sampling location, for pieces with heat-treatment weights equal to or heavier than 500 kg.

At least four test temperatures shall be used, of which two shall be 0 °C and the lowest loading temperature. This test may be waived for pieces of steel grade 15 MnNi 6 3 with wall thicknesses smaller than or equal to 150 mm.

f) One notched-bar impact bend test to clause 4.4.6.5 at one sampling location per test unit to verify the upper shelf impact energy for pieces with heat-treatment weights equal to or heavier than 150 kg in the normalized or air quenched and tempered condition and equal to or heavier than 50 kg in the liquid quenched and tempered condition. It shall be demonstrated that the smallest individual value of upper shelf impact energy is equal to or larger than 100 J. This test may be performed during determination of the impact energy vs. temperature curves. In general, 80 °C shall be selected as the test temperature. The test shall be performed only in test group A 1, and may be waived if the value of impact energy determined per d) is equal to or greater than 100 J. This test may be waived for pieces of steel grade 15 MnNi 6 3 with wall thicknesses smaller than or equal to 150 mm.

g) One notched-bar impact bend test to clause 4.4.6.5 at 80 °C at one sampling location in the middle of the thickness for products with heat-treatment weights heavier than 500 kg and heat-treatment thicknesses larger than 150 mm, unless otherwise stipulated in the appraisal.

(3) Each piece shall be subjected to a materials identification check.

(4) Each piece shall be subjected in the as-delivered condition to a visual inspection of its external finish.

(5) A dimensional check of each piece shall be performed.

(6) The Sections 11.1 and 11.4 shall apply to the non-destructive tests and examinations.

5.3.4 Marking

(1) Each piece shall be marked with the following information:

a) manufacturer's symbol,

b) steel grade,

c) heat number,

d) specimen number,

e) authorized inspector's mark.

(2) In the case of lotwise examination, the piece from which the specimens were taken shall additionally be marked.

5.3.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check and non-destructive tests and exami-

nations performed by the manufacturer, and if necessary of the hardness test shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process, the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

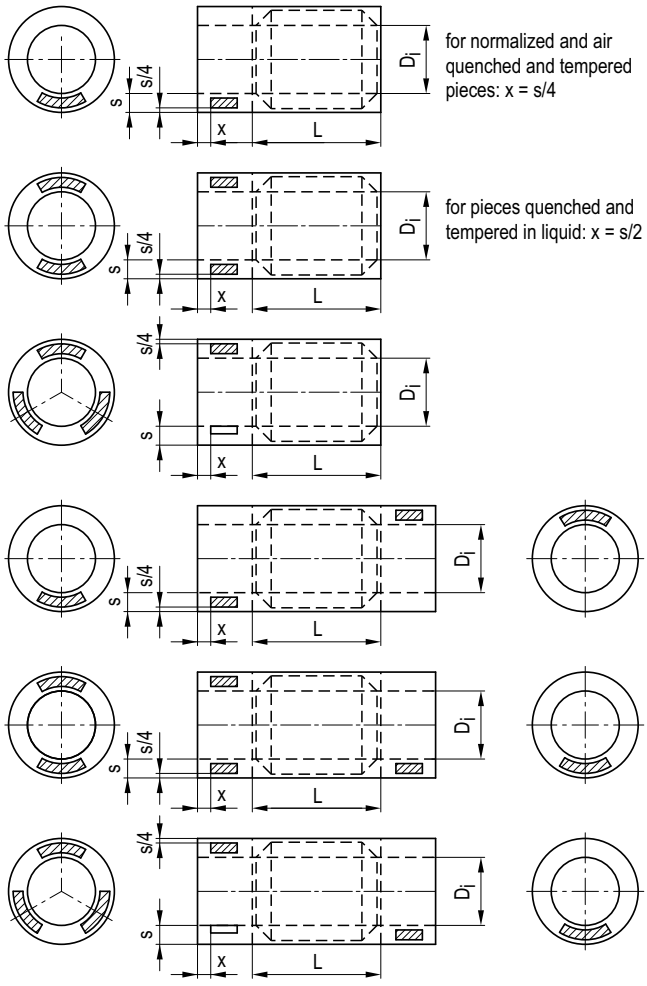
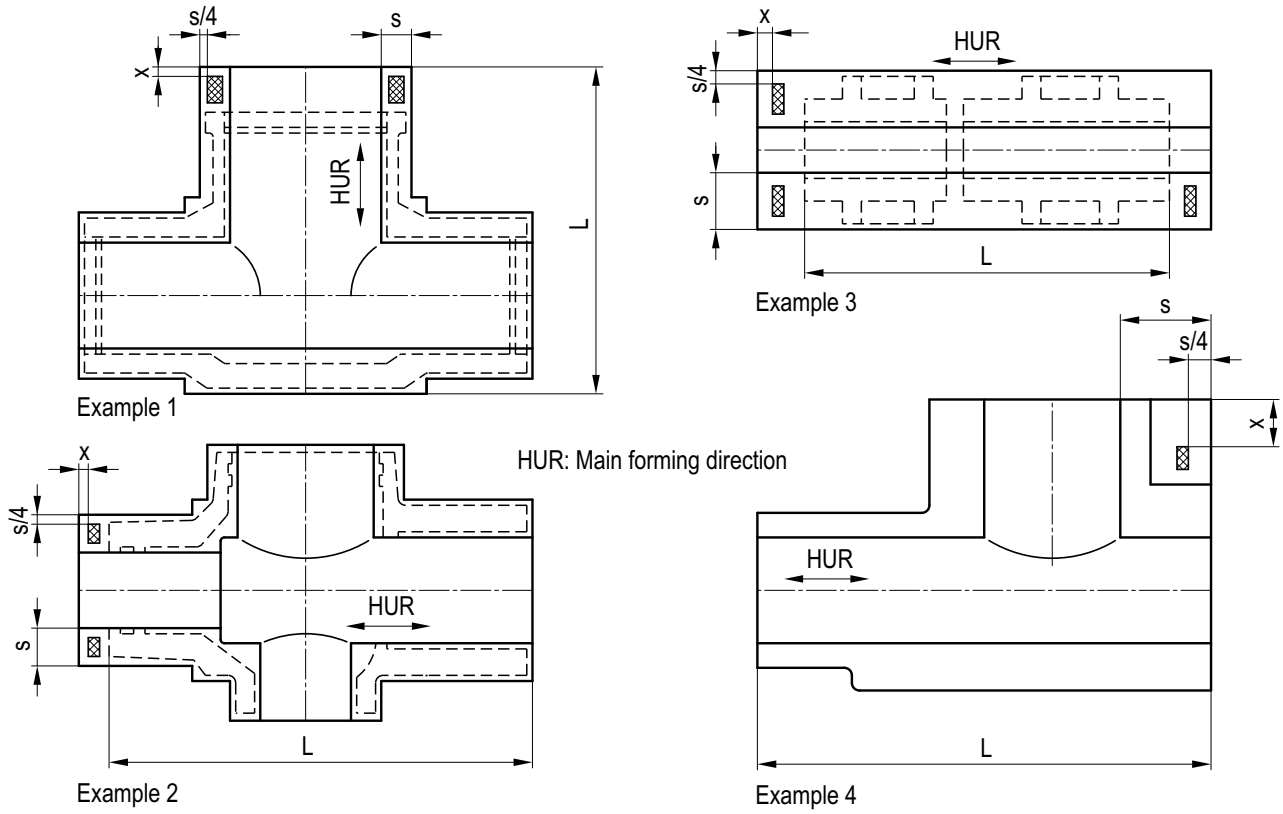
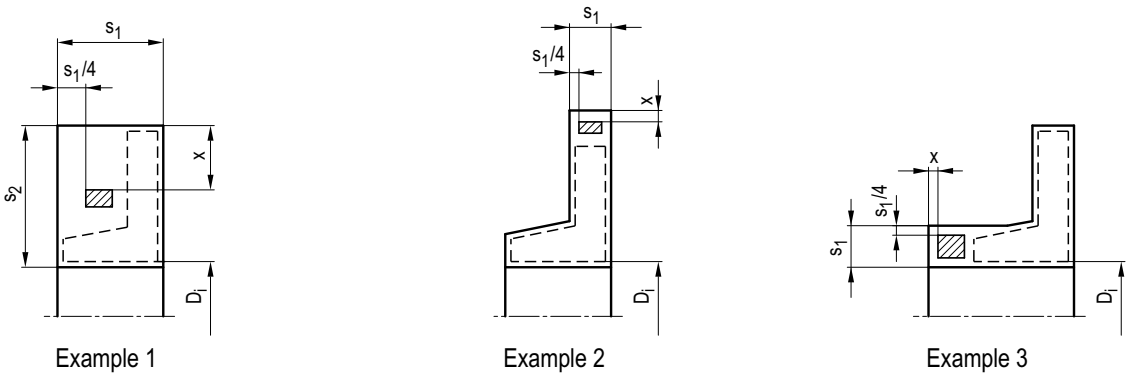
No.	Finished length	Inside diameter D_i	Examples for sampling
1	Normalized and air quenched and tempered pieces: $L \leq 5000$ mm Pieces quenched and tempered in liquid: $L \leq 2000$ mm	≤ 500 mm	
2		> 500 mm up to ≤ 2000 mm	
3		> 2000 mm	
4	Normalized and air quenched and tempered pieces: $L > 5000$ mm Pieces quenched and tempered in liquid: $L > 2000$ mm	≤ 500 mm	
5		> 500 mm up to ≤ 2000 mm	
6		> 2000 mm	

Figure 5.3-1: Examples for sampling from forged hollow parts



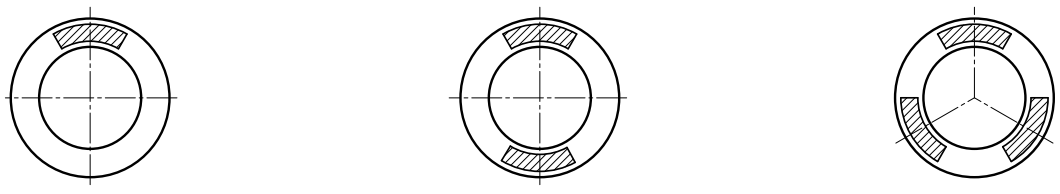
for pieces quenched and tempered in liquid: x = s/2
for normalized and air quenched and tempered pieces: x = s/4

Figure 5.3-2: Examples for sampling from forged valve bodies



For parts quenched and tempered in liquid: $x = s_1/2$
For normalized or air quenched and tempered parts: $x = s_1/4$

a) Examples for sampling



b) Distribution of sampling locations on the circumference or at the end as a function of inside diameter

Figure 5.3-3: Examples for sampling from seamless rolled or forged rings or flanges

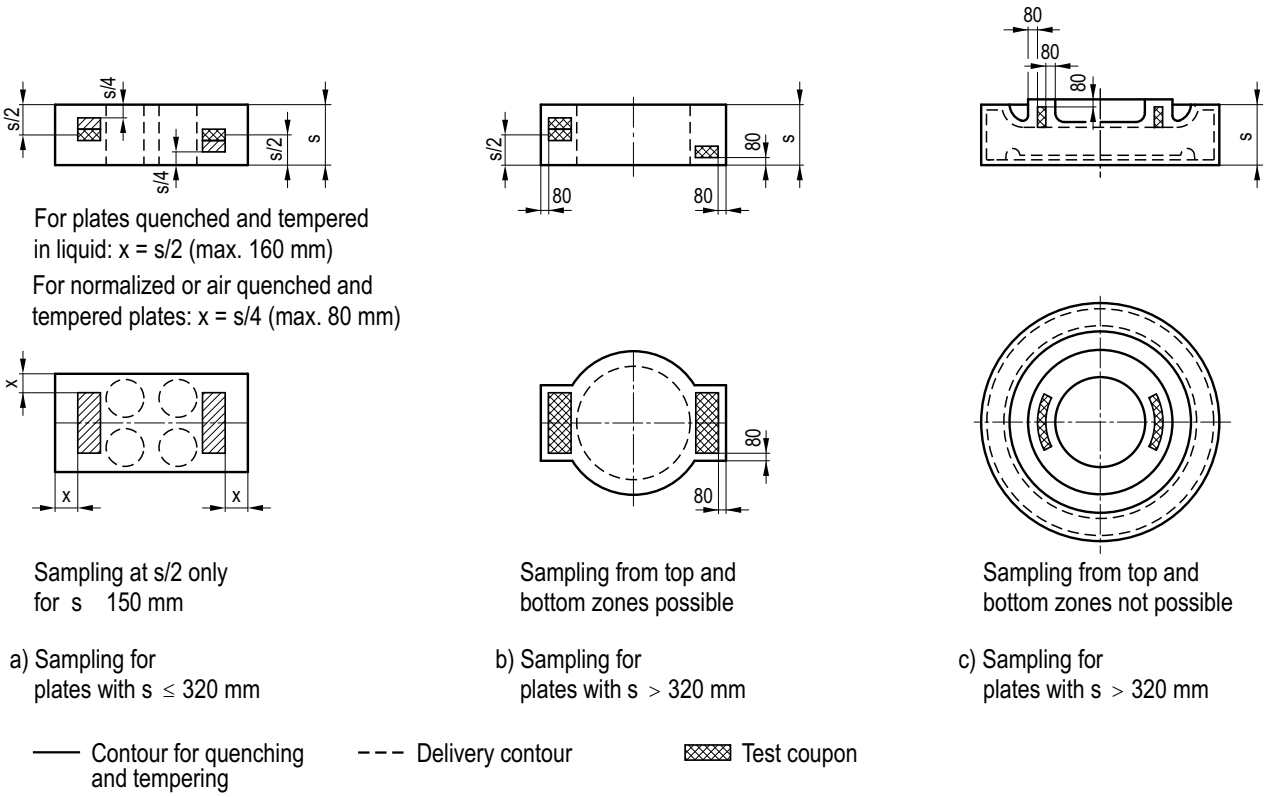


Figure 5.3-4: Examples for sampling from forged plates

5.4 Seamless pipes larger than DN 50

5.4.1 Scope

(1) The stipulations of this Section shall apply to seamless, rolled or pressed pipes larger than DN 50.

Note:
For forged pipes Section 5.3 shall apply.

(2) The stipulations of this Section shall also apply to pipes equal to or smaller than DN 50 if pipe elbows larger than DN 50 are made from such pipes.

(3) The stipulations of this Section shall not apply to pipes for vessel shells.

5.4.2 Materials

(1) The following steel grades may be used:

a) steel grades to Section A 3,

b) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

5.4.3 Additional requirements for the materials

Pipes with nominal wall thicknesses equal to or larger than 15 mm and subject to loading perpendicular to the surface shall at least meet the requirements of quality class Z35 to DIN EN 10164. This shall be specified in the purchase order.

5.4.4 Tests and examinations

5.4.4.1 Sampling and specimen preparation

(1) The pipes shall be tested in manufacturing lengths.

(2) Specimens shall be taken from the ends of manufacturing lengths.

(3) Transverse specimens shall be taken for tensile tests and notched-bar impact bend tests. If this is not possible, it is permitted to take longitudinal specimens.

(4) Notched-bar impact bend tests shall be performed only for pipes with nominal wall thicknesses equal to or larger than 10 mm.

(5) For tensile tests carried out on round tensile test specimens and for notched-bar impact bend tests, the test coupons shall be taken such that they are located at one quarter of the wall thickness under the outside surface and at one half of the wall thickness under the end face or as close as possible to that location.

(6) Specimens for determination of reduction of area at fracture on perpendicular specimens shall be taken at the same location as for the room-temperature tensile-test specimens.

5.4.4.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis on each of two manufacturing lengths per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) Room-temperature tensile tests for every 20 manufacturing lengths of the same heat, dimension and heat treatment

  aa) at one end of one manufacturing length for pipes of normalized or air quenched and tempered steels

  ab) at both ends of one manufacturing length for pipes of liquid quenched and tempered steels.

b) One elevated-temperature tensile test per heat, dimension and heat treatment if the design temperature is higher than 100 °C. The test temperature is defined in Section A 3 or in the authorized inspector's appraisal.

c) Room-temperature tensile tests to DIN EN 10164 in order to determine the reduction of area at fracture on perpendicular specimens from one sampling location every 20 manufacturing lengths of the same heat, dimension and heat treatment for pipes with nominal wall thicknesses equal to or larger than 15 mm, if as per clause 5.1.2 (1) quality class Z35 is required. This test may be waived for steel grades for which it was demonstrated in the material appraisal that the mean value of reduction of area at fracture is at least 45 % and that none of the individual values is smaller than 35 %.

d) One notched-bar impact bend test to clause 4.4.6.5 at 33 °C or at the lowest operating temperature, whichever is lower, at one end of one manufacturing length per 20 manufacturing lengths of the same heat, dimension and heat treatment for pipes of normalized or air quenched and tempered steels with nominal thicknesses not exceeding 38 mm, and at one end of each manufacturing length for pipes with nominal thicknesses exceeding 38 mm. For pipes of steel grade 15 MnNi 6 3, the test temperature shall be 0 °C.

e) One notched-bar impact bend test to clause 4.4.6.5 at 33 °C or at the lowest operating temperature, whichever is lower, at both ends of one manufacturing length per 20 manufacturing lengths of the same heat, dimension and heat treatment for pipes of liquid quenched and tempered steels with nominal wall thicknesses equal to or smaller than 16 mm, and at both ends of each manufacturing length for pipes with nominal wall thicknesses larger than 16 mm.

f) Notched-bar impact bend tests for determination of an impact energy vs. temperature curve to clause 4.4.6.6 at one end of one manufacturing length per heat, dimension and heat treatment for pipes with nominal wall thicknesses equal to or larger than 10 mm. At least four test temperatures shall be used, of which two shall be 0 °C and the lowest loading temperature. This test may be waived for pipes of steel grade 15 MnNi 6 3.

g) One notched-bar impact bend test to clause 4.4.6.5 at one end of each manufacturing length to determine the upper shelf impact energy for pipes of normalized or air quenched and tempered steels with nominal wall thicknesses larger than 38 mm as well as for pipes of liquid quenched and tempered steels with nominal wall thicknesses larger than 16 mm. This test may be performed during determination of the impact energy vs. temperature curves. In general, 80 °C shall be selected as the test temperature. This test shall be performed only in test group A 1, and may be waived if the value of impact energy determined per d) or e) is equal to or greater than 100 J.

h) Technological tests per **Table 5.4-1** at both ends of each manufacturing length for pipes with nominal wall thicknesses equal to or smaller than 40 mm.

Nominal wall thickness s of the pipes in mm	Nominal outside diameter of the pipes in mm	
	≤ 146	> 146
s < 2	Flattening test	—
2 ≤ s ≤ 16	Ring expanding test [1)]	Ring tensile test
16 < s ≤ 40	Flattening test	Ring tensile test

[1)] The drift test also may be performed.

Table 5.4-1: Dimensional ranges for application of the technological tests to pipes

(3) The Sections 11.1 and 11.5.1 shall apply to the non-destructive tests and examinations.

(4) Each pipe shall be subjected to a materials identification check.

(5) The inside and outside surfaces of each pipe shall be subjected to a visual inspection.

(6) The diameter and wall thickness shall be checked for dimensional accuracy at both ends of each pipe.

(7) Each pipe shall be examined for leak tightness in accordance with DIN EN 10216-2.

5.4.5 Marking

(1) Each pipe shall be marked at both ends, 300 mm from the ends, with the following information:

a) manufacturer's symbol,

b) steel grade, for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164) and

c) authorized inspector's mark.

(2) Each pipe shall additionally be marked at one end with the following information:

a) heat number,

b) pipe number.

5.4.6 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check, tightness test and non-destructive tests and examinations performed by the manufacturer shall be documented with inspection certificates 3.1 to DIN EN 10204. The steel making process, the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

5.5 Seamless pipe elbows larger than DN 50

5.5.1 Scope

(1) This Section shall apply to seamless pipe elbows (weld-in elbows) made by cold or hot forming followed by heat treatment (normalization; quenching and tempering).

(2) This Section shall not apply to pipe bends made with inductive bending machines or by cold forming with or without subsequent heat treatment. These pipe bends are subject to the requirements of KTA 3211.3 Section 6.

5.5.2 Materials

(1) The following steel grades may be used:

a) steel grades to Section A 3 and

b) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

(3) For finished pipe elbows, the values of the mechanical and technological characteristics to Section A 3 shall apply even if forged hollow parts are used as starting products.

5.5.3 Starting products

(1) Forged hollow parts to Section 5.3 or seamless pipes to Section 5.4 shall basically be used as starting products.

(2) Starting products that have not been completely examined and heat-treated to the stipulations in Sections 5.3 or 5.4 may also be used, provided

a) the finished pipe elbows are examined individually to clause 5.5.4.2 and

b) the non-destructive tests and examinations of the starting products have been carried out according to the requirements in Section 11.4 or Section 11.5.1 prior to forming.

In this case the determination of mechanical and technological characteristics and the corresponding verification may be waived for the starting products. An inspection certificate 3.1 to DIN EN 10204 shall then be adequate for visual inspection and dimensional check of the starting products.

5.5.4 Tests and examinations of pipe elbows

5.5.4.1 Sampling and specimen preparation

(1) Specimens shall be taken from the ends of the pipe elbows in conformity with the authorized inspector's appraisal.

(2) The test coupons shall be located at one quarter of the wall thickness under the outside surface and at one half of the wall thickness under the end face or as close as possible to that location.

(3) Transverse specimens shall be used for tensile tests and notched-bar impact bend tests, provided that they can be taken from unstraightened test coupons. If this is not possible, longitudinal specimens shall be tested.

(4) Notched-bar impact bend tests shall be performed only for pipe elbows with nominal wall thicknesses equal to or larger than 10 mm.

(5) If starting products that have not been completely examined and heat-treated to the stipulations in Sections 5.3 or 5.4 are used, test coupons shall be taken from both ends of pipe elbows with an arc length greater than 3000 mm, measured along the outside of the bend.

(6) In all other cases, test coupons shall be taken from only one end of the pipe elbow.

(7) If the pipe elbows are not tested individually, test units consisting of pipe elbows of the same heat, dimension and heat treatment shall be formed for determination of mechanical and technological characteristics.

(8) For the room-temperature tensile tests and for the notched-bar impact bend tests, the number of pipe elbows per test unit shall not exceed:

a) 30 pieces for pipe elbows smaller than DN 200

b) 20 pieces for pipe elbows equal to or larger than DN 200 and smaller than DN 350

c) 10 pieces for pipe elbows equal to or larger than DN 350.

5.5.4.2 Extent of tests and examinations

(1) The chemical composition shall be verified on the starting product.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test for each sampling location of one pipe elbow per test unit, and for each sampling location of each pipe elbow in the case of individual testing.

b) One elevated-temperature tensile test for one sampling location of one pipe elbow per heat, dimension and heat treatment, and for one sampling location of each pipe elbow in the case of individual testing. The test temperature is defined in Section A 3 or in the authorized inspector's appraisal.

c) One notched-bar impact bend test to clause 4.4.6.5 at 33 °C or at the lowest operating temperature, whichever is lower, for each sampling location of one pipe elbow per test unit for pipe elbows of normalized or air quenched and tempered steels with nominal wall thicknesses not exceeding 38 mm, as well as for pipe elbows of liquid quenched and tempered steels with nominal wall thicknesses not exceeding 16 mm. For greater wall thicknesses as well as in the case of individual testing, this test shall be performed at each sampling location of each pipe elbow. For pipe elbows of steel grade 15 MnNi 6 3, the test temperature shall be 0 °C.

d) Notched-bar impact bend tests for determination of an impact energy vs. temperature curve to clause 4.4.6.6 for one sampling location of one pipe elbow per heat, dimension and heat treatment for pipe elbows with nominal wall thicknesses equal to or larger than 10 mm. At least four test temperatures shall be used, of which two shall be 0 °C and the lowest loading temperature. This test may be waived for pipe elbows of steel grade 15 MnNi 6 3.

e) One notched-bar impact bend test to clause 4.4.6.5 to determine the upper shelf impact energy at one sampling location of each elbow for pipe elbows of normalized or air quenched and tempered steels with nominal wall thicknesses exceeding 38 mm as well as for pipe elbows of liquid quenched and tempered steels with nominal wall thicknesses exceeding 16 mm. This test may be performed during determination of the impact energy vs. temperature curves. In general, 80 °C shall be selected as the test temperature. This test shall be performed only in test group A 1, and may be waived if the value of impact energy determined per d) or e) is equal to or greater than 100 J.

f) For pipe elbows grouped together as test units, one hardness test per pipe elbow to verify uniformity.

Note:
Verification of uniformity shall be acknowledged if the difference between the highest and lowest hardness values in a test unit does not exceed 30 HB units.

(3) The Sections 11.1 and 11.6.1 shall apply to the non-destructive tests and examinations.

(4) Each pipe elbow shall be subjected to a materials identification check.

(5) The inside and outside surfaces of each pipe elbow shall be subjected to a visual inspection.

(6) For each pipe elbow, the wall thickness and, depending on the purchase order, either the outside or inside diameter shall be measured over the arc length, including the ends, and to a sufficient extent over the circumference. The smallest wall thickness as well as the ovality shall be determined.

5.5.5 Marking

(1) Each pipe elbow shall be marked with the following information:

a) manufacturer's symbol,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) pipe-elbow number,

e) authorized inspector's mark.

5.5.6 Verification of quality characteristics

(1) The results of the materials identification check and of non-destructive tests and examinations performed by the manufacturer as well as of hardness test, if any, shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons shall be indicated in the inspection certificate 3.1.

(2) The forming process used shall be indicated in the inspection certificate 3.1 to DIN EN 10204.

(3) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

5.6 Seamless fittings larger than DN 50

Note:
The nominal diameter of a reducer or of a tee shall refer to the end with the larger diameter.

5.6.1 Scope

(1) This Section shall apply to the following seamless fittings:

a) reducers made by cold or hot forming,

b) tees fabricated to the liqued bulge method

followed by heat treatment (normalization; quenching and tempering)

5.6.2 Materials

(1) The following steel grades may be used:

a) steel grades to Section A 3 and

b) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

(3) For fabricated fittings, the values of the mechanical and technological characteristics to Section A 3 shall apply even if forged hollow parts are used as starting products.

5.6.3 Starting products

(1) Forged hollow parts to Section 5.3 or seamless pipes to Section 5.4 shall basically be used as starting products.

(2) Starting products that have not been completely examined and heat-treated to the stipulations in Sections 5.3 or 5.4 may also be used, provided

a) the finished pipe elbows are examined individually to clause 5.6.4.2 and

b) the non-destructive tests and examinations of the starting products have been carried out according to the requirements in Section 11.4 or Section 11.5.1 prior to forming.

In this case the determination of mechanical and technological characteristics and the corresponding verification may be waived for the starting products. An inspection certificate 3.1 to DIN EN 10204 shall then be adequate for visual inspection and dimensional check of the starting products.

5.6.4 Tests and examinations of fittings

5.6.4.1 Sampling and specimen preparation

(1) Specimens shall be taken from one end of the fittings in conformity with the authorized inspector's appraisal.

(2) The test coupons shall be located at one quarter of the wall thickness under the outside surface and at one half of the wall thickness under the end face or as close as possible to that location.

(3) Transverse specimens shall be used for tensile tests and notched-bar impact bend tests, provided that they can be taken from unstraightened test coupons. If this is not possible, longitudinal specimens shall be tested.

(4) Notched-bar impact bend tests shall be performed only for fittings with nominal wall thicknesses equal to or larger than 10 mm.

(5) If the fittings are not tested individually, test units consisting of fittings of the same heat, dimension and heat treatment shall be formed for determination of mechanical and technological characteristics.

(6) For the room-temperature tensile tests and for the notched-bar impact bend tests, the number of fittings per test unit shall not exceed:

a) 30 pieces for fittings smaller than DN 100

b) 10 pieces for fittings equal to or larger than DN 100.

5.6.4.2 Extent of tests and examinations

(1) The chemical composition shall be verified on the starting product.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per test unit.

b) One elevated-temperature tensile test per heat, dimension and heat treatment, if the design temperature is higher than 100 °C. The test temperature is defined in Section A 3 or in the authorized inspector's appraisal.

c) One notched-bar impact bend test to clause 4.4.6.5 at 33 °C or at the lowest operating temperature, whichever is lower, on one piece per test unit for fittings of normalized or air quenched and tempered steels with nominal wall thicknesses not exceeding 38 mm, as well as for fittings of liquid quenched and tempered steels with nominal wall thicknesses not exceeding 16 mm. For fittings of steel grade 15 MnNi 6 3, the test temperature shall be 0 °C.

d) Notched-bar impact bend tests for determination of an impact energy vs. temperature curve to clause 4.4.6.6 on one piece per heat, dimension and heat-treatment lot for fittings with nominal wall thicknesses equal to or larger than 10 mm. At least four test temperatures shall be used, of which two shall be 0 °C and the lowest loading temperature. This test may be waived for fittings of steel 15 MnNi 6 3.

e) One notched-bar impact bend test to clause 4.4.6.5 on each piece to determine the upper shelf impact energy for fittings of normalized or air quenched and tempered steels with nominal wall thicknesses exceeding 38 mm as well as for fittings of liquid quenched and tempered steels with nominal wall thicknesses exceeding 16 mm. In general, 80 °C shall be selected as the test temperature. This test may be performed during determination of the energy absorbed vs. temperature curves. This test shall be performed only in test group A 1, and may be waived if the value of energy absorbed determined per d) or e) is equal to or greater than 100 J.

f) For fittings grouped together as test units, one hardness test per fitting to verify uniformity.

Note:
Verification of uniformity shall be acknowledged if the difference between the highest and lowest hardness values in a test unit does not exceed 30 HB units.

(3) Each fitting shall be subjected to a materials identification check.

(4) The inside and outside surfaces of each fitting shall be subjected to a visual inspection.

(5) For each fitting, the ovality, diameter and thickness shall be measured at the ends.

(6) The Sections 11.1 and 11.7.1 shall apply to the non-destructive tests and examinations.

5.6.5 Marking

(1) Each fitting shall be marked with the following information:

a) manufacturer's symbol,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) fitting number or test lot number,

e) authorized inspector's mark.

5.6.6 Verification of quality characteristics

(1) The results of the materials identification check and of non-destructive tests and examinations performed by the manufacturer as well as of hardness test, if any, shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons shall be indicated in the inspection certificate 3.1.

(2) The forming process used shall be indicated in the inspection certificate 3.1 to DIN EN 10204.

(3) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

5.7 Castings

5.7.1 Materials

(1) The following cast-steel grades may be used:

a) GS-C 25 S to Section A 4 and

b) other cast-steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

5.7.2 Requirements for casting condition

(1) As regards their general internal quality and external finish, the castings shall meet the conditions of **Table 11-6** applicable to their test group.

(2) Feeder heads and large casting-related thickenings that impair amenability of castings to heat treatment shall be eliminated before normalization or quenching and tempering.

(3) The casting technique shall be designed according to the principles of controlled solidification. For castings with nominal widths equal to or larger than 200 mm, the gate and feeder technique shall be explained on the basis of the saturation calculation as well as drawings illustrating the position of the feeders, feed zones and specimen location.

Note:
The feature characterizing the dimensions of the body or case shall be the nominal width, as follows:
a) for pumps, the nominal width of the pressure nozzle,
b) for valves, the largest nominal width involved,
c) for safety valves, the nominal width of the inlet nozzle.

(4) For each casting model, the description of the casting technique shall be attached to the interim file (internal manufacturer documentation) for retention by the manufacturer.

(5) Together with the drawing of the casting in the as-delivered condition, the following documents shall generally be submitted as standard plans for the design approval:

a) test and inspection sequence plan and heat-treatment plan, in case of differences from the standard production scheme to **Figure 5.7-1**,

b) for forgings of test group A 1 with nominal widths equal to or larger than 200 mm, instructions for the non-destructive examinations as well as a coordinate reference system (reference-point grid),

c) for prototypes of test groups A 2 and A 3 with nominal widths equal to or greater than 200 mm a film location plan and a radiation source plan,

d) welding procedure qualification and welding procedure sheet for production welds and if applicable construction welds (see **Annex B**),

e) test and inspection sequence plan for construction welds, if necessary.

f) list of planned production control tests.

(6) If changes are made compared with the conditions stipulated in the welding procedure sheet, or if a different welding method is chosen, the welding procedure sheet shall be amended accordingly and resubmitted for design approval.

5.7.3 Tests and examinations

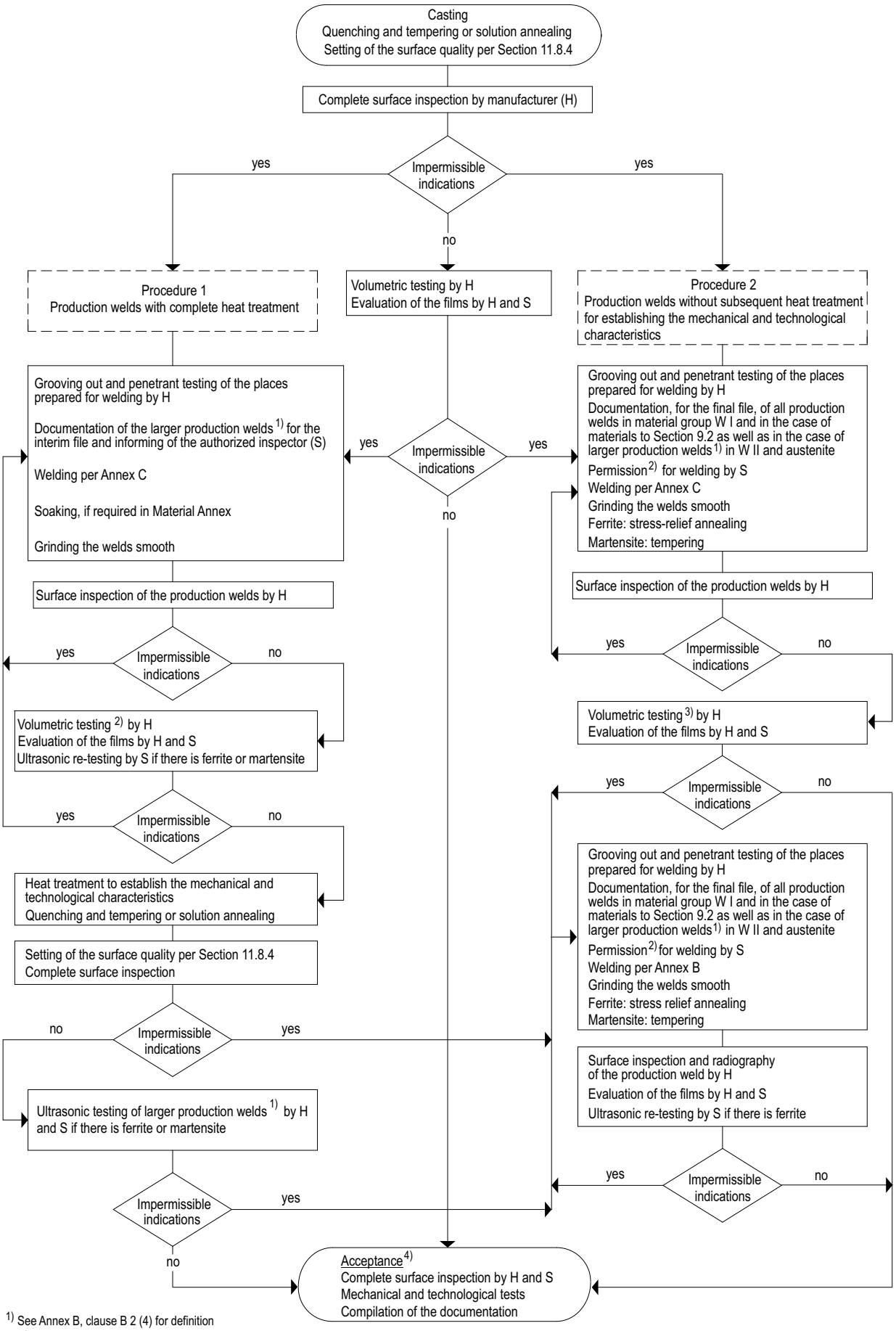
5.7.3.1 Sampling and specimen preparation

(1) Castings with a delivery weight equal to or lighter than 500 kg shall be tested in lots, and castings with a delivery weight heavier than 500 kg shall be tested individually.

(2) The number of sampling locations shall be as indicated in **Table 5.7-1**.

Product weight (delivery weight) in kg	Test unit	Number of sampling locations
≤ 100	At most 2500 kg per heat, dimension and heat-treatment lot	1
> 100 up to ≤ 500	At most 10 pieces, but not more than 2500 kg per heat, dimension and heat-treatment lot	1
> 500 up to ≤ 1000	Individual piece	1
> 1000	Individual piece	2

Table 5.7-1: Number of sampling locations on castings made of ferritic steels of material group W I



1) See Annex B, clause B 2 (4) for definition of larger production weld.

2) Applies only to material group W I, test group A 1 and in the case of materials to Section 9.2.

3) Note when there are additional volumetric examinations: Radiographed welds and casting zones with permissible indications need not be re-tested.

4) If, in exceptional cases in the course of further processing, it becomes necessary for the component manufacturer to perform production welds in order to eliminate casting defects in an advanced state of processing, then deviations relative to the standard production scheme shall be permissible by agreement with the authorized inspector.

Figure 5.7-1: Production scheme for cast steel cases and bodies made of ferritic, austenitic or martensitic cast-steel grades

(3) The specimens shall be taken from cast-on test blocks to DIN EN 1559-2 or from overlengths. Separately cast test blocks are permitted only for castings with piece weights equal to or lighter than 150 kg.

(4) The test blocks shall be provided in sufficient number and size that the prescribed specimens can be taken.

(5) The thickness of the cast-on test blocks shall correspond to the governing wall thickness. In this connection, the governing wall thickness shall be the thickness of the wall subjected to pressure loading, and not the thickness of cast-on flanges or local thickenings.

(6) Cast-on test blocks at the gate system are not permitted.

(7) For castings with piece weights heavier than 1000 kg, the position of the cast-on test coupons on the casting shall be documented by a photograph or in a sketch.

5.7.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis for one sampling location per test unit.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location. The value of reduction of area at fracture shall also be determined for information.

b) One elevated-temperature tensile test per heat, dimension and heat-treatment lot. The test temperature is defined in Section A 4 or in the authorized inspector's appraisal. The value of reduction of area at fracture shall also be determined for information.

c) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 33 °C or at the lowest operating temperature, whichever is lower.

d) Notched-bar impact bend tests for determination of an impact energy vs. temperature curve to clause 4.4.6.6 at one sampling location per test unit. At least four test temperatures shall be used, of which two shall be 33 C or the lowest loading temperature and 0 °C.

e) One notched-bar impact bend test to clause 4.4.6.5 to verify the upper shelf impact energy at one sampling location per test unit. In general, this test shall be performed at 80 °C. The test shall be performed only in test group A 1, and may be waived if the notched-bar impact bend test at the lower of 33 °C or the lowest loading temperature has already verified that the requirements are met.

f) One hardness test on each piece to verify uniformity of the quenching and tempering treatment in the case of lotwise examination of castings of quenched and tempered steel.

(3) The Sections 11.1 and 11.8 shall apply to the non-destructive tests and examinations.

(4) Each casting shall be subjected to a materials identification check.

(5) Each casting shall be subjected in the as-delivered condition to a visual inspection.

(6) Each casting shall be subjected in the as-delivered condition to a dimensional check.

(7) Each casting shall be subjected in a condition suitable for the purpose, generally by the further processor, to a tightness test in the form of an internal pressure test, which shall be performed to DIN 50104. Pressurizing fluid, test pressure and pressure-loading duration shall be indicated in the purchase order. The test pressure has to be limited to ensure that a safety margin against the yield point or 0.2 % proof stress at room temperature of at least 1.1 is achieved.

5.7.4 Marking

(1) Each casting shall be marked with the following information:

a) manufacturer's symbol,

b) steel grade,

c) heat number,

d) specimen number and

e) authorized inspector's mark.

5.7.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check and non-destructive tests and examinations performed by the manufacturer as well as of the hardness test, if any, shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check, tightness test and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with the inspection certificate 3.1 as an inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) For castings with piece weights heavier than 1000 kg, a photograph or a sketch of the location of the cast-on test blocks on the casting shall be attached to the inspection certificate.

6 Product forms of ferritic steels of material group W II

6.1 Flat products

6.1.1 Materials

(1) The following steel grades may be used:

a) 15 MnNi 6 3 to Section A 1

b) P275NH (1.0486) to DIN EN 10028-3 in conjunction with VdTÜV material sheet 352/1

c) P355NH (1.0565) to DIN EN 10028-3 in conjunction with VdTÜV material sheet 354/1

d) 16Mo3 (1.5415) to DIN EN 10028-2

e) P235GH (1.0345) to DIN EN 10028-2

f) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.1.

(3) The selection of materials shall be based on the lowest operating temperature.

6.1.2 Additional requirements for the materials

(1) Flat products with nominal thicknesses equal to or larger than 15 mm which are subjected to loading perpendicular to the rolled surface shall at least meet the requirements of quality class Z25 to DIN EN 10164. This shall be specified in the purchase order.

(2) When flat products are used for tubesheets, the same requirements as for specimens longitudinal to or transverse to the main rolling direction shall apply for the room-temperature yield point or 0.2 % proof stress and tensile strength of standard specimens perpendicular to the flat product surface. This shall be specified in the purchase order.

(3) The surface finish shall satisfy the stipulations of DIN EN 10163-2 Class B Subgroup 3.

6.1.3 Tests and examinations

6.1.3.1 Sampling and specimen preparation

(1) Specimens shall be taken in accordance with the DIN standards and VdTÜV material sheets referred to in 6.1.1 (1). For steel grade 15 MnNi 6 3 clause 5.1.3 shall apply.

(2) Specimens for determination of the reduction of area at fracture on perpendicular specimens shall be taken and prepared to the stipulations in DIN EN 10164.

6.1.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis on one sampling location of one rolled plate per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One tensile test at a temperature of 300 °C per heat, dimensional range and total weight of at most 30 metric tons.

c) Room-temperature tensile tests to DIN EN 10164 per rolled plate for flat products with nominal thicknesses equal to or larger than 15 mm, in order to determine the reduction of area at fracture, whenever the quality class Z25 is required acc. to clause 6.1.2 (1).

d) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 0 °C or at 20 °C for nominal thicknesses equal to or larger than 5 mm.

e) Notched-bar impact bend tests for determination of an impact energy vs. temperature curve to clause 4.4.6.6 at one sampling location per heat, dimensional range and identical heat treatment for flat products with nominal thicknesses equal to or larger than 10 mm. At least four test temperatures shall be used, of which one shall be 0 °C or 20 °C. This test may be waived for flat products of steel grade 15 MnNi 6 3.

(3) Each rolled plate shall be subjected to a materials identification check.

(4) Each flat product shall be subjected to a visual inspection.

(5) The dimensional and shape accuracy of each rolled plate shall be measured.

(6) The Sections 11.1 and 11.2 shall apply to the non-destructive tests and examinations, the Sections 11.1 and 11.4 in the case of flat products for tubesheets.

6.1.4 Marking

(1) Each flat product shall be marked at least with the following information:

a) manufacturer's symbol,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) specimen number and

e) authorized inspector's mark.

(2) The marking shall be applied such that it appears upright when viewed in the main rolling direction.

6.1.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process, the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

6.2 Dished or pressed product forms made from flat products

6.2.1 Materials

Section 6.1.1 shall apply to the materials.

6.2.2 Additional requirements for the materials

The requirements of Section 6.1.2 shall apply.

6.2.3 Starting products

(1) Starting products shall be subject to the stipulations in Section 6.1.

(2) If the finished parts are tested individually to clause 6.2.4.2, the tests to clause 6.1.3.2 (2) as well as the corresponding verifications can be omitted.

Note:
The stipulations of KTA 3211.3 shall apply to welded joints made with the starting plates and remaining in the finished parts.

6.2.4 Testing and examination of dished or pressed product forms made from flat products

6.2.4.1 Sampling and specimen preparation

(1) For product forms with a diameter or length equal to or smaller than 3000 mm, the tests or examinations shall be performed on one part per rolled plate and heat-treatment lot. The maximum permissible lot size shall be 10 parts.

Note:
Correlation of parts with the rolled plate can be achieved, for example, through the specimen number of the starting products.

(2) For product forms with a diameter or length greater than 3000 mm, each part shall be tested. For lengths or diameters exceeding 6 m one test coupon each shall be taken at two opposite sides.

(3) One test coupon shall be taken from each part to be examined regardless of its diameter or length.

(4) The test coupons shall be taken such that transverse specimens can be machined. Deviations up to 20 degrees from the theoretical transverse direction are permitted for

heads (ends) and similar parts. If this is not possible, a different type of sampling shall be agreed with the authorized inspector.

(5) Round tensile-test specimens with a test diameter equal to or larger than 10 mm shall be made for both the room-temperature and elevated-temperature tensile tests. For nominal wall thicknesses larger than 40 mm, the specimen axis shall be located at a distance of one quarter of the product-form thickness under the rolled surface.

For product-form thicknesses that do not permit a test diameter of 10 mm, the largest possible diameter shall be chosen.

(6) For nominal wall thicknesses equal to or smaller than 40 mm, one side of the specimens for the notched-bar impact bend test shall be as close as possible to the rolled surface. For nominal wall thicknesses larger than 40 mm, the specimen axis shall be located at a distance of one quarter of the product-form thickness under the rolled surface.

6.2.4.2 Extent of tests and examinations

(1) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One tensile test at a temperature of 300 °C per heat, dimensional range and total weight of at most 30 metric tons.

c) Room-temperature tensile tests to DIN EN 10164 per rolled plate for product forms with nominal thicknesses equal to or larger than 15 mm, in order to determine the reduction of area at fracture, whenever the quality class Z25 is required acc. to clause 6.1.2 (1). This test may be waived if it has already been performed on the rolled plate and documented with an inspection certificate 3.2 to DIN EN 10204.

Note:
Correlation of parts with the rolled plate can be achieved, for example, through the specimen number.

d) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 0 °C or at 20 °C for nominal wall thicknesses equal to or larger than 5 mm.

e) Notched-bar impact bend tests for determination of an impact energy vs. temperature curve to clause 4.4.6.6 at one sampling location per heat, dimensional range and heat-treatment lot for product forms with nominal wall thicknesses equal to or larger than 10 mm. At least four test temperatures shall be used, of which one shall be 0 °C or 20 °C. This test may be waived for product forms of steel grade 15 MnNi 6 3.

(2) Each product form shall be subjected to a materials identification check.

(3) Each product form shall be subjected to a visual inspection.

(4) The dimensional and shape accuracy of each product form shall be measured.

(5) The Sections 11.1 and 11.3 shall apply to the non-destructive tests and examinations.

6.2.5 Marking

(1) Each finished part shall be marked at least with the following information:

a) symbol of the manufacturer of the product form,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) specimen number and

e) authorized inspector's mark.

(2) In the case of lotwise examination, the product form from which the specimens were taken shall also be marked.

(3) The marking shall be applied such that it appears upright when viewed in the main rolling direction of the rolled plate.

6.2.6 Verification of quality characteristics

(1) The results of the materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The forming method shall be indicated in the inspection certificate 3.1 to DIN EN 10204.

(3) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

6.3 Forgings, bars and rolled rings

6.3.1 Materials

(1) The following steel grades may be used:

a)	15 MnNi 6 3	to Section A 2
b)	P250GH (1.0460)	to DIN EN 10273 or DIN EN 10222-2
c)	16Mo3 (1.5415)	to DIN EN 10273 or DIN EN 10222-2
d)	P355NH (1.0565)	to DIN EN 10273 in conjunction with VdTÜV material sheet 354/1 or DIN EN 10222-4 in conjunction with VdTÜV material sheet 354/3
e)	P355QH1 (1.0571)	to DIN EN 10222-4 in conjunction with VdTÜV material sheet 354/3
f)	P235GH (1.0345)	to DIN EN 10273

g) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.2.

(3) The selection of materials shall be based on the lowest operating temperature.

6.3.2 Tests and examinations

6.3.2.1 Sampling and specimen preparation

6.3.2.1.1 Test units

(1) Unless otherwise stipulated in clause 6.3.2.2, pieces with heat-treatment weights between 100 kg and equal to or lighter than 500 kg from the same heat, with similar dimensions and from the same heat-treatment lot shall be grouped as test units containing at most 10 parts, while pieces with heat-treatment weights lighter than or equal to 100 kg may be grouped as test units of 1000 kg each.

(2) Pieces with heat-treatment weights heavier than 500 kg shall be tested individually.

6.3.2.1.2 Sampling locations

(1) For forged hollow parts, e.g., for shell courses, nozzles or valve bodies, specimens shall be taken from one end as a

function of inside diameter D_i as follows: from one sampling location for D_i equal to or smaller than 500 mm; from two sampling locations separated by 180 degrees for D_i between 500 mm and 2000 mm; and from three sampling locations separated by 120 degrees for D_i larger than 2000 mm.

(2) At the opposite end, specimens shall be taken from one sampling location for normalized or air quenched and tempered forgings having a finished length longer than 5000 mm and for liquid quenched and tempered forgings having a finished length longer than 2000 mm. For pieces with inside diameters smaller than or equal to 500 mm, this sampling location shall be offset by 180 degrees relative to that at the other end (according to **Figures 5.3-1** and **5.3-2**).

Note:

Finished length designates the length of the product form during the governing heat treatment, less the length of the test coupons.

(3) For seamless rolled or forged rings or flanges, specimens shall be taken from the circumference or end of the flange. They may also be taken from the end of the welding end, if the heat-treatment thickness of the welding end is equal to that of the flange. Specimens shall be taken as follows: from one sampling location for inside diameters D_i smaller than or equal to 1000 mm; from two sampling locations separated by 180 degrees for D_i between 1000 mm and 2000 mm; and from three sampling locations separated by 120 degrees for Di larger than 2000 mm (according to **Figure 5.3-3**).

(4) For plates such as tubesheets, tube plates or blanking-off covers with heat-treatment weights lighter than 1000 kg, specimens shall be taken from one sampling location. If permitted by the forging method employed, this location shall be in the top or bottom zone (according to **Figure 5.3-4**).

(5) For plates with heat-treatment weights equal to or heavier than 1000 kg, specimens shall be taken from two sampling locations. If permitted by the forging method employed, these locations shall be in the top and bottom zones (according to **Figure 5.3-4**).

(6) For bars, specimens shall be taken at one end as a function of the diameter D of the bars: from one sampling location for D smaller than or equal to 500 mm; and from two sampling locations separated by 180 degrees for D larger than 500 mm.

(7) In the case of

a) normalized or air quenched and tempered bars having a finished length longer than 5000 mm and
b) liquid quenched and tempered bars having a finished length longer than 2000 mm

specimens shall be taken from one sampling location at the opposite end. For bars having diameters smaller than or equal to 500 mm, this location shall be offset by 180 degrees relative to that at the other end.

6.3.2.1.3 Sampling depth

The requirements of the DIN standards or VdTÜV material sheets applicable for the respective product form shall apply. In the case of steel 15 MnNi 6 3 the specimens shall be taken from at least one quarter of the governing heat-treatment thickness but at most 80 mm under the heat-treatment surfaces.

6.3.2.1.4 Specimen direction

(1) Transverse specimens shall be taken for tensile tests and notched-bar impact bend tests if geometrically possible and nothing to the contrary is stipulated in the authorized inspector's appraisal.

(2) Notwithstanding the foregoing, longitudinal specimens or axial specimens taken from bars are permitted, specifically for tensile tests if the diameter or greatest length of a cross-sectional edge is smaller than 160 mm, or for notched-bar impact bend tests if the diameter or the greatest length of a cross-sectional edge is smaller than 68 mm.

6.3.2.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.
b) One product analysis on in each of two separately manufactured products per heat. If possible, the top zone of one piece and the bottom zone of the other shall be tested. For piece weights equal to or heavier than 5000 kg, one product analysis shall be performed on one sampling location of each piece. It possible, the top or bottom of the starting ingot shall be tested.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One hardness test per piece to verify uniformity for pieces grouped together in test units.

   Note:

   Verification of uniformity shall be acknowledged if the difference between the highest and lowest hardness values in a test unit does not exceed 30 HB units.

b) One room-temperature tensile test per sampling location.
c) For pieces of similar dimension, one elevated-temperature tensile test per heat and heat-treatment lot.
d) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 0 °C or at 20 °C.
e) Notched-bar impact bend tests for determination of an impact energy vs. temperature curve to clause 4.4.6.6 at one sampling location per heat and heat-treatment lot for pieces with heat-treatment weights greater than 150 kg. At least four test temperatures shall be used, of which one shall be 0 °C or 20 °C.

(3) The Sections 11.1 and 11.4 shall apply to the non-destructive tests and examinations.

(4) Each piece shall be subjected to a materials identification check.

(5) Each piece shall be subjected in the as-delivered condition to a visual inspection.

(6) A dimensional check of each piece shall be performed.

6.3.3 Marking

(1) Each piece shall be marked at least with the following information:

a) manufacturer's symbol,
b) steel grade,
c) heat number,
d) specimen number or test lot number,
e) authorized inspector's mark.

(2) In the case of lotwise examination, the piece from which the specimens were taken shall additionally be marked.

6.3.4 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check and non-destructive tests and examinations performed by the manufacturer, and if necessary of the hardness test shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process, the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as

simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

6.4 Seamless pipes larger than DN 50

6.4.1 Scope

(1) The stipulations of this Section shall apply to seamless, rolled or pressed pipes larger than DN 50.

Note:
For forged pipes Section 6.3 shall apply.

(2) The stipulations of this Section shall also apply to pipes equal to or smaller than DN 50 if pipe elbows larger than DN 50 are made from such pipes.

(3) The stipulations of this Section shall not apply to pipes for vessel shells.

6.4.2 Materials

(1) The following steel grades may be used:

a) 15 MnNi 6 3 to Section A 3

b) P235GH (1.0345) to DIN EN 10216-2,

c) P275NL1 (1.0488) to DIN EN 10216-3 in conjunction with VdTÜV material sheet 352/2,

d) P355NH (1.0565) to DIN EN 10216-3 in conjunction with VdTÜV material sheet 354/2,

e) 16Mo3 (1.5415) to DIN EN 10216-2 and

f) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.2.

(3) The selection of materials shall be based on the lowest operating temperature.

6.4.3 Additional requirements for the materials

Pipes with nominal wall thicknesses equal to or larger than 15 mm and subjected to loading perpendicular to the rolled surface shall at least meet the requirements of quality class Z25 to DIN EN 10164. This shall be specified in the purchase order.

6.4.4 Tests and examinations

6.4.4.1 Sampling and specimen preparation

Specimens shall be taken in accordance with the DIN standards and VdTÜV material sheets referred to in 6.4.2 and in the case of steel grade 15 MnNi 6 3 in accordance with Section 5.4.4.

6.4.4.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis on each of two manufacturing lengths per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) Room-temperature tensile tests in compliance with the requirements for test category 2 in the DIN standards referred to in 6.4.2, but in the case of steel grade 15 MnNi 6 3 one room-temperature tensile test for every 50 manufacturing lengths of the same heat, dimension and heat treatment at one end of one manufacturing length.

b) One tensile test at 300 °C per heat, dimension and heat treatment, if the design temperature is higher than 100 °C.

c) Room-temperature tensile tests to DIN EN 10164 per tensile test specimen to a) on perpendicular specimens in order to determine the reduction of area at fracture for pipes with nominal wall thicknesses equal to or larger than 15 mm, whenever the quality class Z25 is required acc. to clause 6.4.3. This test may be waived for steel grades for which it was demonstrated in the material appraisal that the mean value of reduction of area at fracture is at least 35 % and that none of the individual values is smaller than 25 %.

d) One notched-bar impact bend test to clause 4.4.6.5 at 0 °C or 20 °C

   da) per tensile test specimen to a) for pipes of normalized or air quenched and tempered steels with nominal wall thicknesses equal to or larger than 10 mm up to and including 38 mm,

   db) at one end of each manufacturing length for pipes of normalized or air quenched and tempered steels with nominal wall thicknesses exceeding 38 mm,

   dc) per tensile test specimen to a) for pipes of liquid quenched and tempered steels at both ends of one manufacturing length in the case of nominal wall thicknesses equal to or larger than 10 mm up to and including 16 mm and at both ends of each manufacturing length for pipes exceeding 16 mm.

   For pipes of steel grade 15 MnNi 6 3, the test temperature shall be 0 °C.

e) Notched-bar impact bend tests for determination of the impact energy vs. temperature curve to clause 4.4.6.6 at one end of one manufacturing length per heat, dimension and heat treatment for pipes with nominal wall thicknesses exceeding 16 mm. At least four test temperatures shall be used, of which one shall be 0 °C or 20 °C. This test may be waived for pipes of steel grade 15 MnNi 6 3.

f) Technological tests for pipes with nominal wall thicknesses equal to or smaller than 40 mm per tensile test specimen to a) using test methods in compliance with the DIN standards referred to in 6.4.2. In the case of pipes made of steel grade 15 MnNi 6 3 at both ends of each manufacturing length using test methods to **Table 5.4-1**.

(4) The Sections 11.1 and 11.5.2 shall apply to the non-destructive tests and examinations.

(5) Each pipe shall be subjected to a materials identification check.

(6) The inside and outside surfaces of each pipe shall be subjected to a visual inspection.

(7) The diameter and wall thickness shall be checked for dimensional accuracy at both ends of each pipe.

(8) Each pipe shall be examined for leak tightness to DIN EN 10216-2 or DIN EN 10216-3.

6.4.5 Marking

(1) Each pipe shall be marked at both ends at least with the following information:

a) manufacturer's symbol,

b) steel grade and number of the DIN standard, for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164,
c) heat number,
d) pipe number,
e) test category and
f) authorized inspector's mark.

6.4.6 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check, tightness test and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process, the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

6.5 Seamless pipe elbows larger than DN 50

6.5.1 Scope

(1) This Section shall apply to seamless pipe elbows (weld-in elbows) made by cold or hot forming followed by heat treatment (normalization; quenching and tempering).

(2) This Section shall not apply to pipe bends made with inductive bending machines or by cold forming with or without subsequent heat treatment. These pipe bends shall be subject to the requirements of KTA 3211.3 Section 6.

6.5.2 Materials

(1) The Sections 6.3.1 and 6.4.2 apply to the materials.

(2) For finished pipe elbows, the values of the mechanical and technological characteristics for pipes shall apply even if forged hollow parts are used as starting products.

6.5.3 Starting products

(1) Forged hollow parts to Section 6.3 or seamless pipes to Section 6.4 shall basically be used as starting products.

(2) Starting products that have not been completely examined and heat-treated per the stipulations in Sections 6.3 or 6.4 may also be used, provided

a) the finished pipe elbows are examined individually per clause 6.5.4.2 and
b) the non-destructive tests and examinations of the starting products have been carried out according to the requirements in Section 11.4 or Section 11.5.1 prior to forming.

In this case, the determination of mechanical and technological characteristics and the corresponding verification may be waived for the starting products. An inspection certificate 3.1 to DIN EN 10204 shall then be adequate for visual inspection and dimensional check of the starting products.

6.5.4 Tests and examinations of pipe elbows

6.5.4.1 Sampling and specimen preparation

(1) Specimens shall be taken from the ends of the pipe elbows in conformity with the authorized inspector's appraisal.

(2) Transverse specimens shall be tested in the tensile tests and notched-bar impact bend tests, provided that they can be taken from unstraightened test coupons. If this is not possible, longitudinal specimens shall be tested.

(3) If starting products that have not been completely examined and heat-treated to the stipulations in Sections 6.3 or 6.4 are used, test coupons shall be taken from both ends of pipe elbows with a chord length greater than 3000 mm, measured along the outside of the bend.

(4) In all other cases, test coupons shall be taken from only one end of the pipe elbow.

(5) If the pipe elbows are not tested individually, test units consisting of pipe elbows of the same heat, dimension and heat treatment shall be formed for determination of mechanical and technological characteristics.

(6) For the room-temperature tensile tests and for the notched-bar impact bend tests, the number of pipe elbows per test unit shall not exceed:

a) 50 pieces for pipe elbows smaller than DN 200
b) 25 pieces for pipe elbows equal to or larger than DN 200 and smaller than DN 350
c) 10 pieces for pipe elbows equal to or larger than DN 350.

6.5.4.2 Extent of tests and examinations

(1) The chemical composition shall be verified on the basis of the starting product.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test on one pipe elbow per test unit.
b) One tensile test at 300 °C on one pipe elbow per heat, dimension and heat treatment, if the design temperature is higher than 100 °C.
c) One notched-bar impact bend test to clause 4.4.6.5 at 0 °C or at 20 °C on one pipe elbow per test unit for pipe elbows with nominal wall thicknesses equal to or larger than 10 mm. For pipe elbows of steel grade 15 MnNi 6 3, the test temperature shall be 0 °C.
d) Notched-bar impact bend tests for determination of the impact energy vs. temperature curve to clause 4.4.6.6 on one pipe elbow per heat, dimension and heat treatment for pipe elbows with nominal wall thicknesses exceeding 16 mm. At least four test temperatures shall be used, of which one shall be 0 °C or 20 °C. This test may be waived for pipe elbows of steel grade 15 MnNi 6 3.
e) For pipe elbows grouped together as test units, one hardness test per pipe elbow to verify uniformity.

Note:
Verification of uniformity shall be acknowledged if the difference between the highest and lowest hardness values in a test unit does not exceed 30 HB units.

(3) The Sections 11.1 and 11.6.2 shall apply to the non-destructive tests and examinations.

(4) Each pipe elbow shall be subjected to a materials identification check.

(5) The inside and outside surfaces of each pipe elbow shall be subjected to a visual inspection.

(6) For each pipe elbow, the wall thickness and, depending on the purchase order, either the outside or inside diameter shall be measured over the arc length, including the ends, and to a sufficient extent over the circumference. The smallest wall thickness as well as the ovality shall be determined.

6.5.5 Marking

(1) Each pipe elbow shall be marked at least with the following information:

a) manufacturer's symbol,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) elbow number,

e) authorized inspector's mark.

6.5.6 Verification of quality characteristics

(1) The results of the materials identification check and non-destructive tests and examinations performed by the manufacturer as well as the hardness test, if any, shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The forming process used shall be indicated in the inspection certificate 3.1 to DIN EN 10204.

(3) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

6.6 Seamless fittings larger than DN 50

Note:
The nominal diameter of a reducer or of a tee shall refer to the end with the larger diameter.

6.6.1 Scope

(1) This Section shall apply to the following seamless fittings:

a) reducers made by cold or hot forming,

b) tees fabricated to the liqued bulge method

followed by heat treatment (normalization; quenching and tempering).

6.6.2 Materials

(1) The Sections 6.3.1 and 6.4.2 apply to the materials.

(2) For fabricated fittings, the values of the mechanical and technological characteristics for pipes shall apply even if forged hollow parts are used as starting products.

6.6.3 Starting products

(1) Forged hollow parts to Section 6.3 or seamless pipes to Section 6.4 shall basically be used as starting products.

(2) Starting products that have not been completely examined or heat-treated to the stipulations in Sections 6.3 or 6.4 may also be used, provided

a) the finished fittings are examined individually per clause 6.6.4.2 and

b) the non-destructive tests and examinations of the starting products have been carried out according to the requirements in Section 11.4 or Section 11.5.2 prior to forming.

In this case the determination of mechanical and technological characteristics and the corresponding verification may be waived for the starting products. An inspection certificate 3.1 to DIN EN 10204 shall then be adequate for visual inspection and dimensional check of the starting products.

6.6.4 Tests and examinations of fittings

6.6.4.1 Sampling and specimen preparation

(1) Specimens shall be taken from the ends of the fittings in conformity with the authorized inspector's appraisal.

(2) Transverse specimens shall be tested in the tensile tests and notched-bar impact bend tests, provided that they can be taken from unstraightened test coupons. If this is not possible, longitudinal specimens shall be tested.

(3) If the fittings are not tested individually, test units consisting of fittings of the same heat, dimension and heat treatment shall be formed for determination of mechanical and technological characteristics.

(4) For the room-temperature tensile tests and for the notched-bar impact bend tests, the number of fittings per test unit shall not exceed:

a) at most 50 pieces for fittings with nominal diameters smaller than 100,

b) at most 25 pieces for fittings of unalloyed steels with nominal diameters equal to or larger than 100, or at most 10 pieces for such fittings of alloyed steels.

6.6.4.2 Extent of tests and examinations

(1) The chemical composition shall be verified on the basis of the starting product.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per test unit.

b) One tensile test at 300 °C per heat, dimension and heat treatment, if the design temperature is higher than 100 °C.

c) One notched-bar impact bend test to clause 4.4.6.5 at 0 °C or at 20 °C on one piece per test unit for fittings with nominal wall thicknesses equal to or larger than 10 mm. For fittings of steel grade 15 MnNi 6 3 the test temperature shall be 0 °C.

d) Notched-bar impact bend tests for determination of the impact energy vs. temperature curve to clause 4.4.6.6 on one piece per heat, dimension and heat treatment for fittings with nominal wall thicknesses exceeding 16 mm. At least four test temperatures shall be used, of which one shall be 0 °C or 20 °C. This test may be waived for pipe elbows of steel grade 15 MnNi 6 3.

e) For fittings grouped together as test units, one hardness test on each fitting to verify uniformity.

Note:
Verification of uniformity shall be acknowledged if the difference between the highest and lowest hardness values in a test unit does not exceed 30 HB units.

(3) The Sections 11.1 and 11.7.2 shall apply to the non-destructive tests and examinations.

(4) Each fitting shall be subjected to a materials identification check.

(5) The inside and outside surfaces of each fitting shall be subjected to a visual inspection.

(6) For each fitting, the ovality, diameter and thickness shall be measured at the ends.

6.6.5 Marking

(1) Each fitting shall be marked at least with the following information:

a) manufacturer's symbol,

b) steel grade (for steels with guaranteed reduction of area at fracture perpendicular to the product surface additionally quality class to DIN EN 10164),

c) heat number,

d) fitting number or test lot number,

e) authorized inspector's mark.

6.6.6 Verification of quality characteristics

(1) The results of the materials identification check and non-destructive tests and examinations performed by the manufacturer as well as the hardness test, if any, shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The forming process used shall be indicated in the inspection certificate 3.1 to DIN EN 10204.

(3) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

6.7 Castings

6.7.1 Materials

(1) The following cast-steel grades may be used:

a) GP240GH+QT (1.0619+QT) to DIN EN 10213,

b) other cast-steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.2.

(3) The selection of materials shall be based on the lowest operating temperature.

6.7.2 General requirements for casting finish

(1) As regards their general internal and external finish, the castings shall satisfy the stipulations of **Table 11-6** applicable to their test group.

(2) Feeder heads and large casting-related thickenings that impair amenability of castings to heat treatment shall be eliminated before the heat treatment for establishment of the mechanical and technological characteristics.

(3) The casting technique shall be designed according to the principles of controlled solidification. For castings with nominal widths equal to or larger than 200 mm, the gate and feeder technique shall be explained on the basis of the saturation calculation as well as drawings illustrating the position of the feeders, feed zones and specimen location.

(4) For each casting model, the description of the casting technique shall be attached to the interim file (internal manufacturer documentation) for retention by the manufacturer.

Note:
The feature characterizing the dimensions of the body or case shall be the nominal width, as follows:
a) for pumps, the nominal width of the pressure nozzle,
b) for valves, the largest nominal width involved,
c) for safety valves, the nominal width of the inlet nozzle.

(5) Together with the drawing of the casting in the as-delivered condition, the following documents shall generally be submitted as standard plans for the design approval:

a) test and inspection sequence plan and heat-treatment plan, in case of differences from the standard production scheme to **Figure 5.7-1**,

b) for prototypes of test groups A 2 and A 3 with nominal widths equal to or greater than 200 mm a film location plan and a radiation source plan,

c) welding procedure qualification and welding procedure sheet for production welds and if applicable construction welds (see **Annex B**),

d) test and inspection sequence plan for construction welds, if necessary.

e) list of planned production control tests.

(6) If changes are made compared with the conditions stipulated in the welding procedure sheet, or if a different welding method is chosen, the welding procedure sheet shall be amended accordingly and resubmitted for design approval.

6.7.3 Tests and examinations

6.7.3.1 Sampling and specimen preparation

(1) Castings with a delivery weight equal to or lighter than 500 kg shall be tested in lots, and castings with a delivery weight heavier than 500 kg shall be tested individually. The number of sampling locations shall be as indicated in **Table 5.7-1**.

(2) The specimens shall be taken from cast-on test blocks to DIN EN 1559-2 or from overlengths. Separately cast test blocks are permitted only for castings with piece weights equal to or lighter than 50 kg. The test blocks shall be provided in sufficient number and size that the prescribed specimens can be taken.

(3) The thickness of the cast-on test blocks shall correspond to the governing wall thickness. In this connection, the governing wall thickness shall be the thickness of the wall subjected to pressure loading, and not the thickness of cast-on flanges or local thickenings.

(4) Cast-on test blocks at the gate system are not permitted.

(5) For castings with piece weights heavier than 1000 kg, the position of the cast-on test blocks on the casting shall be documented by a photograph or in a sketch.

6.7.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis for one sampling location per test unit.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location. The value of reduction of area at fracture shall also be determined for information.
b) One tensile test at 350 °C per heat, dimension and heat-treatment lot, if the design temperature is higher than 100 °C.
c) One notched-bar impact bend test to clause 4.4.6.5 per sampling location at 0 °C or at 20 °C.
d) One hardness test on each piece to verify uniformity of the quenching and tempering treatment in the case of lotwise examination of castings of quenched and tempered steel.

(3) The Sections 11.1 and 11.8 shall apply to the non-destructive tests and examinations.

(4) Each casting shall be subjected to a materials identification check.

(5) Each casting shall be subjected in the as-delivered condition to a visual inspection.

(6) Each casting shall be subjected in the as-delivered condition to a dimensional check.

(7) Each casting shall be subjected in a condition suitable for the purpose, generally by the further processor, to a tightness test in the form of an internal pressure test, which shall be performed to DIN 50104. Pressurizing fluid, test pressure and pressure-loading duration shall be indicated in the purchase order. The test pressure has to be limited to ensure that a safety margin against the yield point or 0.2 % proof stress at room temperature of at least 1.1 is achieved.

6.7.4 Marking

(1) Each casting shall be marked at least with the following information:

a) manufacturer's symbol,
b) cast-steel grade,
c) heat number,
d) specimen number and
e) authorized inspector's mark.

6.7.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check and non-destructive tests and examinations performed by the manufacturer as well as of the hardness test, if any, shall be certified with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check, tightness test and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer. For castings with piece weights heavier than 1000 kg, a photograph or a sketch of the location of the cast-on test blocks on the casting shall be attached to the inspection certificate.

7 Product forms of austenitic steels

7.1 Flat products

7.1.1 Materials

(1) The following steel grades may be used:

a) X6CrNiNb18-10 (1.4550) to DIN EN 10028-7,
b) X6CrNiTi18-10 (1.4541) to DIN EN 10028-7,
c) X6CrNiMoTi17-12-2 (1.4571) to DIN EN 10028-7,
d) X6CrNiMoNb17-12-2 (1.4580) to DIN EN 10028-7 and
e) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.3.

(3) For hot (operating temperature $T \geq 200$ °C during continuous operation) reactor water containing product form and components in BWR plants only the steel grade to clause (1) a), and only with the following additional requirements for the chemical composition shall be used:

$C \leq 0{,}03$ %

$Si \leq 0{,}5$ %

$P \leq 0{,}025$ %

$S \leq 0{,}010$ %

$18{,}0\ \% \leq \%\ Cr \leq 19{,}0\ \%$

$13 \cdot \%\ C \leq \%\ Nb \leq 0{,}65\ \%$

$Co \leq 0{,}2$ %

The inspection certificate shall show the nitrogen content.

7.1.2 Additional requirements for the materials

The surfaces shall be free of ferritic impurities which are relevant for the corrosions resistance of the product form. Scale layers from hot forming or heat treatment shall be removed. Tempering colours from hot forming or heat treatment shall be avoided by taking appropriate measures. Decision on the permissibility of tempering colours up to and including “yellow” shall be made in each individual case.

7.1.3 Tests and examinations

7.1.3.1 Sampling and specimen preparation

(1) Room-temperature tensile tests shall be performed using

a) for flat products with nominal thicknesses equal to or smaller than 30 mm, flat tensile-test specimens containing both rolled surfaces,
b) for flat products with nominal thicknesses exceeding 30 mm and equal to or smaller than 75 mm, flat tensile-test specimens at least 30 mm thick, containing at least one intact rolled surface.

(2) Elevated-temperature tensile tests shall be performed using,

a) for flat products with nominal thicknesses equal to or smaller than 12 mm, flat tensile-test or round tensile-test specimens,
b) for flat products with nominal thicknesses exceeding 12 mm, round tensile-test specimens.

(3) The notched-bar impact bend test shall be subject to the following requirements:

a) For flat products with nominal thicknesses smaller than or equal to 30 mm, specimens shall be taken from 2 mm under the rolled surface.
b) For flat products with nominal thicknesses exceeding 30 mm and equal to or smaller than 75 mm, specimens shall be taken from 1/4 of the flat product thickness under the rolled surface.

(4) The sampling depth for flat products with nominal thicknesses exceeding 75 mm shall be subject to the stipulations in the authorized inspector's appraisal.

(5) The specimens shall be taken as transverse specimens such that the specimens are located halfway between long edges and centerline of the flat products.

(6) The number of sampling locations shall be as required in DIN EN 10028-7.

7.1.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis on one sampling location of one flat product per heat. The nitrogen content shall be documented.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One tensile test at 350 °C per heat, dimensional range and heat-treatment lot, if the design temperature in test group A 1 is higher than 200 °C and in test groups A 2 and A 3 is higher than 300 °C.

c) One room-temperature notched-bar impact bend test to clause 4.4.6.5 per sampling location for flat products with nominal thicknesses exceeding 16 mm.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat, dimensional range and heat-treatment lot.

(4) One bead-on-plate test to determine the delta ferrite content to **Annex C** shall be performed per heat, if values smaller than 3 are found in calculation of the ferrite number from the chemical composition in the ladle analysis.

(5) Each flat product shall be subjected to a materials identification check.

(6) Each flat product shall be subjected to a visual inspection.

(7) The dimensional and shape accuracy of each flat product shall be measured.

(8) The Sections 11.1 and 11.2 as well as the Sections 11.1 and 11.4 in the case of flat products for tube sheets shall apply to the non-destructive tests and examinations.

7.1.4 Marking

(1) Each flat product shall be marked at least with the following information:

a) manufacturer's symbol,

b) steel grade,

c) heat number,

d) specimen number,

e) authorized inspector's mark.

(2) The marking shall be applied transverse to the rolling direction. For flat products cut from strip, roller stamping in the longitudinal direction is also permitted.

7.1.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, test for resistance to intergranular corrosion, determination of the delta ferrite content, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process and the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) For flat products of test groups A 1 and A 2, the results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer. For flat products of test group A 3, the stipulations shall be the same as for steels for conventional pressure vessel plants subject to supervision to AD 2000-Merkblatt W 2.

7.2 Dished or pressed product forms made from flat products

7.2.1 Materials

The materials shall meet the requirements of clause 7.1.1.

7.2.2 Additional requirements for the materials

The requirements of clause 7.1.2 shall apply.

7.2.3 Tests and examinations of the starting products

(1) Starting products shall be subject to the stipulations in Section 7.1.

(2) If the finished parts are tested individually to clause 7.2.4.2, the tests to clause 7.1.3.2 (2) as well as the corresponding verifications shall not be required.

Note:
The stipulations of KTA 3211.3 shall apply to welded joints made with the starting products and remaining in the finished parts.

7.2.4 Tests and examinations of dished or pressed product forms made from flat products

7.2.4.1 Sampling and specimen preparation

(1) For product forms with a diameter or length smaller than or equal to 500 mm and a wall thickness smaller than or equal to 16 mm, the mechanical tests shall be performed on one part per heat, thickness range and heat-treatment lot. The maximum permissible lot size shall be 20 parts, but the lot weight shall not exceed 500 kg.

(2) For product forms with a diameter or length greater than 500 mm or wall thickness greater than 16 mm, each part shall be tested individually, in which case

a) for product forms with a diameter or length greater than 500 mm and equal to or smaller than 6000 mm or a wall thickness greater than 16 mm one test coupon shall be taken,

b) for product forms with a diameter or length greater than 6000 mm one test coupon each from two opposite sides shall be taken.

(3) The test coupons shall be taken such that transverse specimens can be machined. Deviations up to 20 degrees from the theoretical transverse direction are permitted for heads (ends) and similar parts. In making the specimens, plastic deformation of the specimen in the zone of the gauge length shall be avoided. If applicable, a different type of sampling or procedure for making specimens shall be agreed with the authorized inspector.

(4) The stipulations of clause 7.1.3.1 and of DIN EN 10028-7 shall apply as relevant to sampling.

7.2.4.2 Extent of tests and examination

(1) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One tensile test at 350 °C per heat, thickness range and heat-treatment lot, if the design temperature in test group A 1 is higher than 200 °C and in test groups A 2 and A 3 is higher than 300 °C.

c) One notched-bar impact bend test to clause 4.4.6.5 at room temperature per sampling location for product forms with nominal wall thicknesses larger than 16 mm.

(2) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat, dimensional range and heat-treatment lot.

(3) One bead-on-plate test to determine the delta ferrite content to **Annex C** shall be performed per heat, if values smaller than 3 are found in calculation of the ferrite number from the chemical composition in the ladle analysis. This test may be replaced by a corresponding test of the starting products.

(4) Each product form shall be subjected to a materials identification check.

(5) Each product form shall be subjected to a visual inspection.

(6) The dimensional and shape accuracy of each product form shall be measured.

(7) The Sections 11.1 and 11.3 shall apply to the non-destructive tests and examinations.

7.2.5 Marking

(1) Each product form shall be marked at least with the following information:

a) manufacturer's symbol,

b) steel grade,

c) heat number,

d) specimen number,

e) authorized inspector's mark.

(2) In the case of lotwise examination, the product form from which the specimens were taken shall additionally be marked.

(3) The marking shall be applied such that it appears upright when viewed in the main rolling direction of the rolled plate.

7.2.6 Verification of quality characteristics

(1) The results of the test for resistance to intergranular corrosion, determination of the delta ferrite content, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The forming method shall be indicated in the inspection certificate 3.1.

(3) For product forms of test groups A 1 and A 2, the results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer. For product forms of test group A 3, the stipulations shall be the same as for steels for conventional pressure vessel plants subject to supervision to AD 2000-Merkblatt W 2.

7.3 Forgings, bars and rolled rings

7.3.1 Materials

(1) The following steel grades may be used:

a) X6CrNiNb18-10 (1.4550) to DIN EN 10222-5 or DIN EN 10272,

b) X6CrNiTi18-10 (1.4541) to DIN EN 10222-5 or DIN EN 10272,

c) X6CrNiMoTi17-12-2 (1.4571) to DIN EN 10222-5 or DIN EN 10272,

d) X6CrNiMoNb17-12-2 (1.4580) to DIN EN 10272 and

e) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.3.

(3) For hot (operating temperature $T \geq 200$ °C during continuous operation) reactor water containing product form and components in BWR plants only the steel grade to clause (1) a), and only with the following additional requirements for the chemical composition shall be used:

$C \leq 0{,}03$ %

$Si \leq 0{,}5$ %

$P \leq 0{,}025$ %

$S \leq 0{,}010$ %

$18{,}0 \leq (\%\ Cr) \leq 19{,}0$

$13 \times (\%\ C) \leq (\%\ Nb) \leq 0{,}65$

$Co \leq 0{,}2$ %

The inspection certificate shall show the nitrogen content.

7.3.2 Additional requirements for the materials

The surfaces shall be free of ferritic impurities which are relevant for the corrosions resistance of the product form. Scale layers from hot forming or heat treatment shall be removed. Tempering colours from hot forming or heat treatment shall be avoided by taking appropriate measures. Decision on the permissibility of tempering colours up to and including “yellow” shall be made in each individual case.

7.3.3 Tests and examinations

7.3.3.1 Test units

(1) Pieces from the same heat, with similar dimensions and from the same heat-treatment lot shall be grouped as test units weighing at most 500 kg.

(2) Pieces with heat-treatment weights heavier than 500 kg or governing dimensions exceeding 250 mm shall be tested individually.

7.3.3.2 Sampling for forgings and rings

7.3.3.2.1 Sampling location

Specimens shall be taken from one end face of the prices. For heat treatment weights exceeding 2500 kg specimens shall be taken from both ends of the forging. At diameters exceeding 1000 mm the specimens shall be taken offset by 180 degrees. Unless otherwise stipulated, specimens shall be taken from one piece per test unit.

7.3.3.2.2 Sampling depth

(1) The requirements of the DIN standards applicable for the respective product form shall apply.

(2) If the exact sampling location cannot be given in advance for any pieces, it shall be specified by agreement with the authorized inspector.

7.3.3.2.3 Specimen direction

(1) Specimens shall be taken transverse to the main forming direction.

(2) Longitudinal specimens are permitted in the following cases: tensile-test specimens for pieces with a cross-sectional area corresponding to solid parts with a diameter smaller than 160 mm; and notched-bar impact-test specimens for pieces with a cross-sectional area corresponding to solid parts with a diameter smaller than 100 mm.

7.3.3.3 Sampling for bars

7.3.3.3.1 Sampling location

(1) Specimens shall be taken from one end of the bars.

(2) Unless otherwise stipulated, specimens shall be taken from one piece per test unit.

7.3.3.3.2 Sampling depth

(1) For bars with a diameter or heat-treatment thickness smaller than or equal to 25 mm, specimens shall be taken from the core of the bars.

(2) For bars with a diameter or heat-treatment thickness larger than 25 mm and smaller than or equal to 160 mm, specimens shall be taken at least 12.5 mm under the surface.

(3) The sampling depths for bars with larger diameter or larger heat-treatment thickness shall be determined by the stipulations in the authorized inspector's appraisal.

(4) The distance of the sampling location from the end faces shall be at least 25 mm.

7.3.3.3.3 Specimen direction

Longitudinal specimens shall be taken for bars with a diameter or heat-treatment thickness smaller than or equal to 100 mm, and transverse specimens shall be taken for bars with a diameter or heat-treatment thickness larger than 100 mm.

7.3.3.4 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.
b) One product analysis per heat. The nitrogen content shall be documented.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.
b) One tensile test at 350 °C per heat, similar dimension and heat-treatment lot, if the design temperature in test group A 1 is higher than 200 °C and in test groups A 2 and A 3 is higher than 300 °C.
c) One notched-bar impact bend test to clause 4.4.6.5 at room temperature per sampling location.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat, similar dimension and heat-treatment lot.

(4) One bead-on-plate test to determine the delta ferrite content shall be performed per heat, if values of ferrite number smaller than 3 are calculated by the procedure of **Annex C** from the chemical composition in the ladle analysis.

(5) The Sections 11.1 and 11.4 shall apply to the non-destructive tests and examinations.

(6) Each piece shall be subjected to a materials identification check.

(7) Each piece shall be subjected to a visual inspection.

(8) A dimensional check shall be performed for each piece.

7.3.4 Marking

(1) Each piece shall be marked durably at least with the following information:

a) manufacturer's symbol,
b) steel grade,
c) heat number,
d) specimen number,
e) authorized inspector's mark.

(2) In the case of lotwise examination, the piece from which the specimens were taken shall additionally be marked.

7.3.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, test for resistance to intergranular corrosion, determination of the delta ferrite content, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) For pieces of test groups A 1 and A 2, the results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer. For pieces of test group A 3, the stipulations shall be the same as for steels for conventional pressure vessel plants subject to supervision to AD 2000-Merkblatt W 2

7.4 Seamless pipes larger than DN 50

7.4.1 Scope

(1) The stipulations of this Section shall apply to seamless, rolled or pressed pipes larger than DN 50.

Note:
For forged pipes Section 7.3 shall apply.

(2) The stipulations of this Section shall also apply to pipes equal to or smaller than DN 50 if pipe elbows larger than DN 50 are made from such pipes.

7.4.2 Materials

(1) The following steel grades may be used:

a) X6CrNiNb18-10 (1.4550) to DIN EN 10216-5,
b) X6CrNiTi18-10 (1.4541) to DIN EN 10216-5,
c) X6CrNiMoTi17-12-2 (1.4571) to DIN EN 10216-5,
d) X6CrNiMoNb17-12-2 (1.4580) to DIN EN 10216-5 and
e) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.3.

(3) For hot (operating temperature T ≥ 200 °C during continuous operation) reactor water containing product form and components in BWR plants only the steel grade to clause (1) a), and only with the following additional requirements for the chemical composition shall be used:

C ≤ 0,03 %

Si ≤ 0,5 %

P ≤ 0,025 %

S ≤ 0,010 %

18,0 ≤ (% Cr) ≤ 19,0

13 x (% C) ≤ (% Nb) ≤ 0,65

Co ≤ 0,2 %

The inspection certificate shall show the nitrogen content.

7.4.3 Additional requirements for the materials

The surfaces shall be free of ferritic impurities which are relevant for the corrosions resistance of the product form. Scale layers from hot forming or heat treatment shall be removed. Tempering colours from hot forming or heat treatment shall be avoided by taking appropriate measures. Decision on the permissibility of tempering colours up to and including “yellow” shall be made in each individual case.

7.4.4 Testing and examinations

7.4.4.1 Sampling and specimen preparation

Specimens shall be taken in compliance with the requirements in DIN EN 1026-5. The distance between pipe end and sampling location of tensile and notched-bar impact bend test specimens shall be at least equal to the nominal wall thickness but shall not exceed 25 mm.

7.4.4.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis per heat. The nitrogen content shall be documented.

(2) The mechanical and technological characteristics shall be determined by performing:

a) Room-temperature tensile tests in compliance with the requirements for test category 2 in DIN EN 10216-5.

b) One tensile test at 350 °C per heat, dimensional range and heat-treatment lot, if the design temperature for pipes of test group A 1 is higher than 200 °C and for pipes of test groups A 2 and A 3 is higher than 300 °C.

c) One room-temperature notched-bar impact bend test to clause 4.4.6.5 per tensile test specimen to a) for pipes with nominal wall thicknesses exceeding 16 mm.

d) For pipes with wall thicknesses smaller than or equal to 40 mm, technological tests in compliance with the requirements in DIN EN 1026-5.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat, dimension and heat-treatment lot.

(4) One bead-on-plate test to determine the delta ferrite content shall be performed per heat, if the calculation to **Annex C** yields values of ferrite number smaller than 3 from the chemical composition in the ladle analysis.

(5) Each pipe shall be subjected to a materials identification check.

(6) The inside and outside surfaces of each pipe shall be subjected to a visual inspection.

(7) The dimensional and shape accuracy of each pipe shall be measured at both ends.

(8) The Sections 11.1 and 11.5.3 shall apply to the non-destructive tests and examinations.

(9) Each pipe shall be examined for leak tightness to DIN EN 10216-5.

7.4.5 Marking

(1) Each pipe shall be marked durably at least with the following information at one end:

a) manufacturer's symbol,

b) dimensions of the pipe,

c) steel grade and number of the DIN standard,

d) heat number,

e) test category,

f) mark of the delivery condition,

g) pipe number,

h) authorized inspector's mark.

7.4.6 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, test for resistance to intergranular corrosion, determination of the delta ferrite content, materials identification check, tightness test and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process and the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) For pipes of test group A 3 and wall thicknesses smaller than or equal to 5.6 mm, an inspection certificate 3.1 to DIN EN 10204 will suffice.

7.5 Seamless pipe elbows larger than DN 50

7.5.1 Scope

(1) This Section shall apply to seamless pipe elbows (weld-in elbows) made by cold or hot forming followed by heat treatment (solution annealing and quenching).

(2) This Section shall not apply to pipe bends made with inductive bending machines or by cold forming with or without subsequent heat treatment. These pipe bends shall be subject to the requirements of KTA 3211.3 Section 6.

7.5.2 Materials

(1) The materials shall meet the requirements of clauses 7.3.1 and 7.4.2.

(2) For finished pipe elbows, the values of the mechanical and technological characteristics for pipes shall apply even if forged hollow parts are used as starting product.

7.5.3 Additional requirements for the materials

The requirements of clauses 7.3.2 and 7.4.3 shall apply.

7.5.4 Starting products

(1) Forged hollow parts to Section 7.3 or seamless pipes to Section 7.4 shall basically be used as starting products.

(2) Starting products that have not been completely examined per the stipulations in Sections 7.3 or 7.4 may also be used, provided

a) the finished pipe elbows are examined individually per clause 7.5.5.2 and

b) the non-destructive tests and examinations of the starting products have been carried out according to the requirements in Section 11.4 or Section 11.5.3 prior to forming.

(3) If the finished pipe elbows are examined individually to clause 7.5.5.2, the determination of mechanical and technological characteristics and the corresponding verification may be waived for the starting products. An inspection certificate 3.1 to DIN EN 10204 shall then be adequate for visual inspection and dimensional check of the starting products.

7.5.5 Tests and examinations of pipe elbows

7.5.5.1 Sampling and specimen preparation

(1) Specimens shall be taken from the ends of the pipe elbows in conformity with the authorized inspector's appraisal.

(2) The distance between pipe-elbow end and sampling location shall be at least equal to the nominal wall thickness but shall not exceed 25 mm. Deviations from the foregoing are permitted by agreement with the authorized inspector.

(3) Transverse specimens shall be tested in the tensile tests and notched-bar impact bend tests, provided that they can be taken from unstraightened test coupons. If this is not possible, longitudinal specimens shall be tested.

(4) For pipe elbows with nominal wall thicknesses larger than or equal to 20 mm, specimens shall be taken from the middle of the pipe wall if at all possible.

(5) If the pipe elbows are not tested individually, test units consisting of pipe elbows of the same heat, dimension and heat treatment shall be formed for determination of mechanical and technological characteristics.

(6) For the room-temperature tensile tests and for the notched-bar impact bend tests, the number of pipe elbows per test unit shall not exceed:

a) 50 pieces for pipe elbows smaller than DN 200

b) 25 pieces for pipe elbows larger than or equal to DN 200 to smaller than DN 350

c) 10 pieces for pipe elbows larger than or equal to DN 350.

7.5.5.2 Extent of tests and examinations

(1) The chemical composition shall be verified on the basis of the starting product.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test on one pipe elbow per test unit or, in the case of individual testing, on each pipe elbow.

b) One tensile test at 350 °C on one pipe elbow per heat, dimension and heat-treatment lot, if the design temperature for pipe elbows of test group A 1 is higher than 200 °C and for pipe elbows of test groups A 2 and A 3 is higher than 300 °C.

c) One notched-bar impact bend test to clause 4.4.6.5 at room-temperature per test unit for wall thicknesses exceeding 16 mm.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat, dimension and heat-treatment lot.

(4) One bead-on-plate test to determine the delta ferrite content to **Annex C** shall be performed per heat, if values smaller than 3 are found in calculation of the ferrite number from the chemical composition in the ladle analysis. This test may be replaced by a corresponding test on the starting product.

(5) Each pipe elbow shall be subjected to a materials identification check.

(6) The inside and outside surfaces of each pipe elbow shall be subjected to a visual inspection.

(7) For each pipe elbow, the wall thickness and, depending on the purchase order, either the outside or inside diameter shall be measured over the arc length, including the ends, and to a sufficient extent over the circumference. The smallest wall thickness as well as the ovality shall be determined.

(8) The Sections 11.1 and 11.6.3 shall apply to the non-destructive tests and examinations.

7.5.6 Marking

(1) Each pipe elbow shall be marked at least with the following information:

à) manufacturer's symbol,

b) steel grade with abbreviation for the type of construction in compiance with the requirements in the DIN standard for the starting product,

c) heat number,

d) elbow number or test lot number and

e) authorized inspector's mark,

f) designation „X“ in the case of hot-finished elbows (of the Hamburg type) from the steel grades X6CrNiTi18-10 and X6CrNiMoTi18-10.

7.5.7 Verification of quality characteristics

(1) The results of the test for resistance to intergranular corrosion, determination of the delta ferrite content, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) The acceptance inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

(4) For pipe elbows of test group A 3 with wall thicknesses smaller than or equal to 5.6 mm, an inspection certificate 3.1 to DIN EN 10204 will suffice.

7.6 Seamless fittings larger than DN 50

Note:

The nominal diameter of a reducer or of a tee shall refer to the end with the larger diameter.

7.6.1 Scope

(1) This Section shall apply to the following seamless fittings:

a) reducers made by cold or hot forming,

b) tees fabricated to the liqued bulge method

followed by heat treatment (solution annealing and quenching).

7.6.2 Materials

(1) The materials shall meet the requirements of clauses 7.3.1 and 7.4.2.

(2) For the mechanical and technological characteristics of fabricated fittings, the values of the mechanical and technological characteristics for pipes shall apply even if forged hollow parts are used as starting products.

7.6.3 Additional requirements for the materials

The requirements of clauses 7.3.2 and 7.4.3 shall apply.

7.6.4 Starting products

(1) Forged hollow parts to Section 7.3 or seamless pipes to Section 7.4 shall basically be used as starting products.

(2) Starting products that have not been completely examined per the stipulations in Sections 7.3 or 7.4 may also be used, provided

a) the finished pipe elbows are examined individually per clause 7.6.5.2 and
b) the non-destructive tests and examinations of the starting products have been carried out according to the requirements in Section 11.4 or Section 11.5.3 prior to forming.

(3) If the finished pipe elbows are examined individually to clause 7.6.5.2, the determination of mechanical and technological characteristics and the corresponding verification may be waived for the starting products. An inspection certificate 3.1 to DIN EN 10204 shall then be adequate for visual inspection and dimensional check of the starting products.

7.6.5 Tests and examinations of fittings

7.6.5.1 Sampling and specimen preparation

(1) Specimens shall be taken from the ends of the fittings in conformity with the authorized inspector's appraisal.

(2) The test coupons shall be located at one half of the wall thickness under the end face or as close as possible to that location.

(3) Transverse specimens shall be tested in the tensile tests and notched-bar impact bend tests, provided that they can be taken from unstraightened test coupons. If this is not possible, longitudinal specimens shall be tested.

(4) For fittings with nominal thicknesses larger than or equal to 20 mm, specimens shall be taken from the middle of the pipe wall if at all possible.

(5) If the fittings are not tested individually, test units consisting of fittings of the same heat, dimension and heat-treatment lot shall be formed for determination of characteristics.

(6) For the room-temperature tensile tests and for the notched-bar impact bend tests, the number of fittings per test unit shall not exceed:

a) 50 pieces for fittings smaller than DN 100
b) 10 pieces for fittings larger than or equal to DN 100

7.6.5.2 Extent of tests and examinations

(1) The chemical composition shall be verified on the basis of the starting product.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per test unit.
b) One tensile test at 350 °C per heat, dimension and heat-treatment lot, if the design temperature for fittings of test group A 1 is higher than 200 °C and for fittings of test groups A 2 and A 3 is higher than 300 °C.
c) One notched-bar impact bend test to clause 4.4.6.5 at room-temperature per test unit for wall thicknesses exceeding 16 mm.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat, dimension and heat-treatment lot.

(4) One bead-on-plate test to determine the delta ferrite content to **Annex C** shall be performed per heat, if values smaller than 3 are found in calculation of the ferrite number from the chemical composition in the ladle analysis. This test may be replaced by a corresponding test on the starting product.

(5) Each fitting shall be subjected to a materials identification check.

(6) The inside and outside surfaces of each fitting shall be subjected to a visual inspection.

(7) For each fitting the ovality, diameter and wall thickness shall be measured at the ends.

(8) The Sections 11.1 and 11.7.3 shall apply to the non-destructive tests and examinations.

7.6.6 Marking

(1) Each fitting shall be marked at least with the following information:

a) manufacturer's symbol,
b) steel grade with abbreviation for the type of construction in compiance with the requirements in the DIN standard for the starting product,
c) heat number,
d) number of the fitting or test lot number,
e) authorized inspector's mark,
f) designation „X“ in the case of hot-finished fittings from the steel grades X6CrNiTi18-10 and X6CrNiMoTi18-10.

7.6.7 Verification of quality characteristics

(1) The results of the test for resistance to intergranular corrosion, determination of the delta ferrite content, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) The inspection certificate of the starting product shall be attached to the inspection certificate 3.2.

(4) For fittings of test group A 3 with wall thicknesses smaller than or equal to 5.6 mm, an inspection certificate 3.1 to DIN EN 10204 will suffice.

7.7 Castings

7.7.1 Materials

(1) The following cast-steel grades may be used:

a) GX5CrNiNb19-11 (1.4552) to DIN EN 10213,

b) GX5CrNiMoNb19-11-2 (1.4581) to DIN EN 10213 and

c) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) The materials shall meet the requirements of clause 4.3.3.

7.7.2 General requirements for casting condition

(1) The base metal shall have a delta ferrite content corresponding to ferrite numbers of 2 to 12 to **Annex C**.

(2) As regards their general internal and external finish, the castings shall satisfy the stipulations of **Table 11-6** applicable to their test group.

(3) Feeder heads and large casting-related thickenings that impair the heat treatment of the casting shall be eliminated before the heat treatment for establishment of the mechanical and technological characteristics.

(4) The casting technique shall be designed according to the principles of controlled solidification. For castings with nominal widths larger than or equal to 200 mm, the gate and feeder technique shall be explained on the basis of the saturation calculation as well as drawings illustrating the position of the feeders, feed zones and specimen location.

(5) For each casting model, the description of the casting technique shall be attached to the interim file (internal manufacturer documentation) for retention by the manufacturer.

Note:

The feature characterizing the dimensions of the body or case shall be the nominal width, as follows:

a) for pumps, the nominal width of the pressure nozzle,

b) for valves, the largest nominal width involved,

c) for safety valves, the nominal width of the inlet nozzle.

(6) Together with the drawing of the casting in the as-delivered condition, the following documents shall generally be submitted as standard plans for the design approval:

a) test and inspection sequence plan and heat-treatment plan, in case of differences from the standard production scheme to **Figure 5.7-1**.

b) for castings of test group A 1 with nominal widths equal to or larger than 200 mm, instructions for the non-destructive examinations as well as a coordinate reference system (reference-point grid).

c) for prototypes of test groups A 2 and A 3 with nominal widths greater than 200 mm a film location plan and a radiation source plan,

d) welding procedure qualification and welding procedure sheet for production welds and if applicable construction welds (see **Annex B**)

e) test and inspection sequence plan for construction welds, if necessary.

f) list of planned production control tests.

(7) If changes are made compared with the conditions stipulated in the welding procedure sheet, or if a different welding method is chosen, the welding procedure sheet shall be resubmitted for design approval in this respect.

7.7.3 Tests and examinations

7.7.3.1 Sampling and specimen preparation

(1) Castings with a delivery weight lighter than or equal to 500 kg shall be tested in lots, and castings with a delivery weight heavier than 500 kg shall be tested individually.

(2) The number of sampling locations shall be as indicated in **Table 5.7-1**.

(3) The specimens shall be taken from cast-on test blocks to DIN EN 1559-2 or from overlengths. Separately cast test blocks are permitted only for castings with piece weights equal to or lighter than 50 kg. The test blocks shall be provided in sufficient number and size that the prescribed specimens can be taken.

(4) The thickness of the cast-on test blocks shall correspond to the governing wall thickness. In this connection, the governing nominal wall thickness shall be the thickness of the wall subjected to pressure loading, and not the thickness of cast-on flanges or local thickenings.

(5) Cast-on test blocks at the gate system are not permitted.

(6) For castings with piece weights heavier than 1000 kg, the position of the cast-on test blocks on the casting shall be documented by a photograph or in a sketch.

7.7.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis for one sampling location per test unit. The nitrogen content shall be documented.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One tensile test at 350 °C per heat, dimension and heat-treatment lot, if the design temperature for castings of test group A 1 is higher than 200 °C and for castings of test groups A 2 and A 3 is higher than 300 °C.

c) One notched-bar impact bend test to clause 4.4.6.5 at room-temperature per sampling location.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat, dimension and heat-treatment lot.

(4) The delta ferrite content shall be determined from the nitrogen content by the method of **Annex C**. If the value of the ferrite number calculated from the chemical composition per the ladle analysis is smaller than 3, the delta ferrite content shall be determined metallographically per heat.

(5) The Sections 11.1 and 11.8 shall apply to the non-destructive tests and examinations.

(6) Each casting shall be subjected to a materials identification check.

(7) Each casting shall be subjected in the as-delivered condition to a visual inspection.

(8) Each casting shall be subjected in the as-delivered condition to a dimensional check.

(9) Each casting shall be subjected in a condition suitable for the purpose, generally by the further processor, to a tightness test in the form of an internal pressure test, which shall be performed to DIN 50104. Pressurizing fluid, pressure level and pressure-loading duration shall be indicated in the purchase order. The test pressure has to be limited to ensure that a safety margin against the 0.2 % proof stress at room temperature of at least 1.1 is achieved.

7.7.4 Marking

(1) Each casting shall be marked at least with the following information:

a) manufacturer's symbol,

b) cast-steel grade,

c) heat number,

d) specimen number and

e) authorized inspector's mark.

7.7.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, test for resistance to intergranular corrosion, determination of the delta ferrite content, materials identification check and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process and the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check, tightness test and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer. For castings with piece weights heavier than 1000 kg, a photograph or a sketch of the location of the cast-on test blocks on the casting shall be attached to the inspection certificate.

8 Bolts and nuts

8.1 Scope

This Section shall apply to:

a) bolts and nuts made by machining from quenched and tempered bars,

b) bolts and nuts made by machining from hot-cold work hardened austenitic bars,

c) bolts and nuts made by machining from solution-annealed and quenched austenitic bars,

d) bolts and nuts made by hot or cold forming ___ and then quenched and tempered,

e) bolts and nuts of unalloyed and alloyed ferritic steels of the strength classes to DIN EN ISO 898-1 and DIN EN ISO 898-2 as well as of austenitic steels of steel grades A 2, A 3, A 4 and A 5 to DIN EN ISO 3506-1 and DIN EN ISO 3506-2 within the limits of **Table 8-1**.

Note:

Thread rolling shall not be considered as cold forming that requires renewed heat treatment.

Steel group	Product form	Strength class	Limits of application
Unalloyed and alloyed ferritic steels [1]	Bolts	5.6 and 8.8 per DIN EN ISO 898-1	≤ M 30 for the scope of application: ≤ 2.5 MPa and ≤ 100 °C [2]; strength class 8.8 only in combination with flanges ≤ DN 500
	Nuts	5-2 and 8 per DIN EN ISO 898-2	≤ M 30 for the scope of application: < 4 MPa and ≤ 300 °C; strength class 8 only in combination with flanges ≤ DN 500
Austenitic steels of steel grades A 2 [3], A 3, A 4 [3] and A 5 to DIN EN ISO 3506-1 and DIN EN ISO 3506-2	Bolts and nuts	50 and 70 per DIN EN ISO 3506-1 and DIN EN ISO 3506-2	≤ M 39, strength class 70 only for ≤ M 30

[1] Permitted in test group A3 only.

[2] Without verification of the elevated temperature proof stress, bolts made of the steels for strength class 8.8 shall only be used up to 50 °C.

[3] Bolts and nuts from non-stabilized austenitic steels of steel groups A 2 and A 4 shall not be used if in permanent contact with the fluid. Exceptions shall be agreed between purchaser and authorized inspector.

Table 8-1: Application limits of bolts and nuts to DIN EN ISO 898-1 and DIN EN ISO 898-2 as well as to DIN EN ISO 3506-1 and DIN EN ISO 3506-1

8.2 Materials

(1) The following steel grades may be used:

a) steels to Section A 5,

b) steels C35E+QT (1.1181+QT), 25CrMo4 (1.7218) and 21CrMoV5-7 (1.7709) to DIN EN 10269 in combination with the additional requirements of Section 8.3 as well as the dimensional limits and other stipulations in Section A 6,

c) steels

ca) X6CrNiNb18-10 (1.4550) to DIN EN 10222-5 or DIN EN 10272,

cb) X6CrNiTi18-10 (1.4541) to DIN EN 10222-5 or DIN EN 10272,

cc) X6CrNiMoTi17-12-2 (1.4571) to DIN EN 10222-5 or DIN EN 10272,

cd) X6CrNiMoNb17-12-2 (1.4580) to DIN EN 10272,

d) steels X22CrMoV12-1+QT1 (1.4923+QT1) to DIN EN 10269 and X 8 CrNiMoBNb 16-16 +wk (1.4986+wk) to VdTÜV material sheet 113/2 in combination with the dimensional limits and other stipulations in Section A 6,

e) ferritic and austenitic steels for bolts and nuts to **Table 8-1**,

f) other steels meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

(2) Locking by welding is not permitted.

8.3 Additional requirements for the materials

(1) For ferritic steels for bolts, except X22CrMoV12-1+QT1 (1.4923+QT1) and bolts of strength classes, the following additional stipulations shall apply in the notched-bar impact bend test on longitudinal specimens at room temperature:

a) for dimensions larger than M 24 and smaller than or equal to M 100, the smallest individual value of lateral expansion shall not be less than 0.6 mm and

b) for dimensions larger than M 100 the smallest individual value of impact energy shall not be less than 61 J and the smallest individual value of lateral expansion shall not be less than 0.6 mm.

8.4 Bolts and nuts made by machining from quenched and tempered bars or from hot-cold work hardened austenitic bars

8.4.1 Tests and examinations on the bars

8.4.1.1 Sampling and specimen preparation

(1) Longitudinal specimens shall be taken.

(2) The test cross section of the tensile-test and notched-bar impact-test specimens shall be located at least one half of the bar diameter from the end face, and the specimen axis shall be located at the bar center for diameters equal to or smaller than 40 mm and at a depth of one sixth of the diameter under the surface for diameters larger than 40 mm.

8.4.1.2 Test units

The bars shall be tested in test units of at most 5000 kg, consisting of bars of the same dimension, same heat and same heat-treatment lot.

For steel grade X 8 CrNiMoBNb 16-16 +wk (1.4986+wk) the stipulations in VdTÜV material sheet 113/2 shall apply.

8.4.1.3 Extent of tests and examinations

(1) One ladle analysis shall be performed per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) Hardness test to DIN EN ISO 6506-1 as follows: with one indentation at one end of each bar of the test unit for bars with diameter larger than 120 mm; and with one indentation at one end of 10 % of the bars of the test unit for bars with diameter equal to or smaller than 120 mm, except that at least 10 bars or, if the test unit consists of fewer than 10 bars, every bar shall be tested.

b) One room-temperature tensile test on the bars exhibiting the lowest and highest hardness values.

c) One tensile test at 350 °C on bars for fabrication of bolts of test group A 1 as well as on bars made of 20 NiCrMo 14 5 and 26 NiCrMo 14 6 for fabrication of bolts of test groups A 1, A 2 and A 3, if the design temperature is higher than 100 °C.

d) One notched-bar impact bend test to clause 4.4.6.5 at room-temperature to determine the impact energy and lateral expansion for bars with diameters equal to or larger than 14 mm on both bars that were subjected to the tensile test.

(3) Each bar shall be subjected to visual inspection.

(4) The marking on each bar shall be inspected.

(5) Each bar shall be inspected for dimensional accuracy.

(6) Each bar shall be subjected to a materials identification check.

(7) The following requirements shall apply to the non-destructive tests and examinations:

a) Sections 11.1 and 11.9.2.1 in the case of ferritic and martensitic quenched and tempered bars,

b) Sections 11.1 and 11.9.3.1 in the case of bars made of the steel X 8 CrNiMoBNb 16-16 +wk (1.4986+wk).

8.4.2 Tests and examinations on finished parts

(1) In the course of inspection for dimensional accuracy the main and secondary features shall be examined to **Table 8-2.** The extent of random examination and the acceptance levels shall be subject to the stipulations in **Table 8-3**. Subject to agreement of the authorized inspector, it is permitted to supplement or replace the secondary features cited in **Table 8-2** by application-specific requirements.

(2) The marking shall be checked at random. The extent of random checking shall be subject to the stipulations in **Table 8-3**.

(3) Bolts and nuts of alloyed steels shall randomly subjected to a materials identification check. The extent of random checking shall be subject to the stipulations in **Table 8-4.** The acceptance level shall be zero, regardless of the extent of random checking.

(4) The Sections 11.1 and 11.9.2.2 shall apply to the non-destructive tests and examinations.

Main features
Thread limit dimensions (trueness to gauge size)
Force-application areas for assembly
Transition under the bolt head
Thread root radius at the thread-to-shank transition
Secondary features
Lengths (bolt length, thread length)
Deviations from shape and location
Bearing surfaces
Heights (head heights, nut heights)
Diameters
Note: *Further features as well as their classification can be defined in the purchase order.*

Table 8-2: Features to be inspected during dimensional check as well as their classification as main or secondary features

Number of pieces in the test unit	Extent of random checking				Acceptance levels		
	Dimensional check for main features and check of identification marking		Dimensional check for secondary features and surface inspection		Dimensional check for main features	Dimensional check for secondary features and surface inspection	Check of identification marking
	Bolts	Nuts	Bolts	Nuts			
up to 150	32	20	20	13	0	0	0
151 up to 280	32	20	80	50	0	1	0

Table 8-3: Extent of random checking and acceptance levels for the dimensional check, surface inspection and check of identification marking

Number of pieces in the test unit	Extent of random checking [1)]
up to 150	20
151 up to 280	32
281 up to 500	50
501 up to 1200	80
1201 up to 3200	125
3201 up to 10000	200
[1)] The acceptance level is always zero, regardless of the extent of random checking.	

Table 8-4: Extent of random materials identification checking on bolts and nuts

8.5 Bolts and nuts made by machining from solution-annealed and quenched austenitic bars

8.5.1 Tests and examinations on the bars

8.5.1.1 Sampling and specimen preparation

(1) Longitudinal specimens shall be taken.

(2) The axis of the tensile-test and notched-bar impact-test specimens shall be located at the center for sizes with diameters smaller than or equal to 25 mm and at least 12.5 mm under the surface for sizes with diameters larger than 25 mm.

8.5.1.2 Test units

The bars shall be tested in test units of at most 500 kg, consisting of bars of the same dimension, same heat and same heat-treatment lot.

8.5.1.3 Extent of tests and examinations

(1) One ladle analysis shall be performed per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test on one bar per test unit.
b) One tensile test at 350 °C on bars for fabrication of bolts of test group A 1, if the design temperature for test group A 1 is higher than 200 °C.
c) One notched-bar impact bend test to clause 4.4.6.5 at room-temperature for bars with diameters equal to or larger than 14 mm on the same bar that was subjected to the tensile test.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 shall be performed per heat and heat-treatment lot.

(4) Each bar shall be subjected to visual inspection.

(5) The marking on each bar shall be inspected.

(6) Each bar shall be inspected for dimensional accuracy.

(7) Each bar shall be subjected to a materials identification check.

(8) The Sections 11.1 and 11.9.3.1 shall apply to the non-destructive tests and examinations.

8.5.2 Tests and examinations on finished parts

(1) In the course of inspection for dimensional accuracy the main and secondary features shall be examined per **Table 8-2**. The extent of random examination and the acceptance levels shall be subject to the stipulations in **Table 8-3.** Subject to agreement of the authorized inspector, it is permitted to supplement or replace the secondary features cited in **Table 8-2** by application-specific requirements.

(2) The marking shall be checked at random. The extent of random checking shall be subject to the stipulations in **Table 8-3**.

(3) Bolts and nuts shall be randomly subjected to a materials identification check. The extent of random checking shall be subject to the stipulations in **Table 8-4**. The acceptance level shall be zero, regardless of the extent of random checking.

(4) The Sections 11.1 and 11.9.3.2 shall apply to the non-destructive tests and examinations.

8.6 Bolts and nuts made by hot or cold forming and then quenched and tempered

8.6.1 Tests and examinations

8.6.1.1 Tests and examinations on the bars

(1) One ladle analysis shall be performed per heat.

(2) Each bar shall be subjected to visual inspection.

(3) Each bar shall be subjected to a materials identification check.

(4) The marking on each bar shall be inspected.

8.6.1.2 Tests and examinations on finished parts

The tests and examinations shall be performed on bolts and nuts of the production lot. If this is not possible because of the dimensions of the bolts and nuts, specimens for tensile and notched-bar impact bend tests shall be taken from bar segments that have been turned down to the heat-treatment diameter governing the heat treatment of the formed bolts and nuts and that have been heat-treated together with these bolts and nuts. In this case the stipulations of clause 8.4.1.1 shall apply to the sampling location.

8.6.1.3 Test units

(1) The test shall be performed after the final heat treatment on test units consisting of parts of similar dimension and originating from the same heat and same heat-treatment lot.

(2) The number of pieces to be tested shall depend on the number of pieces in the test unit and on the test method. The stipulations in **Table 8-5** shall apply.

8.6.1.4 Extent of tests and examinations

(1) The mechanical and technological characteristics shall be determined by performing:

a) Hardness testing of the bolts and nuts of a test unit per **Table 8-5** (DIN EN ISO 6506-1). If traveller bar segments were quenched and tempered for the tests to (3) and (4), the hardness shall also be determined on these bar segments.
b) One room-temperature tensile test on turned-down specimens to DIN EN ISO 898-1 or, in the case of testing of quenched and tempered traveller bar segments, on specimens to DIN 50 125. The piece for which the smallest value of hardness was determined in the hardness test shall also be subjected to this tensile test.

c) One notched-bar impact bend test to clause 4.4.6.5 at room-temperature to determine the impact energy, for bolts larger than M 19 per **Table 8-5**; for bolts larger than M 24, the lateral expansion shall additionally be determined. The piece for which the largest value of hardness was determined in the hardness test shall also be subjected to this notched-bar impact bend test.

(2) A drift test to DIN EN ISO 10484 shall be performed on nuts per **Table 8-5**. The piece for which the largest value of hardness was determined shall also be subjected to this drift test.

(3) The Sections 11.1 and 11.9.4 shall apply to the non-destructive tests and examinations.

(4) In the dimensional check, the main and secondary features shall be examined to **Table 8-2**. The extent of random checking and the acceptance levels shall be subject to the stipulation in **Table 8-3**. Subject to agreement of the authorized inspector, it is permitted to supplement or replace the secondary features cited in **Table 8-2** by application-specific requirements.

(5) The marking shall be checked at random. The extent of random checking shall be subject to the stipulations in **Table 8-3.**

(6) Bolts and nuts of alloyed steels shall be randomly subjected to a materials identification check. The extent of random checking shall be subject to the stipulations in **Table 8-4.** The acceptance level shall be zero, regardless of the extent of random checking.

Hardness test		Tensile test Notched-bar impact bend test Drift test	
Number of pieces per test unit	Number of pieces to be tested	Number of pieces per test unit	Number of pieces to be tested
up to 150	8	up to 300	1
151 up to 280	13		
281 up to 500	20	301 up to 800	2
501 up to 1200	32		
1201 up to 3200	50	more than 800	4
3201 up to 10000	80		

Table 8-5: Number of pieces to be subjected to the mechanical and technological tests of bolts and nuts to Section 8.6

8.7 Bolts and nuts of strength classes or steel grades

8.7.1 Tests and examinations

8.7.1.1 Sampling and specimen preparation

(1) The tests and examinations shall normally be performed on bolts and nuts of the production lot.

(2) If this is not possible because of the dimensions of the bolts:

a) specimens for tensile and notched-bar impact bend tests in the case of ferritic steels shall be taken from bar segments that have been turned down to the heat-treatment diameter governing the quenching and tempering of the formed bolts and that have been heat-treated together with these bolts. In this case the stipulations of clause 8.4.1.1 shall apply for the sampling location, and

b) bolts of correspondingly greater length shall be made for the tensile tests of each test unit in the case of austenitic steels.

8.7.1.2 Test units

The test shall be performed after the final heat treatment on test units consisting of parts of similar dimension and the same heat, originating from the same heat-treatment lot. The number of pieces to be tested shall depend on the number of pieces in the test unit. The stipulations in **Table 8-6** shall apply.

8.7.1.3 Extent of tests and examinations

(1) Bolts of ferritic steels shall be tested to DIN EN ISO 898-1 as follows:

a) test series FF1 (Table 8 in DIN EN ISO 898-1) in the case of bolts equal to or smaller than M14 or

b) test series MP1 (Table 12 in DIN EN ISO 898-1) including notched bar impact bend test in the case of bolts greater than M14.

The following requirements shall apply to the impact energy with only one individual value may fall short of the required minimum value by not more than 30 %:

strength class 5.6: not less than 40 J

strength class 8.8: not less than 52 J.

(2) For bolts of ferritic steels of strength class 8.8 for allowable operating temperatures higher than 50 °C, the elevated-temperature yield point shall be verified at design temperature on specimens to DIN 50 125.

(3) Nuts of ferritic steels shall be tested to DIN EN ISO 898-2 in combination with DIN EN ISO 6157-2.

(4) Bolts and nuts of austenitic steels shall be tested to DIN EN ISO 3506-1 and DIN EN ISO 3506-2.

(5) The Sections 11.1 and 11.9.5 shall apply to the non-destructive tests and examinations.

(6) Bolts and nuts shall be subjected to a dimensional check.

a) In the case of austenitic steels in test groups A 1 and A 2 the main and secondary features of **Table 8-2** shall be examined. Subject to agreement of the authorized inspector, it is permitted to supplement or replace the secondary features cited in **Table 8-2** by application-specific requirements. The stipulations in **Table 8-3** apply to the number of pieces to be inspected and the acceptance levels.

b) The requirements of AD 2000-Merkblatt W 7 shall apply in the case of ferritic steels and the requirements of AD 2000-Merkblatt W 2 in the case of austenitic steels in test group A 3.

8.8 Marking

8.8.1 Marking of the bars

(1) The marking shall be applied on labels for bars with diameters equal to or smaller than 25 mm and on the bars themselves for bars with diameters larger than 25 mm.

(2) The marking shall contain the following information:

a) manufacturer's symbol,
b) steel grade,
c) heat number, if necessary abbreviation and
d) authorized inspector's mark.

8.8.2 Marking of the bolts and nuts

The marking shall contain the following information:

a) manufacturer's symbol,
b) steel grade or strength class,
c) the heat number for dimensions larger than M 52, if necessary an abbreviation for nuts,
d) the authorized inspector's mark for bolts larger than M 52,
e) a mark of correlation to the inspection certificate for bolts larger than M 24, except for bolts of steels to Section 8.7.

8.9 Verification of quality characteristics.

(1**)** The stipulations in **Table 8-7** shall govern verification of the quality characteristics of parts as per Sections 8.4, 8.5 and 8.6.

(2**)** The stipulations in **Table 8-8** shall govern verification of the quality characteristics of bolts and nuts as per Section 8.7.

Number of pieces per test unit (test lot)	Number of pieces to be tested (extent of random checking)
up to 200	1
201 up to 400	2
401 up to 800	3
801 up to 1200	4
1201 up to 1600	5
1601 up to 3000	6
3001 up to 3500	7
If the bolts and nuts of one delivery originate from one heat with the same heat treatment, it will suffice to test 4 specimen sets regardless of the number of pieces.	

Table 8-6: Number of pieces to be subjected to the mechanical and technological tests of bolts and nuts to Section 8.7

Test	Type of required certificate to DIN EN 10204						
	Bars to Section 8.4 and 8.5 for		Finished parts to Section 8.4 and 8.5		Bars for parts to	Finished parts to Section 8.6	
	Bolts	Nuts	Bolts [1)]	Nuts [1)]	Section 8.6	Bolts [1)]	Nuts [1)]
Ladle analysis	3.1	3.1	—	—	3.1	3.1	3.1
Hardness test	3.1	3.1	—	—	—	3.1	3.1
Strength test	3.2	3.1	—	—	—	3.2	3.1
Notched-bar impact toughness test	3.2	3.1	—	—	—	3.2	—
Drift test	—	—	—	—	—	—	3.1
Non-destructive examination	3.2	3.2	3.2	3.1	—	3.2	3.1
Resistance to intergranular corrosion [2)]	3.1	3.1	—	—	3.1	—	—
Visual inspection	3.2	3.1	—	—	—	—	—
Dimensional check	3.1	3.1	3.2	3.1	—	3.2	3.1
Inspection of the marking	3.2	3.1	3.2	3.1	3.1	3.2	3.1
Materials identification check	3.1	3.1	3.1	3.1	3.1	3.1	3.1
[1)] Certificates for the tests on the bars are additionally necessary. [2)] For products to Section 8.5.							

Table 8-7: Review of required tests and test certificates for products to Sections 8.4, 8.5 and 8.6

Steel grades	Product	Strength class	Certificate to DIN EN 10204
Unalloyed and alloyed ferritic steels	Bolts	5.6	3.1 [1]
		8.8	3.2 [2]
	Nuts	5 and 8	3.1 [1]
Austenitic steels of steel grades A 2, A 3, A 4 and A 5	Bolts and nuts	50 and 70	3.1 [3]

[1] The requirement of filling out an inspection certificate 3.1 to DIN EN 10204 may be waived if the manufacturer has constantly carried out the tests necessary as basis for filling out an inspection certificate 3.1 and has kept the results ready for review by the authorized inspector at all times. In this case the marking to Section 8.8 will suffice as the quality verification.

[2] For pressure vessels for which the product of capacity [l] in liters and pressure [p] in MPa is less than or equal to 500 ($l \times p \leq 500$) an inspection certificate 3.1 to DIN EN 10204 will suffice.

[3] In test group A 3 the requirement of filling out an inspection certificate 3.1 to DIN EN 10204 may be waived if the manufacturer has constantly carried out the tests necessary as basis for filling out an inspection certificate 3.1 and has kept the results ready for review by the authorized inspector at all times. In this case the marking to Section 8.8 will suffice as quality verification.

Table 8-8: Review of required inspection certificates for bolts and nuts to Section 8.7

9 Product forms of steels for special loads

9.1 Forgings, bars and rolled rings

9.1.1 Materials

The following steel grades may be used:

a) X3CrNiMo13-4 (1.4313) to VdTÜV material sheet 395/3,

b) other steel grades meeting the prerequisites of Section 3 and subsection 4.3.4 in in consideration of the stipulations in the authorized inspector's appraisal.

9.1.2 Additional requirements for the materials

The surfaces shall be free of ferritic impurities which are relevant for the corrosions resistance of the product form. Scale layers from hot forming or heat treatment shall be removed. Tempering colours from hot forming or heat treatment shall be avoided by taking appropriate measures. Decision on the permissibility of tempering colours up to and including “yellow” shall be made in each individual case.

9.1.3 Tests and examinations

9.1.3.1 Sampling locations and specimen preparation

The requirements of VdTÜV material sheet 395/3 apply to the sampling location and specimen preparation. Deviating here from the lot size for pieces with partial-weights not exceeding 1000 kg is limited to 25 pieces from the same heat treatment lot.

9.1.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis at one sampling location on each of two separately manufactured pieces per heat. If possible, the top or bottom of the starting ingot shall be tested. For pieces heavier than 5000 kg, the analysis shall be perormed on one sampling location of each piece. If possible, the top or bottom of the starting ingot shall be tested.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per test unit on 2 parts.

b) One tensile test at 350 °C per heat, similar dimension and heat-treatment lot, if the design temperature is higher than 100 °C. For piece weights heavier than 3000 kg in test group A 1, each piece shall be tested.

c) One notched-bar impact bend test to clause 4.4.6.5 at room temperature per test unit on 2 parts in the case of thicknesses exceeding 10 mm.

d) One hardness test (at least 3 hardness indentations) to DIN EN ISO 6506-1 on each piece.

(3) The Sections 11.1 and 11.10.1 shall apply to the non-destructive tests and examinations.

(4) Each piece shall be subjected to a materials identification check.

(5) Each piece shall be subjected to a visual inspection.

(6) A dimensional check shall be performed for each piece.

9.1.4 Marking

(1) Each piece shall be marked durably with the following information:

a) manufacturer's symbol,

b) steel grade,

c) heat number,

d) specimen number and

e) authorized inspector's mark.

(2) In the case of lotwise examination, the pieces from which the specimens were taken shall additionally be marked.

9.1.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check, hardness test and non-destructive tests and examinations performed by the manufacturer shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process and the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

9.2 Castings

9.2.1 Materials

(1) The following cast-steel grades may be used:

a) G-X4 CrNi 13 4 (1.4317) to VdTÜV material sheet 452 and meeting the additional requirements according to Annex A 7

b) other steel grades meeting the prerequisites of Section 3 and subsection 4.3.4 in combination with the stipulations in the authorized inspector's appraisal.

(2) The stipulations of clause 4.3.4 shall be met.

9.2.2 General casting finish

(1) As regards their general internal and external finish, the castings shall satisfy the stipulations of **Table 11-6** applicable to their test group.

(2) Feeder heads and large casting-related thickenings that impair amenability of the casting to the heat treatment shall be eliminated before the heat treatment for establishment of the mechanical and technological characteristics.

(3) The casting technique shall be designed according to the principles of controlled solidification. For castings with nominal widths equal to or larger than 200 mm, the gate and feeder technique shall be explained on the basis of the saturation calculation as well as drawings illustrating the position of the feeders, feed zones and specimen location. For each casting model, the description of the casting technique shall be attached to the interim file (internal manufacturer documenation) for retention by the manufacturer.

Note:

The feature characterizing the dimensions of the body or case shall be the nominal width, as follows:

a) for pumps, the nominal width of the pressure nozzle,

b) for valves, the largest nominal width involved,

c) for safety valves, the nominal width of the inlet nozzle.

(4) Together with the drawing of the casting in the as-delivered condition, the following documents shall generally be submitted as standard plans for the design approval:

a) test and inspection sequence plan and heat-treatment plan, in case of differences from the standard production scheme to **Figure 5.7-1**,

b) for castings of test group A 1 with nominal widths larger than 200 mm, instructions for the non-destructive examinations as well as a coordinate reference system (reference-point grid),

c) for prototypes of test groups A 2 and A 3 with nominal widths greater than 200 mm a film location plan and a radiation source plan,

d) welding procedure qualification and welding procedure sheet for production welds and if applicable construction welds (see **Annex B**).

e) test and inspection sequence plan for construction welds, if necessary.

f) list of planned production control tests.

(5) Stipulations for production welds including procedure inspection and production control test are listed in **Annex B**.

(6) If changes are made compared with the conditions stipulated in the welding procedure sheet, or if a different welding method is chosen, the welding procedure sheet shall be resubmitted for design approval in this respect.

9.2.3 Tests and examinations

9.2.3.1 Sampling and specimen preparation

(1) Castings with a delivery weight equal to or lighter than 500 kg shall be tested in lots, and castings with a delivery weight heavier than 500 kg shall be tested individually.

(2) The number of sampling locations shall be as indicated in **Table 5.7-1**.

(3) The specimens shall be taken from cast-on test blocks according to DIN EN 1559-2 or from overlengths. Separately cast test blocks are permitted only for castings with piece weights equal to or lighter than 150 kg.

(4) The test blocks shall be provided in sufficient number and size that the prescribed specimens can be taken.

(5) The thickness of the cast-on test blocks shall correspond to the governing wall thickness. In this connection, the governing nominal wall thickness shall be the thickness of the wall subjected to pressure loading, and not the thickness of cast-on flanges or local thickenings.

(6) Cast-on test blocks at the gate system are not permitted.

(7) For castings with piece weights heavier than 1000 kg, the position of the cast-on test blocks on the casting shall be documented by a photograph or in a sketch.

(8) For simulation-heat treated specimens and travelling specimens the requirements of VdTÜV material sheet 452, cl. 10.7.1 shall apply.

9.2.3.2 Extent of tests and examinations

(1) The following procedures shall be performed for the chemical analysis:

a) One ladle analysis per heat.

b) One product analysis for one sampling location per test unit.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per sampling location.

b) One tensile test at 350 °C per heat, dimension and heat-treatment lot, if the design temperature is higher than 100 °C.

c) One notched-bar impact bend test to clause 4.4.6.5 at room-temperature per sampling location.

d) One hardness test on each piece to verify uniformity of the quenching and tempering treatment in the case of lotwise examination of castings of quenched and tempered steel.

(3) The Sections 11.1 and 11.10.2 shall apply to the non-destructive tests and examinations.

(4) Each casting shall be subjected to a materials identification check.

(5) Each casting shall be subjected in the as-delivered condition to a visual inspection.

(6) Each casting shall be subjected in the as-delivered condition to a dimensional check.

(7) Each casting shall be subjected in a condition suitable for the purpose, generally by the further processor, to a tightness test in the form of an internal pressure test, which shall be performed to DIN 50104. Pressurizing fluid, test pressure and pressure-loading duration shall be indicated in the purchase order. The test pressure has to be limited to ensure that a safety margin against the yield point or 0.2 % proof stress at room temperature of at least 1.1 is achieved.

9.2.4 Marking

(1) Each casting shall be marked with the following information:

a) manufacturer's symbol,

b) cast-steel grade,

c) heat number,

d) specimen number and

e) authorized inspector's mark.

9.2.5 Verification of quality characteristics

(1) The results of the ladle analysis, product analysis, materials identification check and non-destructive tests and examinations performed by the manufacturer as well as hardness test, if any, shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process and the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check, tightness test and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer. For castings with piece weights heavier than 1000 kg, a photograph or a sketch of the location of the cast-on test blocks on the casting shall be attached to the inspection certificate.

10 Heat-exchanger tubes

10.1 Seamless straight heat-exchanger tubes of ferritic steels with wall thicknesses smaller than or equal to 4 mm and with outside diameters smaller than or equal to 38 mm

10.1.1 Materials

(1) The following steel grades may be used:

a) P235GH (1.0345) to DIN EN 10216-2,

b) 16Mo3 (1.5415) to DIN EN 10216-2,

c) 13CrMo4-5 (1.7335) to DIN EN 10216-2,

d) 10CrMo9-10 (1.7380) to DIN EN 10216-2 and

e) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

10.1.2 Tests and examinations

10.1.2.1 Sampling and specimen preparation

Specimens shall be taken in compliance with DIN EN 10216-2.

10.1.2.2 Extent of tests and examinations

Note:

The extent of tests and examinations shall apply both to tubes used as straight tubes and to tubes that will subsequently be bent.

(1) One ladle analysis shall be performed per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) For each production run, two tensile tests at room-temperature for each of the first two test units to DIN EN 10216-2 and one tensile test at room-temperature for each further test unit to DIN EN 10216-2 at one end of one manufacturing length.

b) One technological test to DIN EN 10216-2 at one end of each manufacturing length for heat-exchanger tubes of test group A 1. For heat-exchanger tubes of test groups A 2 and A 3, 20 % of every 100 manufacturing lengths of the same heat, dimension and heat treatment shall be subjected to a technological test to DIN EN 10216-2 at one end.

(3) The Sections 11.1 and 11.11.1.1 shall apply to the non-destructive tests and examinations.

(4) Each tube shall be subjected to a materials identification check.

(5) The inside and outside surfaces of each tube shall be subjected to a visual inspection.

(6) The diameter and wall thickness shall be checked for dimensional accuracy at both ends of each tube.

(7) Each tube shall be examined for leak tightness by an internal hydrostatic pressure test to DIN EN 10216-2. If the tube is bent, the tightness test shall be performed on the bent tube. In this case the tightness test on the straight tube is not required.

10.1.3 Marking

(1) Lists of tubes shall be maintained for tubes scheduled for bending. In this case the tubes shall be marked with heat number and tube number at one end. Other tubes may be marked in the same way if lists of tubes are maintained. The authorized inspector's mark shall be entered in the list of tubes.

(2) If lists of tubes are not maintained, the tubes shall be marked at one end with the following information:

a) manufacturer's symbol,

b) steel grade,

c) heat number,

d) tube number,

e) authorized inspector's mark.

10.1.4 Verification of quality characteristics

(1) The results of the ladle analysis, materials identification check, leak tightness test and non-destructive tests and examinations shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process and the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions as well as simulated stress-relief annealing temperature and holding time of test coupons, if any, shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) For heat-exchanger tubes of test group A 3 made of unalloyed steels an inspection certificate 3.1 to DIN EN 10204 will suffice.

10.2 Seamless bent heat-exchanger tubes of ferritic steels with wall thicknesses smaller than or equal to 4 mm and with outside diameters smaller than or equal to 38 mm

10.2.1 Materials

Section 10.1.1 shall apply to the materials.

10.2.2 Starting tubes

Only tubes per Section 10.1 may be used. Lists of tubes per clause 10.1.3 (1) shall be maintained for the tubes.

10.2.2.1 Production methods

(1) The bends shall be made by cold bending.

(2) Smooth transition from the tube leg to the tube elbow shall be demonstrated on a specimen bent prior to beginning bending work.

(3) For the case of partial heat treatment of the bent zone, the quality of the transition zone shall be verified by a one-time appraisal of the authorized inspector.

10.2.2.2 Requirements for the geometric form of bent tubes

(1) Bulge-like transitions as well as any kind of wrinkles are not permitted.

(2) The maximum allowable ovality shall be $0.10 \times D_i$, where D_i is the tube inside diameter (nominal diameter).

(3) A ball of diameter $D_K = D_i -$ (largest permissible negative tolerance on size $+ 0.1\ D_i + 2$ mm) shall pass through freely.

10.2.2.3 Heat treatment

(1) Heat treatment is not required after cold bending of tubes with bend radius r_m equal to or larger than $1.3 \times D_a$.

(2) Heat treatment of the bent zone or of the entire tube to the instructions of DIN EN 10216-2 for annealing after cold processing shall be performed after cold bending of tubes with a bend radius r_m smaller than $1.3 \times D_a$.

10.2.3 Tests and examinations

10.2.3.1 Heat-treatment condition of specimens

Verification of the mechanical and technological characteristics shall be required only if the entire tube was heat-treated after bending. In this case the test coupons shall be taken from the product after the last heat treatment.

10.2.3.2 Sampling and specimen preparation

Test coupons shall be taken from the ends of tube legs.

10.2.3.3 Extent of tests and examinations

(1) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test at one end of one tube per 100 bent tubes of the same heat, dimension and heat treatment for heat-treated tubes.
b) One technological test to DIN EN 10216-2 at both ends of one tube per 100 bent tubes of the same heat, dimension and heat treatment for heat-treated tubes.

(2) Each bent tube shall be subjected to a materials identification check.

(3) The outside surface and, wherever it is accessible, the inside surface of each bent tube shall be subjected to a visual inspection.

(4) The Sections 11.1 and 11.11.1.2 shall apply to the non-destructive tests and examinations.

(5) The diameter and wall thickness shall be checked for dimensional accuracy at both ends of each bent tube. In addition, the ovality, arc shape and leg length as well as the wall thickness shall be checked for dimensional accuracy on two cut-open elbows from the series of tubes with the smallest bend radius.

(6) Each bent tube shall be examined for leak tightness by an internal hydrostatic pressure test to DIN EN 10216-2.

(7) The ball-pass test shall be performed on each bent tube.

10.2.4 Marking

Lists of tubes shall be maintained for bent tubes. Each bent tube shall be marked with heat number and tube number at one end. The authorized inspector's mark shall be entered in the list of tubes.

10.2.5 Verification of quality characteristics

(1) The results of the materials identification check, tightness test and ball-pass test shall be documented with an inspection test certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) For bent tubes of test group A 3 made of unalloyed steels an inspection certificate 3.1 to DIN EN 10204 will suffice.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate of the bent tube.

10.3 Seamless straight heat-exchanger tubes of austenitic steels with wall thicknesses smaller than or equal to 3.6 mm and with diameters smaller than or equal to 42.4 mm

10.3.1 Materials

(1) The following steel grades may be used:

a) X6CrNiTi18-10 (1.4541) to DIN EN 10216-5,
b) X6CrNiNb18-10 (1.4550) to DIN EN 10216-5,
c) X6CrNiMoTi17-12-2 (1.4571) to DIN EN 10216-5,
d) X6CrNiMoNb17-12-2 (1.4580) to DIN EN 10216-5 and
e) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

10.3.2 Tests and examinations

10.3.2.1 Sampling and specimen preparation

Specimens shall be taken in compliance with DIN EN 10216-5.

10.3.2.2 Extent of tests and examinations

Note:
The extent of tests and examinations shall apply both to tubes used as straight tubes and to tubes that will subsequently be bent.

(1) One ladle analysis shall be performed per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per 100 manufacturing lengths of the same heat, dimension and heat treatment.

b) One technological test to DIN EN 10216-5 at one end of each manufacturing length for tubes of test group A 1. The extent of testing shall be reduced to 25 % of the tubes for test group A 2 and to 2 % of the tubes for test group A 3.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat and heat treatment.

(4) The Sections 11.1 and 11.11.1.1 shall apply to the non-destructive tests and examinations.

(5) Each tube shall be subjected to a materials identification check.

(6) The inside and outside surfaces of each tube shall be subjected to a visual inspection.

(7) The diameter and wall thickness shall be checked for dimensional accuracy at both ends of each tube.

(8) Each tube shall be examined for leak tightness by an internal hydrostatic pressure test to DIN EN 10216-5. If the tube is bent, the tightness test shall be performed on the bent tube. In this case the tightness test on the straight tube is not required.

10.3.3 Marking

(1) Lists of tubes shall be maintained for tubes scheduled for bending. In this case the tubes shall be marked with heat number and tube number at one end. Other tubes may be marked in the same way if lists of tubes are maintained. The authorized inspector's mark shall be entered in the list of tubes.

(2) If lists of tubes are not maintained, the tubes shall be marked with the following information:

a) manufacturer's symbol,
b) number of the DIN standard and short name or material number with mark of the delivery condition,
c) heat number,
d) tube number,
e) authorized inspector's mark.

10.3.4 Verification of quality characteristics

(1) The results of the ladle analysis, materials identification check, tightness test, test for resistance to intergranular corrosion and non-destructive examinations shall be documented with an inspection certificate 3.1 to DIN EN 10204. The steel making process and the delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) For tubes of test groups A 1 and A 2 the results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) For tubes of test group A 3 the results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be documented with inspection certificate 3.1 to DIN EN 10204.

10.4 Seamless bent heat-exchanger tubes of austenitic steels with wall thicknesses smaller than or equal to 3.6 mm and with diameters smaller than or equal to 42.4 mm

10.4.1 Materials

Section 10.3.1 shall apply to the materials.

10.4.2 Starting tubes

Only tubes to Section 10.3 may be used. Lists of tubes shall be maintained for the tubes.

10.4.2.1 Production methods

(1) The bends shall be made by cold bending.

(2) Smooth transition from the tube leg to the tube elbow shall be demonstrated on a specimen bent prior to beginning bending work.

(3) For the case of partial heat treatment of the bent zone, the quality of the transition zone shall be verified by a one-time appraisal of the authorized inspector.

10.4.2.2 Requirements for the geometric form of bent tubes

(1) Bulge-like transitions as well as any kind of wrinkles are not permitted.

(2) The maximum permissible ovality shall be $0.10 \times D_i$, where D_i is the tube inside diameter (nominal diameter).

(3) A ball of diameter $D_K = D_i -$ (largest permissible negative tolerance on size $+ 0.1\ D_i + 2$ mm) shall pass through freely.

10.4.2.3 Heat treatment

(1) Heat treatment is not required after cold bending of tubes with bend radius r_m larger than or equal to $1.3 \times D_a$.

(2) The bent zone or the entire tube shall be subjected to solution annealing or to annealing in the temperature range of stabilization annealing after cold bending of tubes with a bend radius r_m smaller than $1.3 \times D_a$.

10.4.3 Tests and examinations

10.4.3.1 Heat-treatment condition of specimens

Verification of the mechanical and technological characteristics shall be required only if the entire tube was heat-treated after bending. In this case the test coupons shall be taken from the product form after the heat treatment (solution annealing and quenching).

10.4.3.2 Sampling and specimen preparation

Test coupons shall be taken from the ends of tube legs.

10.4.3.3 Extent of tests and examinations

(1) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per 100 bent tubes of the same heat, dimension and heat treatment for heat-treated tubes.

b) One technological test to DIN EN 10216-5 at the end of both legs of one tube per 100 tubes of the same heat, dimension and heat treatment for heat-treated tubes.

(2) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat and heat treatment.

(3) Each bent tube shall be subjected to a materials identification check.

(4) The outside surface and, wherever it is accessible, the inside surface of each bent tube shall be subjected to a visual inspection.

(5) The Sections 11.1 and 11.11.1.2 shall apply to the non-destructive tests and examinations.

(6) The diameter and wall thickness shall be checked for dimensional accuracy at both ends of each bent tube. In addition, the ovality, bend shape and leg length shall be checked for dimensional accuracy and the wall thickness shall be measured on two cut-open elbows from the series of tubes with the smallest bend radius.

(7) Each bent tube shall be examined for leak tightness by an internal hydrostatic pressure test to DIN EN 10216-5.

(8) One ball-pass test shall be performed on each bent tube.

10.4.4 Marking

The bent tubes shall be marked with heat number and tube number at one end. The authorized inspector's mark shall be entered in the list of tubes.

10.4.5 Verification of quality characteristics

(1) The results of the materials identification check, tightness test, ball-pass test and test for resistance to intergranular corrosion shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) For bent tubes of test group A 3 an inspection certificate 3.1 to DIN EN 10204 will suffice.

(4) The inspection certificate of the starting product shall be attached to the inspection certificate of the bent tube.

10.5 Longitudinally welded straight heat-exchanger tubes of austenitic steels with wall thicknesses smaller than 2 mm and with diameters D_a smaller than or equal to 38 mm

10.5.1 Materials

(1) The following steel grades may be used:

a) X6CrNiTi18-10 (1.4541) to DIN EN 10217-7,

b) X6CrNiMoTi17-12-2 (1.4571) to DIN EN 10217-7 and

c) other steel grades meeting the prerequisites of Section 3 in combination with the stipulations in the authorized inspector's appraisal.

10.5.2 Additional requirements

(1) Only tubes drawn and sunsequently heat-treated after welding are permitted.

(2) The requirements of surface finish and dimensional tolerances shall be determined per purchaser's specifications, but shall be at least as follows:

a) surface finish WCR to DIN EN 10217-7,

b) thickness tolerances: ISO tolerance, class T_3 to DIN EN ISO 1127 and

c) the allowable deviation of outside diameter and ovality as per ISO tolerance, class D_2.

10.5.3 Tests and examinations

10.5.3.1 Sampling and specimen preparation

(1) The tubes shall be tested in manufacturing lengths.

(2) Specimens shall be taken from the ends of manufacturing lengths.

10.5.3.2 Extent of tests and examinations

(1) The chemical composition shall be determined by performing one ladle analysis of the starting material per heat.

(2) The mechanical and technological characteristics shall be determined by performing:

a) One room-temperature tensile test per 100 manufacturing lengths of the same heat, dimension and heat treatment.

b) One flattening test at both ends of each manufacturing length.

(3) One test for resistance to intergranular corrosion to DIN EN ISO 3651-2 with prior annealing (1/2 h at 650 °C) shall be performed per heat and heat treatment.

(4) The Sections 11.1 and 11.11.1.1 shall apply to the non-destructive tests and examinations.

(5) Each tube shall be subjected to a materials identification check.

(6) The outside and inside surfaces of each tube shall be subjected to a visual inspection.

(7) The diameter and wall thickness shall be checked for dimensional accuracy at both ends of each tube.

(8) Each tube shall be examined for leak tightness by an internal hydrostatic pressure test to DIN EN 10217-7.

10.5.4 Marking

(1) If lists of tubes are not maintained, the tubes shall be marked at one end with the following information:

a) manufacturer's symbol,

b) number of the DIN standard and short name or material number with mark of the delivery condition,

c) heat number,

d) tube number,

e) test category to DIN EN 10217-7

f) authorized inspector's mark.

10.5.5 Verification of quality characteristics

(1) The results of the ladle analysis, materials identification check, tightness test, test for resistance to intergranular corrosion and non-destructive examinations shall be documented with an inspection certificate 3.1 to DIN EN 10204. The delivery condition of the product form stating heat treatment temperatures, holding times and cooling conditions shall be indicated in the inspection certificate 3.1.

(2) The results of mechanical and technological tests, visual inspection, dimensional check and non-destructive tests and

examinations shall be confirmed by the authorized inspector and combined with inspection certificate 3.1 as inspection certificate 3.2 to DIN EN 10204 issued by him. Alternatively, these tests shall be confirmed by the authorized inspector on an inspection certificate 3.2 established by the manufacturer.

(3) For tubes of test group A 3 an inspection certificate 3.1 to DIN EN 10204 will suffice.

11 Non-destructive tests and examinations

11.1 General requirements

11.1.1 Test instructions

(1) Test instructions shall be established by the manufacturers for non-destructive tests and examinations.

(2) Independently of the project these instructions may be established for identical test objects in standardized form.

(3) For surface inspection the manufacturer‘s own test instructions may be used independently of the project and test object.

(4) The test instructions shall contain detailed information on:

a) Assignment to the individual test objects,
b) time of testing as far as it will influence the extent and performance of testing according to the test and inspection sequence plan,
c) test requirements, test methods and test facilities/equipment, type of testing level adjustment or check of sensitivity,
d) if required, additional explanations regarding the performance of the test (e.g. drawing to scale),
e) intended substitute measures to be taken if the applicability of the requirements of this Section is restricted,
f) system of coordinates (reference system and counting direction) for a description of indications or irregularities assigned to a test object and
g) where required, supplementary data as regards the recording and evaluation of indications or irregularities (e.g. in case of substitute measures as regards the test requirements).

11.1.2 Requirements for surfaces

11.1.2.1 Radiographic testing

For radiographic testing, the surfaces shall be such that the evaluation is in no way impaired.

11.1.2.2 Surface inspection by magnetic particle, penetrant or magnetic flux leakage testing

(1) For the surface inspection by magnetic particle, penetrant or magnetic flux leakage testing, the surfaces shall be free from scale or any other contaminants. Any grooves or notches affecting the test result shall be eliminated.

(2) The arithmetical mean deviation of the assessed profile (average roughness) Ra to DIN EN ISO 4287 shall not exceed 10 µm on the areas to be examined. For the surface condition of casings the requirements laid down in clause 11.8.4 shall apply.

11.1.2.3 Ultrasonic and eddy-current testing

(1) The scanning surfaces shall be free from disturbing unevenness and contaminants (e.g. notches, scale, machining grooves).

(2) Residual notches and deviations from the specified contour due to processing or fabrication are only permitted if the detection sensitivity of testing, including periodic (in-service) inspections, is not impaired.

(3) The arithmetical mean deviation of the assessed profile (average roughness) Ra to DIN EN ISO 4287 on the areas to be examined shall not exceed 20 µm in the case of ultrasonic testing and 10 µm in the case of eddy-current testing. For the surface condition of casings the requirements laid down in clause 11.8.4 shall apply.

(4) In addition, the following shall apply to ultrasonic testing:

a) In the case of waviness of the scanning surfaces the waviness shall be so little as to provide sufficient probe shoe contact. This is generally the case if the distance between probe shoe surface and scanning surface does not exceed 0.5 mm at any point.
b) In relation to a reference surface of 40 mm x 40 mm, the deviation from the specified contour of the scanning surfaces shall not exceed 0.5 mm. When selecting other dimensions of reference surfaces, the allocated deviation from the specified contour shall be linearly converted in accordance with the side length of the reference surface selected.
c) Where the opposite surface is used as reflection surface, the same requirements as for the scanning surface apply to the reflection surface.

11.1.2.4 Proof of required surface condition

(1) It shall be proved that the requirements for the surface condition have been met.

(2) The proof of the surface condition may be omitted if it is ensured by the surface processing method used that the required surface condition has been obtained.

11.1.3 Requirements to be met by the testing personnel

(1) Non-destructive testing supervisors shall

a) have the technical knowledge required to perform their tasks and know the possibilities of application as well as limits of test procedures,
b) have basic knowledge of fabrication processes and of the characteristic appearance of fabrication irregularities.

The test supervisory personnel shall normally be independent from the fabrication department and the authorized inspector shall be notified of their names. The test supervisory personnel is responsible for the application of the test procedure, for the details of the implementation of the test and for the evaluation in accordance with the relevant specifications. They are responsible for the employment of qualified and certified operators. This applies also to the employment of personnel not belonging to the works.

(2) The test supervisory personnel shall have been qualified and certified for the testing procedures in the relevant product or industrial sectors at least with level 2 to DIN EN ISO 9712. For radiographic, ultrasonic and eddy-current testing level 3 qualification and certification is required.

(3) The NDT operators shall be capable of conducting the tests described in this safety standard. They shall have been qualified and certified at least with level 2 to DIN EN ISO 9712 for the applicable testing procedure in the relevant product or industrial sector.

11.1.4 Extent and time of testing

(1) The type, extent and time of testing are stipulated relating to product forms in Sections 11.2 to 11.11.

(2) Depending on the machining location, the non-destructive testing shall be performed by the product-form manufacturer or component manufacturer. The tests shall take

place after the last forming step and heat treatment and in general shall be performed by the product-form manufacturer. If non-destructive tests are not performed completely by the product-form manufacturer, a corresponding note shall be made in the inspection certificate.

11.1.5 Procedural requirements

11.1.5.1 Manual ultrasonic testing

(1) The general specifications laid down in **Annex D** as well as the requirements laid down in Sections 11.1.8 and 11.2 to 11.11 shall apply.

Note:
The beam angles specified in this safety standard refer to the respective probe nominal angles.

(2) Should it be impossible to maintain the boundary conditions for examination by the distance-gain-size method (DGS method) to Section D 6.2 or the DGS method cannot be applied due to the sound attenuation of the material, then the reference block method or DAC method to Section D 6.3 shall be employed.

(3) When the DGS method is employed, the recording levels given as a function of nominal wall thickness or of bar diameter in Sections 11.2 to 11.11 shall apply.

(4) When the reference block method or DAC method is employed, all indications with echo amplitudes equal to or greater than 50 % of the echo amplitude of the reference reflector shall be registered.

(5) If in manual examination the coupling cannot be checked by other means (e.g., by observing a back-wall echo), the gain shall be increased until the noise signals becomes visible.

(6) The echo amplitudes to be registered and the acceptance criteria are defined depending on the product form and its dimensions in Sections 11.2 to 11.11. Should the permissible indications be exceeded, the further actions shall be determined by agreement between product-form manufacturer and authorized inspector.

(7) The size of indications shall be determined in accordance with Section D 11.2.3 (half-amplitude method). The accuracy in measurement of the reflector extension shall then be improved by additional investigations if these dimensions alone are critical for evaluation of acceptability. Reflectors with extensions smaller than 10 mm shall qualify as point-type indications.

11.1.5.2 Surface inspections

(1) The general specifications laid down in **Annex E** as well as the requirements laid down in Sections 11.2 to 11.11 shall apply.

(2) Surface inspections of sufficiently magnetizable materials shall basically be performed by the magnetic particle method, unless specified otherwise in Sections 11.2 to 11.11.

(3) When subjecting large areas to a magnetic particle examination, the yoke magnetization method shall preferably be used. Small parts shall be examined, if practicable by means of the auxiliary or coil technique.

(4) Methods other than magnetic-particle or penetrant testing are permitted. They shall preferably be mechanized methods such as eddy-current examination or magnetic flux leakage method with probes for detection of surface defects. The acceptance criteria shall be specified in the test instruction.

11.1.5.3 Radiographic testing

The testing shall basically be performed to DIN EN ISO 5579. In addition, the following requirements shall apply:

a) The requirements of class B to DIN EN ISO 5579 shall be met. The substitute solution of Section 4 of DIN EN ISO 5579 shall not be applied in this case.
b) The image quality values of image quality class B to DIN EN ISO 19232-3 shall be adhered to in which case the image quality indicators to DIN EN ISO 19232-1 shall be used.

The stipulations of clause 11.8.6.2 shall apply to the performance of radiographic testing on castings.

11.1.5.4 Visual inspection

The inspection shall be performed locally according to DIN EN 13018.

11.1.5.5 Eddy-current testing

The stipulations of clause 11.11.2 shall apply.

11.1.5.6 Mechanized or automated testing

(1) Mechanized or automated testing systems to be employed for non-destructive testing shall undergo an appraisal by the authorized inspector.

(2) The requirements of the non-destructive testing standard applicable to the respective product form as well as the requirements under Sec. 11.2 to 11.11 shall apply provided, the tests are performed by means of mechanized or automated testing.

11.1.6 Evaluation of the test results

(1) For the evaluation of the test results obtained by the various test methods the criteria as per Sections 11.1.8 and 11.2 to 11.11 apply.

(2) The evaluation of the test results shall normally always take into consideration the measuring tolerances of the test procedure as well as the properties of the tested material or material area.

(3) If several test procedures are employed in order to detect internal or external irregularities, the final evaluation of the test object shall be effected on the basis of the test results of all test procedures.

11.1.7 Organization of non-destructive testing

11.1.7.1 Performance

(1) The manufacturer shall perform and verify all non-destructive examinations to the extent specified by this safety standard.

(2) The authorized inspector shall perform or participate in the non-destructive testing to the extent specified by this safety standard. The scope of random non-destructive testing by the authorized inspector shall be 25 % in test group A 1 and 10 % in test group A 2. In test group A 3 the testing is performed without participation of the authorized inspector.

(3) The following shall apply to the attendence of the authorized inspector in the performance of non-destructive tests:

a) Ultrasonic, eddy-current and magnetic flux leakage testing
   aa) In the case of manual testing the authorized inspector shall check the test reports established by the manufacturer. The manual tests shall be performed and be evaluated by the authorized inspector in the scope of random testing specified in (2) independently of the tests made by the manufacturer.
   ab) In the case of mechanized or automated testing the authorized inspector shall attend the sensitivity calibra-

tion of the test equipment, spot-check the performance of testing and evaluate the test results obtained.

b) Radiographic testing

The results obtained by radiography (images) to be performed by the manufacturer shall be evaluated by the authorized inspector. The performance of radiography shall be spot-checked by the authorized inspector.

c) Surface inspection (magnetic particle and penetrant testing) and visual inspection

The authorized inspector shall attend the test to be performed by the manufacturer and evaluate the result obtained.

(4) Where the test results obtained by the authorized inspector, in consideration of the scattering subject to test method variations, do not match the test results obtained by the manufacturer, additional tests shall commonly be conducted by the authorized inspector and the manufacturer.

11.1.7.2 Recording of test results

11.1.7.2.1 General

(1) The tests performed shall be recorded in test reports. The performance of tests and the test result obtained shall be confirmed by signature of the persons attending the test (manufacturer's NDT operator and - when participating - operator of the authorized inspector).

(2) Test results obtained from similar test objects for which identical test instructions have been established, may be comprised in overall records.

(3) The test report shall document indications and irregularities to be recorded in a traceable manner, stating the location, orientation and size by means of the coordinate system described in the test instruction.

(4) The test supervisor shall confirm the test result by signing it in which case this confirmation may be comprised on each test report or for several tests (e.g. on a cover sheet).

11.1.7.2.2 Manual ultrasonic and eddy-current testing

Recording shall be performed by means of individual test reports of the parties involved. The results obtained by several participants shall be evaluated (e.g. on a common cover sheet).

11.1.7.2.3 Mechanized or automated ultrasonic, eddy-current and magnetic flux leakage testing

Recording shall be performed by means of a test report established by the manufacturer. As regards the attendance at the testing level adjustment, spot-check control of the performance of the test and the test results obtained the authorized inspector shall countersign the manufacturer's report.

11.1.7.2.4 Surface inspection (magnetic particle and penetrant testing) and visual inspection

Recording shall be performed by means of a test report established by the manufacturer. As regards the attendance and the test results obtained the authorized inspector shall countersign the manufacturer's report.

11.1.7.2.5 Radiographic testing

Recording shall be performed by means of a test report established by the manufacturer. As regards the spot-check control of the performance of the test and the test results obtained the authorized inspector shall countersign the manufacturer's report.

11.1.8 Testing of weld edges and nozzles areas

Note:

Further tests prior to welding are specified in KTA 3211.3.

(1) Where weld edges and nozzles are dressed on ferritic product forms, these dressed areas shall be subjected to an ultrasonic testing prior to dressing the fusion faces.

(2) Where weld edges and nozzles are dressed on austenitic product forms, these dressed areas shall be subjected to an ultrasonic testing prior to dressing the fusion faces, if according to KTA 3211.3 Section 11 an ultrasonic testing of the inner surface of weld seams is required.

(3) For the ultrasonic testing of weld edges and nozzle areas, the following requirements apply:

a) For flat products made of ferritic steels the test to DIN EN 10160 and for flat products made of austenitic steels the test to DIN EN 10307 shall be performed. The tested areas shall meet the requirements of quality class E_4 to Table 5 of these standards.

b) For all other product forms the requirements for the testing after welding laid down in KTA 3211.3, Section 11, shall apply.

(4) In the case of wall thicknesses or sections at the point of connection equal to or greater than 30 mm a section width equal to the wall thickness plus 10 mm is considered the weld edge or nozzle area, in the case of greater wall thicknesses or sections at the point of connection, a section width equal to the wall thickness plus 20 mm adjacent to the fusion face or nozzle hole.

(5) In the case of forgings, rings and hollow parts made from austenitic steels the testability of the weld edges and nozzle areas shall be determined additionally for the conditions of weld seam testing. This shall be done, like for the testing to follow, by means of angle-beam scanning. A circumferential notch as reference reflector shall basically be provided on the test object in the area where the weld will be laid, however, at a sufficient distance to the edge. The notch shall normally not exceed a width of 1.0 mm, the reflection area shall be perpendicular to the surface. The depth of the reference reflector shall be determined in dependence of the nominal wall thickness of the finished part in accordance with **Table 11-1**.

Nominal wall thickness s, mm	$8 < s \leq 20$	$20 < s \leq 40$	$40 < s$
Notch depth, mm	1.5	2	3

Table 11-1: Depth of reference reflector for testing of weld edges end nozzle areas

Where for design reasons no oversize for the notch to be inserted on the product front face is possible, the wall thickness oversize shall be provided such that the notch at the inner surface can be completely dressed upon determination of testability. The test method shall follow the method for detecting longitudinal defects on the weld and shall be described in the test instruction. The notch shall be scanned over the full circumference. The resulting notch echo height dynamics shall be recorded by indicating the individual positions on the circumference and the dB values. Where variations exceeding 6 dB are found, the further procedure shall be agreed upon with the authorized inspector.

11.2 Flat products

(1) Each flat product with nominal thickness equal to or larger than 10 mm shall be subjected to an ultrasonic testing of the flat product body by the manufacturer.

(2) The following requirements shall apply to the testing of the flat product body:

a) quality class S_2 to DIN EN 10160 for flat products made from ferritic steels and

b) quality class S_2 to DIN EN 10307 for flat products made from austenitic steels.

11.3 Dished or pressed product forms made from flat products

The formed area of each dished or pressed product form made from flat products shall be subjected to a surface inspection in the finish-machined condition after the last heat treatment. The acceptance criteria are defined in **Tables 11-2** and **11-3**.

Indications ≤ 3 mm	Indications > 3 mm up to ≤ 6 mm			Indications > 6 mm
	Rounded indications	Linear [1] indications, caused by non-metallic inclusions [2] in the case of ferritic steels or by carbides or nitrides or carbonitrides [2] in the case of austenitic steels	Other linear [1] indications	
Permitted as isolated indications and not to be included in frequency [3]	Permitted up to 10 indications on a reference area of 100 mm · 150 mm		Not acceptable	Not acceptable

[1] In penetrant testing an indication shall be considered to have a longitudinal extension (linear indication) if its dimension in the direction of maximum extension is at least three times as large as its smallest dimension transverse to that direction.

[2] Non-metallic inclusions, carbides, nitrides and carbonitrides shall be proved to be present. This proof may be made by spot checking for several similar indications in the tested area.

[3] In the case of indications appearing systematically, the usability of the parts shall be decided jointly with the authorized inspector.

Table 11-2: Acceptance criteria for penetrant testing

Indications ≤ 1.5 mm	Indications > 1.5 mm up to ≤ 6 mm		Indications > 6 mm
	Indications caused by non-metallic inclusions [1]	Other indications	
Permitted as isolated indications and not to be included in frequency [2]	Permitted up to 10 indications on a reference area of 100 mm · 150 mm	Not acceptable	Not acceptable

[1] Non-metallic inclusions shall be proved to be present. This proof may be made by spot checking for several similar indications in the tested area.

[2] In the case of indications appearing systematically, the usability of the parts shall be decided jointly with the authorized inspector.

Table 11-3: Acceptance criteria for magnetic-particle testing

11.4 Forgings, bars and rings

11.4.1 General

(1) Each piece shall be subjected to a non-destructive testing.

(2) When performing manual ultrasonic tests, the requirements laid down in **Annex D** shall be taken into account.

(3) The tests shall be performed and evaluated on the basis of the DIN EN 10228 standard series along with the deviations and supplements made in (4) and in clauses 11.4.2 and 11.4.3.

Note:
In case of the selected ultrasonic test the "forging thicknesses t" mentioned in DIN EN 10228-4 correspond to the nominal wall thicknesses s of the final product.

(4) The surfaces of the parts to be examined shall be conditioned and cleaned such that testing is possible without restrictions. Deviating from the stipulations of the DIN EN 10228 standard series the stipulations of clauses 11.1.2.2 and 11.1.2.3 apply to the arithmetical mean deviation of the assessed profile (average roughness) Ra.

11.4.2 Surface inspection

(1) The entire surface shall be subjected to a surface inspection in the final machined condition.

(2) The magnetic particle test shall be performed and evaluated in compliance with the requirements of DIN EN 10228-1, quality class 4. In addition, the stipulations laid down in **Annex E** shall apply.

(3) The penetrant test shall be performed and evaluated in compliance with the requirements of DIN EN 10228-2, quality class 4. In addition, the stipulations laid down in **Annex E** shall apply.

(4) In addition to the requirements as per quality class 4 to DIN EN 10228-1 and DIN EN 10228-2 the following shall apply: The frequency of allowable indications shall not exceed 10 per square meter relative to the total area.

(5) For areas which are not accessible for magnetic particle or penetrant testing, the procedure shall be laid down in the test instruction.

11.4.3 Ultrasonic testing

11.4.3.1 Procedural requirements

(1) The ultrasonic testing shall be performed after the governing heat treatment for establishment of the mechanical and technological characteristics, while the materials have the minimum possible of contours.

(2) The ultrasonic testing shall basically be performed as selected ultrasonic testing. If no detailed knowledge of the

components to be fabricated from the test object is available at the time of testing, the test may be performed as global ultrasonic testing.

(3) Testing of ferritic parts shall basically be performed by 100 % scanning to DIN EN 10228-3, testing of austenitic parts by 100 % scanning to DIN EN 10228-4. The stipulations of clauses 11.4.3.3.4 and 11.4.3.3.5 shall apply to drop-forged parts and to the stock material for drop-forged parts. Testing of stock material for drop-forged parts from polygonal bars shall be performed by complete scanning to DIN EN 10308.

(4) The testing level adjustment shall either be effected using the DGS method or using the DAC or the reference block method. The method to be used shall be fixed in the test instruction.

(5) Deviating from the stipulations of the standards referenced for the performance of ultrasonic tests the test frequencies shall be equal to or greater than 2 MHz. The test frequency to be used shall be laid down in the test instruction.

(6) During ultrasonic testing the total volume shall be scanned. For the testing of sub-surface areas scanning shall be performed either from the opposite surface or a dual-element probe shall be used. The technique to be used shall be laid down in the test instruction.

(7) Where during ultrasonic testing indications up to 6 dB below recording level are ascertained these areas shall purposefully be tested again from the respective opposite direction.

(8) If, during ultrasonic testing, indications that are to be registered are found in zones that will be removed during further processing of the piece being tested, they need not be considered in the evaluation but shall be documented. All indications due to structural condition of the piece shall not be covered by the evaluation, but be indicated in the test report.

(9) If, for material-related reasons (e.g., reduction of the heat-treatment cross section), the geometry after heat treatment does not allow the entire volume to be examined with the required ultrasonic scanning directions, the zones that will subsequently have restricted examinability shall be additionally examined prior to the heat treatment, while the geometric condition is appropriately favorable.

(10) For the purpose of documenting and correcting the test conditions during ultrasonic testing the sound attenuation and transfer correction shall be determined to the extent such that a complete evaluation of the test object is possible. The location and number of measurements shall be laid down in the test instruction. In the case of product forms made of austenitic steels clause 11.4.3.2 shall be considered.

(11) Depending on the intended use, the sound beam entry positions shall be laid down in accordance with the purchaser's data, however at least the sound beam entry positions laid down in clause 11.4.3.3 shall be used. Where during ultrasonic testing with straight beam scanning in axial component direction the volume cannot be evaluated completely (sidewall influence, sound attenuation), additional tests with angle beam scanning from the lateral surface shall be made in both axial directions.

(12) Deviating from the stipulations in DIN EN 10228-3 and DIN EN 10228-4 (section 12.1 in each standard), angle-beam scanning in circumferential direction on hollow parts is required independently from the outside-to-inside diameter ratio. The incidence angle for angle-beam scanning in circumferential direction shall be between 35 and 45 degrees.

11.4.3.2 Testability of product forms made of austenitic steel

11.4.3.2.1 Determination of testability

(1) The testability shall be determined for each test object. Location and number of measurements shall be specified in the test instruction. In this case at least the following requirements shall be met.

(2) The testability shall be determined jointly by the parties involved in the test.

(3) The wave lengths used for determining the testability shall not be greater than those used for the straight and angle beam scanning that follow.

(4) For plates and discs a grid of 200 mm shall be provided. The back wall echo height shall be determined in all centre ranges of the grid and additionally at the border line of the plates and discs by means of straight-beam scanning and at intended frequency.

(5) For all other product forms a grid of 200 mm shall be provided on each test object in the area of parallel or concentric walls to determine the testability. In all centre ranges of this grid and additionally on all border lines of forgings or rolled rings the back wall echoes shall be determined by straight-beam scanning in wall thickness direction. In areas of non parallel or non-concentric walls reference reflectors shall be used (e.g. boreholes, edges or through-transmission) for this examination.

(6) The number and density of examination points required to determine the testability shall be in a reasonable relationship to the size and geometry of the test object. Here, the absolute number of measuring points may be limited to 50.

(7) Where the test has to be performed by straight-beam scanning, the sound wave attenuation in areas with a back wall echo attenuation greater than 6 dB shall also be determined by means of angle-beam scanning, e.g. by V-scanning.

(8) Areas with a high sound wave attenuation (back wall echo variation greater than 12 dB) shall be identified and be enveloped by a narrow measuring point grid in which case the absolute number of measuring points shall be increased accordingly. The maximum sound attenuation shall be recorded for each required scanning direction.

11.4.3.2.2 Unrestricted testability

If it can be proved for the area with the greatest sound attenuation that with respect to the straight and each angle beam scanning a distance of at least 6 dB between recording levels to clause 11.4.3.4.1.2 and noise level can be satisfied, the test object has unrestricted testability.

11.4.3.2.3 Restricted testability

(1) Where for one or more sound beam entry directions in a sound attenuation region the distance of at least 6 dB between recording levels to clause 11.4.3.4.1.2 and noise level cannot be maintained in a certain area, the volumetric regions with restricted testability and the corresponding degree of restriction shall be determined and be documented.

(2) If, in the course of subsequent mechanical processing, more favourable conditions with regard to ultrasonic testing are created for these regions (e.g. reduction of the wall thickness, shorter sound path travel distances, removal of the regions of restricted testability), then the ultrasonic testing of the regions in question may be carried out for the missing beaming directions in this subsequent fabrication condition. This testing may also be carried out by the subsequent manufacturer, provided the producer of the forging and the subsequent manufacturer agree. If the required testing level is achieved in the subsequent fabrication condition, these regions shall also be considered to be unrestrictedly testable.

(3) For areas of restricted testability additional examinations (e.g. fracture mechanics analyses) shall be performed which make a decision of usability possible.

11.4.3.3 Performance of testing

11.4.3.3.1 Forged or rolled bars

(1) On bars with diameters or side lengths exceeding 30 mm ultrasonic testing shall be performed to DIN EN 10228-3 or DIN EN 10228-4 in due considerations of the stipulations mentioned in (2).

Note:

For straight-beam scanning the requirements of DIN EN 10228-3 are also met by DIN EN 10308.

(2) In case of bars for parts of test group A1 the following shall be performed additionally:

a) In case of diameters or side lengths exceeding 60 mm straight-beam scanning in axial direction; where in this case no distance between recording level and noise level of at least 6 dB can be adhered to over the entire length of the bar, the test shall be performed in the cut-to-length condition or with 45° angle-beam scanning in both axial directions.

b) In case of round bars with diameters exceeding 120 mm angle-beam scanning in both circumferential directions; the incidence angle shall be 35°.

The incidence angles to a) and b) shall also be used for bars used for components with nominal widths exceeding DN 300 of test group A2.

11.4.3.3.2 Forged flat plates, disks and cylindrical hollow parts as well as forged or rolled rings

(1) Ultrasonic testing shall be performed to DIN EN 10228-3 or DIN EN 10228-4 with the requirements for types 2 and 3 in due consideration of the stipulations hereafter.

(2) Hollow parts and rings of test group A1 as well as hollow parts and rings with diameters exceeding DN 300 of test group A2 shall additionally be tested by straight-beam scanning from both front edges.

11.4.3.3.3 Open-die forgings

(1) Ultrasonic testing shall be performed to DIN EN 10228-3 or to DIN EN 10228-4 in compliance with the specifications laid down in (2) in the case of forgings not containing bored holes and the specifications laid down in (3) in the case of forgings containing bored holes. It shall be performed after the governing heat treatment for establishment of the mechanical and technological characteristics, while the materials have the minimum possible of contours.

If the contour after machining and heat treatment permits only restricted testability, testing per (2) or (3) shall be performed before machining and heat treatment and testing per (4) shall be performed after machining and heat treatment.

(2) For forgings not containing bored holes the following shall apply:

The requirements for types 1a or 1b to DIN EN 10228-3 or DIN EN10228-4 shall be met. On parts of test group A1 and parts with nominal widths exceeding DN 300 of test group A2 ultrasonic testing shall additionally be performed from the front edges by straight-beam scanning and in cylindrical regions in both circumferential directions by angle-beam scanning.

(3) For hollow-bored forgings the following shall apply:

The requirements for type 3a to DIN EN 10228-3 or DIN EN 10228-4 shall be met. On parts of test group A1 and parts with nominal widths exceeding DN 300 of test group A2 ultrasonic testing shall additionally be performed from the front edges by straight-beam scanning.

(4) In case of restricted testability upon heat treatment the following applies to the scanning directions:

Straight-beam scanning shall be performed from all outer surfaces if their radius of curvature exceeds 30 mm. On parts of test group A1 and parts with nominal widths exceeding DN 300 of test group A2 angel-beam scanning in both circumferential directions shall be performed in cylindrical regions of open-die forgings.

11.4.3.3.4 Stock material for drop-forged parts

(1) The stock material for drop-forged parts with diameters or edge lengths exceeding 50 mm shall be subjected to ultrasonic testing to DIN EN 10308, DIN EN 10228-3 or DIN EN 10228-4.

(2) Stock material made of austenitic steel may also be tested in the not solution-annealed condition, provided that no restrictions as to their testability exist.

11.4.3.3.5 Drop-forged parts

(1) For drop-forged parts with nominal values larger than 150 mm, an ultrasonic examination shall be performed, if permitted by the geometry, after the governing heat treatment for establishment of the mechanical and technological material characteristics, while the materials have the minimum possible of contours.

(2) The examination shall be performed by straight-beam scanning from the external surfaces.

(3) Ultrasonic testing is not required in zones with radii of curvature smaller than 30 mm.

11.4.3.4 Recording levels and acceptance criteria

11.4.3.4.1 Selected testing

11.4.3.4.1.1 Product forms of ferritic steel

(1) For the testing of forgings, bars and rings the quality classes as per **Table 11-4** and the resulting recording levels and acceptance criteria to DIN EN 10228-3 apply.

Note:

For straight-beam scanning the requirements of DIN EN 10228-3 are also met by DIN EN 10308.

(2) For the testing of stock material used for drop-forged parts the recording levels and acceptance criteria as per quality class 4 to DIN EN 10308 or DIN EN 10228-3 apply.

(3) In addition, the following requirements apply to the testing of forging, bars and rings as well as stock material for drop-forged parts:

a) Clusters of echo indications shall be registered that are up to 6 dB below the recording level and cannot be resolved into individual echo indications in one probe position or during probe travel. In these regions additional investigations (e.g. through-transmission in several directions) shall be performed to be able to make a statement on the reflector type (planar or volumetric).

   The indications are not permitted, if these investigations reveal signs of areal separations, e.g., loss of intensity of a sound-transmission signal by comparison with indication-free zones of the product form.

b) All sites shall be registered where

   ba) the distance between the recording level and the noise level is less than 6 dB,

   bb) the back-wall echo drops to reach the recording level for no apparent reason or where back-wall echo attenuations equal to or greater 6 dB occur in the area of indications liable to recording.

   For these areas examinations shall be laid down jointly with the authorized inspector to make possible a decision on the usability of the product form.

(4) When testing drop-forged parts with nominal values exceeding 150 mm, the quality classes given in **Table 11-4** and the resulting according to DIN EN 10228-3 recording levels and acceptance criteria shall apply.

Nominal wall thickness s of the final produkt, mm	Quality class
s ≤ 60	4
s > 60	3 [1)]

1) Quality class 2 is permitted for straight-beam scanning of nominal wall thicknesses s > 250 mm, provided that monitoring of the backwall echo is possible.

Table 11-4: Quality classes to DIN EN 10228-3 for selected ultrasonic testing

11.4.3.4.1.2 Product forms of austenitic steel

(1) For straight-beam scanning the recording levels and acceptance criteria as per quality class 3 to DIN EN 10228-4 apply.

Note:
For straight-beam scanning the requirements of DIN EN 10228-4 are also met by DIN EN 10308.

(2) For angle-beam scanning the following recording levels and acceptance criteria shall apply:

a) the recording levels and acceptance criteria to Table 6 of DIN EN 10228-4 when using the DGS method,

b) the recording levels and acceptance criteria to Table 7 of DIN EN 10228-4 when using the DAC method or the reference block method.

(3) In addition, the following requirements shall apply:

a) Clusters of echo indications shall be registered that are up to 6 dB below the recording level and cannot be resolved into individual echo indications in one probe position or during probe travel. In these regions additional investigations such as through-transmissions in several directions shall be performed to be able to make a statement about the reflector type (planar or voluminous).

   The indications are not permitted, if these investigations reveal signs of areal separations, e.g., loss of intensity of a sound-transmission signal by comparison with indication-free zones of the product form.

b) All sites shall be registered where

   ba) the distance between recording level and noise level is 6 dB or less,

   bb) the back-wall echo drops to reach the recording level for no apparent reason or where back-wall echo attenuations equal to or greater 6 dB occur in the area of indications liable to recording.

   For these areas examinations shall be laid down jointly with the authorized inspector to make possible a decision on the usability of the product form.

11.4.3.4.2 Global testing of product forms made of ferritic or austenitic steel

(1) In case of global ultrasonic testing the required quality class to DIN EN 10228-3 or DIN EN 10228-4 shall be laid down by the purchaser prior to the beginning of fabrication. Where the globally tested test object is used further it shall be ensured that the final product meets the requirements of selected ultrasonic testing. Where required, supplementary selected ultrasonic tests shall be performed.

(2) In addition to the stipulations of DIN EN 10228-3 or DIN EN 10228-4 such locations shall be documented where

a) the distance of the recording level to the noise level attains or is less than 6 dB,

b) the back-wall echo drops to reach the recording level for no apparent reason or where back-wall echo attenuations equal to or greater 6 dB occur in the area of indications liable to recording,

c) clusters of indications up to 6 dB below recording level occur.

11.5 Seamless pipes larger than DN 50

11.5.1 Seamless pipes larger than DN 50 of ferritic steels of material group W I

(1) The following shall apply to pipes with nominal wall thicknesses not exceeding 30 mm:

a) All pipes shall be subjected to an ultrasonic testing for longitudinal defects to DIN EN ISO 10893-10, acceptance class U2 subclass B.

b) Pipes of test group A 1 shall additionally be subjected to an ultrasonic testing for transverse defects to DIN EN ISO 10893-10, acceptance class U2 subclass C as well as in the case of nominal wall thicknesses equal to or larger than 8 mm to an examination for laminar-type discontinuities to DIN EN ISO 10893-8, acceptance class U0. Pipes of test group A 2 shall be examined for transverse defects to DIN EN ISO 10893-10, acceptance class U2 subclass C if they were hot-pilger-rolled or subjected to hot pilger rolling during the manufacturing process.

c) One surface inspection shall be performed on every fourth pipe of test group A 1. The outside surface shall be examined completely and the inside surface shall be examined over a length of 1 times the outside diameter from each end of the pipe. The acceptance class M1 to DIN EN ISO 10893-5 shall apply.

(2) Pipes with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.5.2 Seamless pipes larger than DN 50 of ferritic steels of material group W II

(1) The following shall apply to pipes with nominal wall thicknesses not exceeding 30 mm:

a) All pipes shall be subjected to an ultrasonic testing for longitudinal defects to DIN EN ISO 10893-10, acceptance class U2 subclass B, calibration on reference tube with “N”-type notch at the inside and at the outside.

b) Pipes of test group A 2, which were hot-pilger-rolled or subjected to hot pilger rolling during the manufacturing process, shall additionally be subjected to

   ba) an examination for laminar-type discontinuities to DIN EN ISO 10893-8, acceptance class U0 and

   bb) an ultrasonic testing for transverse defects examination to DIN EN ISO 10893-10, acceptance class U2 subclass C, calibration on reference tube with notch at the outside or on reference tube with notch at the inside and at the outside.

(2) Pipes with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts .

11.5.3 Seamless pipes larger than DN 50 of austenitic steels

(1) The following shall apply to pipes with nominal wall thicknesses not exceeding 30 mm:

a) All pipes shall be subjected to an ultrasonic testing for longitudinal defects to DIN EN ISO 10893-10, acceptance class U2 subclass B, calibration on reference tube with “N”-type notch at the inside and at the outside.

b) Pipes with nominal wall thicknesses exceeding 5.6 mm and pipes larger than or equal to DN 100 shall be subjected to an ultrasonic testing for transverse defects to DIN EN ISO 10893-10, acceptance class U2 subclass C, calibration on reference tube with notch at the outside or on reference tube with notch at the inside and at the outside.

c) For the purpose of correcting the test conditions the sound attenuation and transfer correction shall be determined at four measuring points offset by 90° each at both ends and over the entire length at a distance of not more than 200 mm. The measurements shall be made with the same probes and test equipment as used during the test for longitudinal and transverse defects. Where the values determined differ from the values determined adjacent to the reference reflectors, this difference shall be considered in the test. In case of differing surface qualities the number of measuring points shall be doubled. Where the variation of measured values determined under same incidence conditions exceeds 6 dB (referred to the sound path to be evaluated), the number of measuring points shall be doubled. Where it is ascertained during the tests that sufficiently equal test conditions are obtained in dependence of the manufacturing process, the material and the dimensions, the extent of measuring points may be reduced to half the number upon agreement by the authorized inspector.

d) One surface inspection shall be performed on every fourth pipe of test group A 1. The outside surface shall be examined completely and the inside surface shall be examined over a length of 1 times the outside diameter from each end of the pipe. The acceptance class P1 to DIN EN ISO 10893-4 shall apply.

(2) Pipes with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.6 Seamless pipe elbows larger than DN 50

11.6.1 Seamless pipe elbows larger than DN 50 of ferritic steels of material group W I

(1) The following shall apply to pipe elbows with nominal wall thicknesses not exceeding 30 mm:

a) The outside and inside surfaces shall basically be subjected to a surface inspection. The acceptance criteria are defined in **Tables 11-2** and **11-3**.

b) Where a surface inspection is not possible on the inner surface, it shall be replaced by ultrasonic or radiographic testing to DIN EN ISO 5579, class B. A combination of the UT and RT methods is permitted. The test conditions shall be laid down in the test instruction. Where the UT method is applied, testing for longitudinal and transverse defects to DIN EN ISO 10893-10 shall be performed. The calibration shall be made on a reference tube with “N“ type notch at the inside. For the testing for longitudinal defects acceptance class U2, subclass B applies. For the testing for transverse defects acceptance class U2, subclass C applies.

(2) Pipe elbows with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.6.2 Seamless pipe elbows larger than DN 50 of ferritic steels of material group W II

(1) The following shall apply to pipe elbows with nominal wall thicknesses not exceeding 30 mm:

a) For pipe elbows of test group A 2, the outside and inside surfaces shall basically be subjected to a surface inspection. The acceptance criteria are defined in **Tables 11-2** and **11-3**.

b) Where a surface inspection is not possible on the inner surface, the inspection on all elbows of test class A2 shall be replaced by ultrasonic or radiographic testing to DIN EN ISO 5579, class B. A combination of the UT and RT methods is permitted. The test conditions shall be laid down in the test instruction. Where the UT method is applied, testing for longitudinal and transverse defects to DIN EN ISO 10893-10 shall be performed. The calibration shall be made on a reference tube with “N“ type notch at the inside. For the testing for longitudinal defects acceptance class U2, subclass B applies. For the testing for transverse defects acceptance class U2, subclass C applies.

(2) Pipe elbows with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.6.3 Seamless pipe elbows larger than DN 50 of austenitic steels

(1) The following shall apply to pipe elbows with nominal wall thicknesses not exceeding 30 mm:

a) The outside and inside surfaces shall basically be subjected to a surface inspection. The acceptance criteria are defined in **Table 11-2**.

b) Where a surface inspection is not possible on the inner surface, the inspection on all elbows shall be replaced by ultrasonic or radiographic testing to DIN EN ISO 5579, class B. A combination of the UT and RT methods is permitted. The test conditions shall be laid down in the test instruction. Where the UT method is applied, testing for longitudinal and transverse defects to DIN EN ISO 10893-10 shall be performed. The calibration shall be made on a reference tube with “N“ type notch at the inside. For the testing for longitudinal defects acceptance class U2, subclass B applies. For the testing for transverse defects acceptance class U2, subclass C applies.

c) For the purpose of correcting the test conditions the sound attenuation and transfer correction shall be determined at four measuring points offset by 90° each at both ends and over the entire length at a distance of not more than 200 mm. The measurements shall be made with the same probes and test equipment as used during the test for longitudinal and transverse defects. Where the values determined differ from the values determined adjacent to the reference reflectors, this difference shall be considered in the test. In case of differing surface qualities the number of measuring points shall be doubled. Where the variation of measured values determined under same incidence conditions exceeds 6 dB (referred to the sound path to be evaluated), the number of measuring points shall be doubled. Where it is ascertained during the tests that sufficiently equal test conditions are obtained in dependence of the manufacturing process, the material and the dimensions, the extent of measuring points may be reduced to half the number upon agreement by the authorized inspector.

(2) Pipe elbows with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.7 Seamless fittings larger than DN 50

11.7.1 Seamless fittings larger than DN 50 of ferritic steels of material group W I

(1) The outside and inside surfaces of fittings with nominal wall thicknesses not exceeding 30 mm shall be subjected to a surface inspection. The acceptance criteria are defined in **Tables 11-2** and **11-3**.

(2) Fittings with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.7.2 Seamless fittings larger than DN 50 of ferritic steels of material group W II

(1) For fittings of test group A 2 with nominal wall thicknesses not exceeding 30 mm, the outside and inside surfaces completely shall be subjected to a surface inspection. The acceptance criteria are defined in **Tables 11-2** and **11-3**.

(2) Fittings with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.7.3 Seamless fittings larger than DN 50 of austenitic steels

(1) The outside and inside surfaces of fittings with nominal wall thicknesses not exceeding 30 mm completely shall be subjected to a surface inspection. The acceptance criteria are defined in **Table 11-2**.

(2) Fittings with nominal wall thicknesses exceeding 30 mm shall be tested to Section 11.4 as forged hollow parts.

11.8 Castings

11.8.1 Test methods to be used

(1) The test methods for the different cast-steel grades and casting zones can be found in Table 11-5.

(2) The ultrasonic testing may be employed as volumetric testing

a) on rough-turned flanges,

b) on machined seat portions,

c) on ribs and cast-on parts,

where complete observation of the back-wall echo is possible at at least one beam incidence direction. For straight-beam scanning it shall be possible to test these regions in opposite direction (see **Figures 11.8-1** to **11.8-11**) at at least two incidence directions being vertical to each other.

(3) If ultrasonic testing is employed as volumetric testing in zones other than those illustrated in **Figures 11.8-1** through **11.8-11**, it shall be ensured that complete observation of the back-wall echo at at least one beam incidence direction and angle-beam scanning in opposite direction at two incidence directions being vertical to each other are possible. Regions that cannot be ultrasonically tested, shall be subject to radiographic testing as per section B 7.1. The procedure to be followed shall be laid down in the test instruction with reference to the respective part.

(4) Volumetric testing shall be supplemented by angle-beam ultrasonic testing in regions where hot cracking may occur, e.g. regions of risers and chill casting, cross-sectional transitions. The regions shall be laid down in the test instruction with reference to the respective part.

11.8.2 Point of time of testing and participation in testing

(1) The point of time of non-destructive testing in the production sequence as well as the participation in testing is defined for cast-steel cases and bodies in **Figure 5.7-1**.

(2) If further machining is performed by the component manufacturer, a surface inspection shall additionally be made of the surfaces produced by such machining.

Cast-steel group	Casting zones					
	Cast body	Adjoining zones [1]	Welding ends	Welded joints	Excavations	Production weld
Ferritic and martensitic cast-steel grades	Magnetic particle testing [2] Radiographic testing [3] [4]	Magnetic particle testing [2]	Magnetic particle testing [2] Radiographic testing [3]	Magnetic particle testing [2] Radiographic testing [3]	Magnetic particle testing [2] Radiographic testing [3]	Magnetic particle testing [2] Radiographic testing [5]
Austenitic cast-steel grades	Penetrant testing Radiographic testing	Penetrant testing	Penetrant testing Radiographic testing	Penetrant testing Radiographic testing	Penetrant testing Radiographic testing	Penetrant testing Radiographic testing

[1] Adjoining zones are zones located outside the pressure-retaining wall, such as
- feet,
- brackets,
- lugs,
- external fins,
- cams.

[2] Magnetic-particle testing shall be preferred for magnetizable materials. However, penetrant testing may be employed:
a) in zones that are difficult to magnetize because of geometry or accessibility considerations and
b) for cast-steel grade G X4 CrNi 13 4, material No. 1.4317.

[3] Alternatively, it is permitted to perform an ultrasonic testing as per clauses 11.8.1 (2) and (3).

[4] A supplementary ultrasonic test with angle-beam scanning as per sub-clause 11.8.1 (4) shall be performed for detecting hot cracking. The procedure to be followed shall be laid down in the test instruction with reference to the respective part.

[5] In test groups A 2 and A 3, it is permitted to replace the radiographic testing of small production welds by an ultrasonic testing, starting with the 4th casting of a production lot. See Annex B, section B 2 (4) as regards the differentiation between small and relatively large production welds.

Table 11-5: Testing methods for cast-steel grades and their casting zones

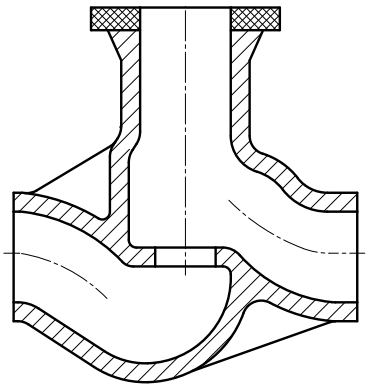


Figure 11.8-1: Straight way valve body

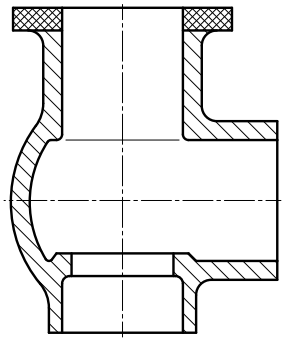


Figure 11.8-2: Angle-valve body

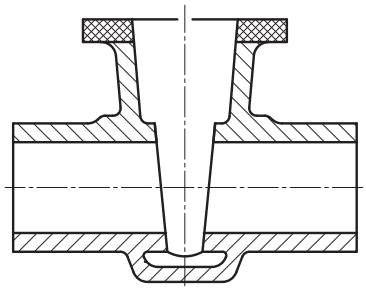


Figure 11.8-3: Wedge-type gate-valve body

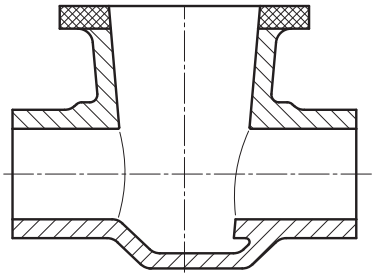


Figure 11.8-4: Swing-check-valve body

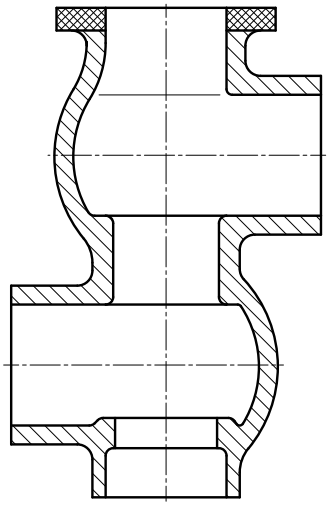


Figure 11.8-5: Multi-way-valve body

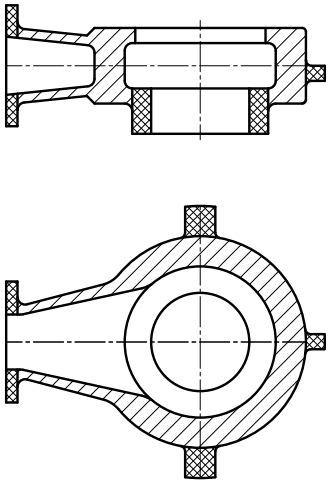


Figure 11.8-6: Discharge casing

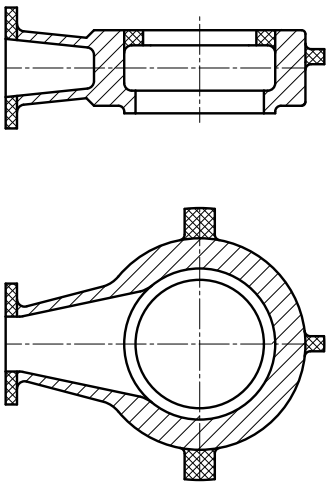


Figure 11.8-7: Suction casing

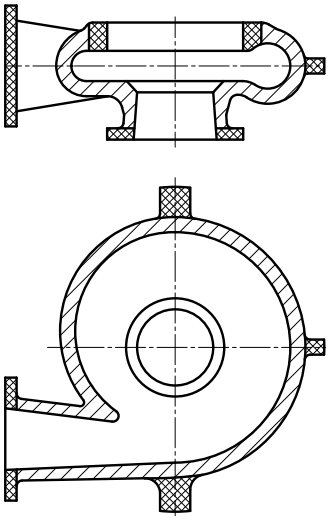


Figure 11.8-8: Scroll casing

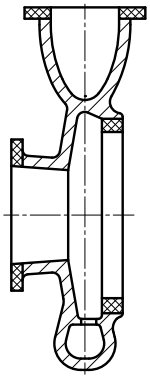


Figure 11.8-9: Double scroll casing

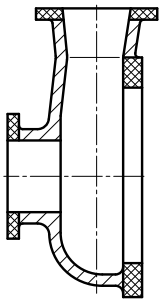


Figure 11.8-10: Annular casing

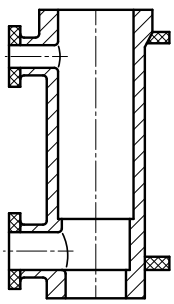
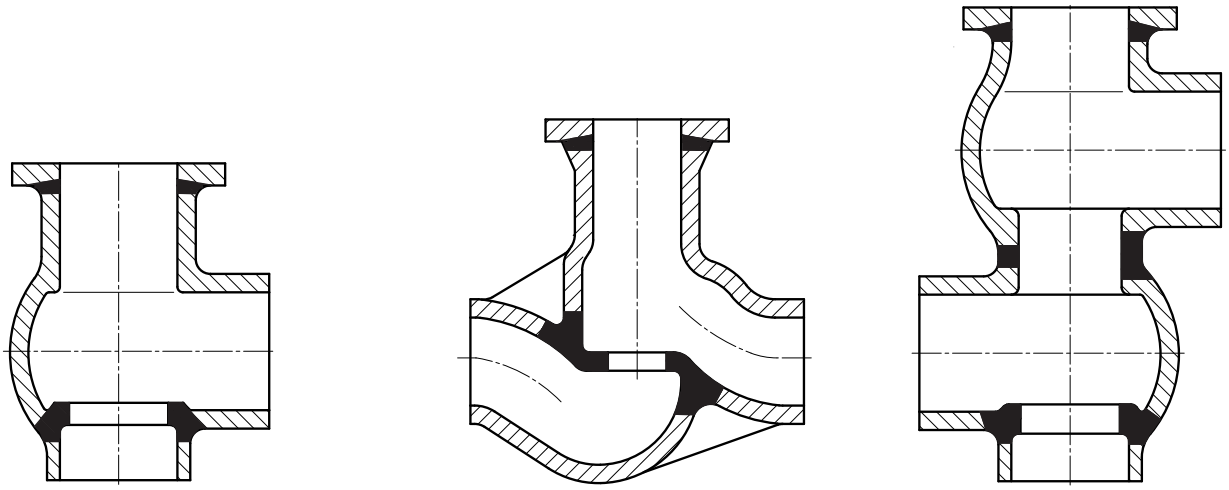
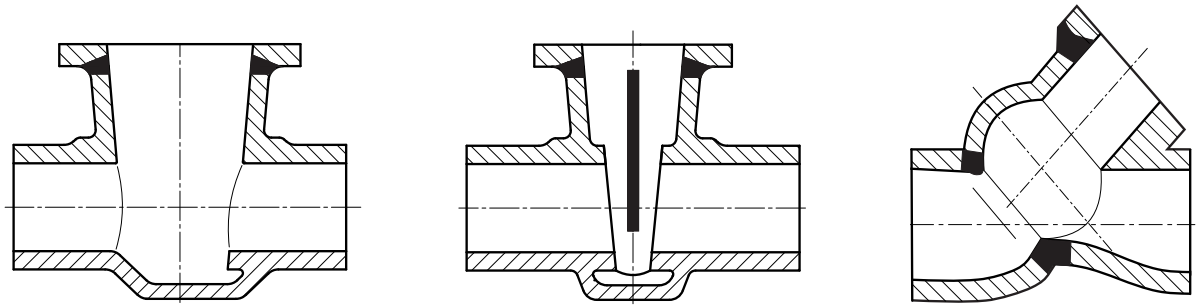


Figure 11.8-11: Annular casing

Figures 11.8-1 through 11.8-11:
Examples of valve-body or pump-casing zones for which ultrasonic testing is permissible

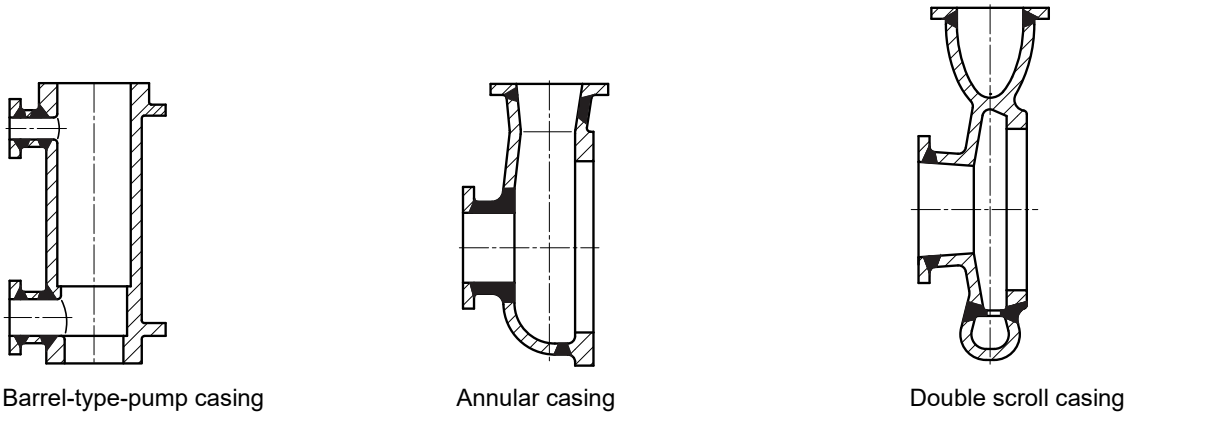


Angle-valve body | Straight way valve body | Multi-way-valve body

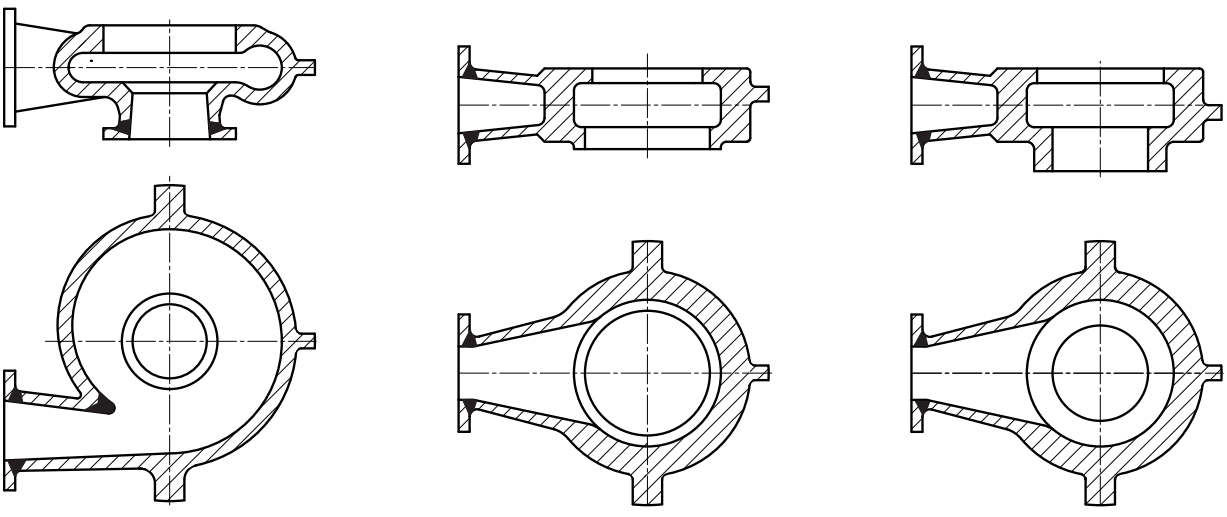


Swing-check-valve body | Wedge-type gate-valve body | Angle seat valve body

Figure 11.8-12: Examples of valve-casing zones that are complex from the viewpoint of casting (black)



Barrel-type-pump casing | Annular casing | Double scroll casing



Scroll casing | Suction casing | Discharge casing

Figure 11.8-13: Examples of pump-casing zones that are complex from the viewpoint of casting (black)

11.8.3 Extent of testing

11.8.3.1 Test group A 1

(1) All cast bodies, welding ends, welded joints and production welds shall be completely radiographed. For ferritic and martensitic cast-steel grades, it is permitted as an alternative to perform an ultrasonic testing in accordance with clause 11.8.1.

(2) All internal and external surfaces, including those of excavations for production welds, shall be subjected to a surface inspection. For inaccessible areas the alternative measures shall be laid down in the design review documents.

11.8.3.2 Test groups A 2 and A 3

(1) Cast body, welding ends, welded joints and production welds of the first three castings of a production lot (prototypes) shall be subjected completely to a volumetric testing.

(2) All further castings of the same production lot with the same melting and casting technique shall be tested in the following zones:

a) zones that are complex from the viewpoint of casting and stress,

b) welding ends,

c) relatively large production welds,

d) places at which defects with acceptable limit sizes were observed in the testing of the prototypes.

(3) The zones that are complex from the viewpoint of casting and stress shall be determined by agreement with the authorized inspector. Where it is intended to combine production lots, the decision shall also be made by agreement with the authorized inspector. Examples of zones that are complex from the viewpoint of casting are shown in Figures **11.8-12** and **11.8-13**.

(4) For small production welds, it is also permitted, starting with the fourth casting, to perform an ultrasonic testing instead of the radiographic testing.

(5) All internal and external surfaces, including those of excavations for production welds as well as the production welds, shall be subjected to a surface inspection.

11.8.4 Surface quality

The surface prepared for the non-destructive testing shall be evaluated to DIN EN 1370 using the comparison specimens referred to therein. The surfaces shall have a surface quality equal to or better than that of BNIF-visualtactile comparators 3 S1 or 4 S2. Castings to be tested by the ultrasonic method shall have a surface quality equal to or better than that of BNIF-visualtactile comparators 3 S1 or 3 S2. Castings to be tested by the penetrant method shall have a surface quality equal to or better than that of BNIF-visualtactile comparators 2 S1 or 3 S2.

11.8.5 Surface inspection

11.8.5.1 Procedural requirements

(1) Penetrant testing shall be performed by magnetic particle or penetrant testing according to **Table 11-5**.

(2) The requirements of DIN EN 1369 shall apply to the performance of magnetic particle testing. In addition, the stipulations of **Annex E** apply.

(3) The requirements of DIN EN 1371-1 shall apply to the performance of penetrant testing. In addition, the stipulations of **Annex E** apply.

11.8.5.2 Acceptance criteria

(1) For the evaluation of magnetic particle and penetrant testing the severity levels shown in **Table 11-6** and the resulting acceptance criteria to DIN EN 1369 or DIN EN 1371-1 apply in dependence of the casting area and test class. In addition, the following applies:

a) Linear indications suggesting cracks are not permitted.

b) The evaluation of the test results obtained by penetrant testing shall be made in due consideration of all indications and points in time of inspection.

(2) For production welds and welded joints the same severity levels as for the respective casting areas apply.

(3) Where excavations are subject to magnetic particle or penetrant testing only such indications are permitted that do not impair weldability and are not associated with inadmissible surface and volumetric defects that are to be eliminated. In case of doubt it shall be proved by radiographic testing that no inadmissible indications are present in the adjacent base metal.

Casting Area	Test group	Severity level to be applied			
		PT [1]	MT [2]	RT [3]	UT [4]
Welding ends	Any	SP1, CP1 [5]	SM1 [5]	1	1
Cast body	A1	SP1, CP1, LP1, AP1	SM1, LM1, AM1,	2	2
	A2 and A3	SP2, CP2, LP2, AP2	SM2, LM2, AM2,	2 [6]	2 [6]
Adjoining zones [7]	A1	SP2, CP2, LP2, AP2	SM2, LM2, AM2,	—	—
	A2 and A3	SP3, CP3, LP3, AP3	SM3, LM3, AM3,	—	—

1) Penetrant testing PT to DIN EN 1371-1.

2) Magnetic particle testing MT to DIN EN 1369.

3) Radiographic testing RT to DIN EN 12681; acceptance criteria to Annex 1 of AD 2000-Merkblatt W 5.

4) Ultrasonic testing UT to DIN EN 12680-2.

5) During surface inspection linear indications or indications grouped in a chain are not permitted.

6) Severity level 3 will suffice if
a) DN ≤ 150 or
b) in the case of DN > 150 the product of nominal width DN and allowable operating pressure, MPa, does not exceed 2000.

7) Adjoining zones are zones located outside the pressure-retaining wall, e.g. feet, brackets, lugs.

Table 11-6: Severity levels to be applied depending on the test group

11.8.6 Volumetric testing

11.8.6.1 Ultrasonic testing

11.8.6.1.1 Procedural requirements

(1) For the performance of ultrasonic testing the stipulations of DIN EN 12680-2 apply.

(2) Deviating from the stipulations in DIN EN 12680-2 test frequencies equal to or greater than 2 MHz shall be applied. The test frequency to be applied shall be laid down in the test instruction.

(3) For the testing of sub-surface regions the test shall be performed either from the opposite face or dual-element probes shall be used up to a depth of 50 mm. The technique to be applied shall be laid down in the test instruction.

(4) The extension of indications shall be determined in accordance with DIN EN 12680-2, clause 5.5.7.

(5) As regards the description of reflectors which cause echoes liable to recording the identification system (reference point grid) established for radiographic testing shall be used.

11.8.6.1.2 Determination of testability

(1) The testability shall be determined for each test object in accordance with DIN EN 12680-2. The location and number of measurements shall be laid down in the test instruction.

(2) The testability shall be determined jointly by the parties involved in the test.

(3) The wave lengths used to determine the testability shall not be greater than those used in tests with straight-beam and angle-beam scanning following thereafter.

11.8.6.1.3 Performance of test

(1) The regions to be tested, the test technique to be applied and the incidence conditions shall be taken from **Table 11-7**.

(2) Testing with dual-element probes shall not exceed a sub-surface depth of 50 mm.

(3) The casting shall be tested such that the regions to be tested are completely covered.

Serial. no.	Test area	Probe	Extent of testing and sound entry positions
1	Welding ends		
1.1	Welding ends with s > 50 mm and accessibility from both sides	Straight beam probe	100 % from both surfaces
		Dual-element angle-beam probe 60°	100 % from two sides using two beam angles which are perpendicular to each other
		Angle-beam probe 45°	
1.2	Welding ends with s > 50 mm and Welding ends with accessibility from one side	Straight beam probe	100 % from one surface
		Dual-element straight beam probe	
		Dual-element angle-beam probe 60°	100 % from two sides using two beam angles which are perpendicular to each other
		Angle-beam probe 45°	
1.3	Welding ends with s ≤ 50 mm	Dual-element straight beam probe	100 % from one surface
		Dual-element angle-beam probe 60°	100 % from two sides using two beam angles which are perpendicular to each other
2	Other casting areas		
2.1	Accessibility from both sides in the case of s > 50 mm	Straight beam probe	100 % from both surfaces
2.2	Accessibility from one side in the case of s > 50 mm	Straight beam probe	100 % from one surface
		Dual-element straight beam probe	
2.3	In the case of s ≤ 50 mm	Dual-element straight beam probe	100 % from one surface
2.4	Regions where hot cracking may occur, e.g. regions of risers, chill casting and cross-sectional transitions [1)]	Dual-element angle-beam probe 60°	100 % from two sides using two beam angles which are perpendicular to each other
		Angle-beam probe 45° or angle-beam probe 60° in the case of long sound path travel distances	
3	Production weldings		
3.1	Production weldings with a depth of ≤ 15 mm	Dual-element straight beam probe	100 % from one surface
3.2	Production weldings with a depth of > 15 mm and ≤ 30 mm	Dual-element straight beam probe	100 % from one surface
		Dual-element angle-beam probe 60°	100 % from two sides using two beam angles which are perpendicular to each other
3.3	Production weldings with a depth of > 30 mm	Dual-element straight beam probe	100 % from one surface
		Dual-element angle-beam probe 60°	100 % from two sides using two beam angles which are perpendicular to each other
		Angle-beam probe 45°	

[1)] Where no detailed date on the casting technique are available which allow conclusion on the occurrence of hot cracks, all castings, where practicable, shall be subject to a 100% testing in opposite direction at two incidence directions vertical to each other with a dual-element 60 degrees angle beam probe.

Table 11-7: Test conditions for ultrasonic testing

(4) The casting regions shall be subjected to straight-beam scanning from all accessible surfaces.

(5) Regions where the traceability of the back-wall echo is not possible with straight-beam scanning, however an echo from a discontinuity can be traced, shall be subject to angle-beam scanning. Details shall be laid down in the test instruction.

(6) In the case of welding ends angle-beam scanning shall be performed on cylindrical casting areas accessible from the outside only.

(7) Testing for hot cracks:

a) The test shall be performed upon quenching and tempering.
b) Angel-beam scanning shall be performed in regions where hot cracking may occur, e.g. regions of risers and chill casting, cross-sectional transitions.
c) The regions shall be scanned up to a depth of 50 mm.
d) The procedure shall be agreed with the authorized inspector with reference to the respective part.

(8) Testing of production welds:

a) Where heat treatments are performed, the test shall be performed upon the last heat treatment.
b) In the case of production welds with a thickness not exceeding 15 mm (except for penetrations) testing shall be performed with a dual-element straight-beam probe from the weld metal surface. In all other cases production welds shall be tested at two incidence directions vertical to each other, where practicable. This shall be done by straight-beam scanning and opposite angle-beam scanning. The transition from base metal to weld metal shall be scanned as vertically as possible.

11.8.6.1.4 Recording levels and acceptance criteria

11.8.6.1.4.1 Recording level

(1) All locations shall be recorded where the back-wall echo drop reaches or exceeds a value of dB 12 (see DIN EN 12680-2, Table 3).

(2) All reflectors with measurable extensions shall be recorded the echo heights of which reach or exceed the values shown in Table 3 of DIN EN 12680-2 if the criteria given in Figures 3 and 4 of DIN EN 12680-2 are also reached or exceeded.

(3) In severity level 1 regions all reflectors without measurable extension (point-type indication) shall be recorded the echo heights of which reach or exceed the values shown in Table 1 of DIN EN 12680-2.

(4) Where angle-beam probes are used which show an echo dynamic or clear extension in wall thickness direction shall be recorded independently of the echo height.

11.8.6.1.4.2 Examination of indications liable to recording

(1) The locations where indications liable to recording were detected shall be examined more detailed with respect to the type, shape, size and position. This may be done by means of ultrasonic testing with reference to Table 4 and Annex C of DIN EN 12680-2 or by additional radiographic testing as per clause 11.8.7.

(2) Indications liable to recording that have been ascertained upon quenching and tempering shall be re-examined and be evaluated with the same test method after the last heat treatment.

11.8.6.1.4.3 Acceptance criteria

(1) The severity levels assigned to the test groups and casting regions shall be taken from **Table 11-6**.

(2) The test results shall be evaluated according to DIN EN 12680-2 in dependence of the severity level to be adhered to.

(3) Indications suggesting cracks or lack of fusion are not permitted.

(4) The finale evaluation shall be made in due consideration of the results of all tests.

11.8.6.2 Radiographic testing

11.8.6.2.1 Procedural requirements

(1) The castings shall be tested in accordance with DIN EN 12681 in connection with DIN EN ISO 5579.

(2) The following applies additionally:

a) Image quality indicators to DIN EN ISO 19232-1 shall be used.
b) The image quality shall be examined on each radiograph.
c) Welding ends, regions intended for welded joints and difficult-to-cast regions shall be radiographed in accordance with DIN EN ISO 5579, test class B; in this case image quality class B to DIN EN ISO 19232-3 shall be adhered to. The other radiographs shall correspond at least to test class A of DIN EN ISO 5579 and to image quality class A to DIN EN ISO 19232-3.

   Note:

   *See Figures **11.8-12** and **11.8-13** showing examples for difficult-to-cast regions.*

d) Linear accelerators with a radiation energy E ≥ 4 MeV may be used at a radiographed wall thickness s ≥ 40 mm in which case this value may be somewhat less than required. At a radiographed wall thickness s < 60 mm a minimum density of 3.0 shall be adhered to as per DIN EN ISO 11699-1 when using films of film system classes C3 to C5.
e) If a region is radiographed using multiple-film techniques, it shall be checked during the control of the individual radiographs whether in the region to be evaluated the required density (test class A: minimum density 1.5; test class B: minimum density 2.0) is adhered to.

11.8.6.2.2 Performance of test

(1) The test shall be performed in accordance with DIN EN 12681.

(2) Steel castings with an outer diameter not exceeding 200 mm shall normally be radiographed as per DIN EN 12681, Figure 7.

(3) In the case of steel castings with an outer diameter greater than 200 mm, the master shot to DIN EN 12681, Figure 7 shall only be selected when the arrangement of radiographs to DIN EN 12681, Figures 3 or 4 cannot be used or the evaluation possibilities have to be improved.

(4) Production welds shall be tested in due consideration of their geometry and location.

11.8.6.2.3 Acceptance criteria

(1) The severity levels assigned to the test groups and casting regions shall be taken from **Table 11-6** and the acceptance criteria to be applied be taken from Annex 1 to AD 2000-Merkblatt W5.

(2) The following stipulations apply additionally:

a) In case of double-wall radiography the acceptance criteria apply to the smaller of the individual wall thicknesses unless additional radiographs make the assignment of indications to a specific wall possible.

b) Where the master shots do not provide clearly evaluable indications, they shall be re-examined by additional selected radiographs.

c) For production weld and welded joints the same requirements as for the respective casting regions apply. Cracks and lack of fusion as well as systematically occurring pores and inclusion are not permitted.

11.9 Bolts and nuts

11.9.1 Procedural requirements

11.9.1.1 General

The procedural requirements laid down in sub-section 11.1.5 shall apply. In addition, the procedural requirements specified in sub-sections 11.9.1.2 and 11.9.1.3 hereinafter apply.

11.9.1.2 Surface inspections

Surface inspections shall be performed by means of penetrant testing to **Annex E**.

11.9.1.3 Ultrasonic testing

(1) Ultrasonic testing of the bars shall be performed by means of grid scanning to DIN EN 10308.

(2) For the testing of sub-surface areas ultrasonic testing shall be performed either from the opposite surface or dual element probes shall be used. The technique to be applied shall be laid down in the test instruction.

(3) In addition, the stipulations of 11.4.3.1 (1), (4), (5), (7), (8), (10), and (11) shall be observed.

11.9.2 Bolts and nuts made by machining from solution-annealed and quenched bars

11.9.2.1 Test on the bars

(1) All bars for bolts and nuts with diameters, widths across flats or side lengths equal to or larger than 30 mm and additionally all bars made of the material X22CrMoV12-1 with diameters, widths across flats or side lengths smaller than 30 mm shall be subject to ultrasonic testing in solution-annealed and quenched condition by the manufacturer for internal defects. During the acceptance procedure, 10 % of the bars for bolts or at least 10 of those bars per delivery and 5 % of the bars for nuts or at least 2 of those bars per delivery shall be tested by the authorized inspector.

(2) The following shall apply to bars for bolts and nuts with diameters, widths across flats or side lengths equal to or larger than 30 mm:

An ultrasonic testing to DIN EN 10308 or to DIN EN 10228-3 shall basically be performed. Straight-beam scanning in axial direction shall additionally be performed on bars for bolts; where in this case no distance between recording level and noise level of at least 6 dB can be adhered to over the entire length of the bar, the test shall be performed in the cut-to-length condition.

(3) The following shall apply to bars of the material X22CrMoV12-1 with diameters, widths across flats or side lengths smaller than 30 mm:

Ultrasonic testing shall be performed by

a) complete scanning to DIN EN 10308, quality class 4

or

b) 100 % scanning to DIN EN 10228-3, quality class 4.

The total volume shall be scanned. For the testing of sub-surface areas, ultrasonic testing shall be performed either from the opposite surface or dual element probes shall be used. The test shall be performed manually or mechanized using probes with nominal frequencies greater than or equal to 4 MHz. The sensitivity shall be adjusted by means of the DGS method or DAC method. The technique to be applied shall be laid down in the test instruction. The reflectors' extension shall be determined by means of the half-amplitude technique to clause D 11.2.3.

(4) In case of bars for nuts, straight-beam scanning to DIN EN 10308 may be omitted. Instead of this, the circumferential face shall be completely scanned by angle-beam scanning in both circumferential directions using a 35° angle-beam probe.

(5) During straight-beam scanning from the circumferential surface all echo heights shall be recorded which correspond to a circular disk diameter equal to or greater than 1.5 mm. Indications up to 12 dB in excess of the recording level and up to a maximum length equal to the bar diameter are permitted.

(6) When scanning from the front faces and in circumferential direction all echo heights shall be recorded which correspond to a circular disk diameter equal to or greater than 2.0 mm. Indications attaining or exceeding the recording level are not permitted.

(7) For the material X22CrMoV12-1, magnetic particle testing shall additionally be performed on the bar upon final heat treatment. **Table 11-3** lays down the acceptance criteria.

11.9.2.2 Tests and examinations on finished parts

(1) A surface inspection shall be performed randomly on bolts and nuts. The maximum lot size is 150 pieces and the number of spot-check samples shall be 20. The acceptance criterion = zero defects.

(2) Bolts shall be evaluated to DIN EN 26157-3 and nuts to DIN EN ISO 6157-2 where deviating from these standards, indications suggesting cracks are not permitted.

11.9.3 Bolts and nuts made by machining from hot-cold work hardened or from solution-annealed and quenched austenitic bars

11.9.3.1 Test on the bars

(1) All bars with diameters, widths across flats or side lengths equal to or larger than 30 mm for bolts and nuts shall be tested in solution-annealed and quenched condition by the manufacturer for internal defects. During the acceptance procedure, 10 % of the bars for bolts, but at least 10 of those bars per delivery, and 5 % of the bars for nuts, but at least 2 of those bars per delivery, shall be tested by the authorized inspector.

(2) In case of bars for bolts and nuts, ultrasonic testing to DIN EN 10308 shall be performed with the recording levels and acceptance criteria to sub-clauses (4) and (5).

(3) In case of bars for nuts, straight-beam scanning to DIN EN 10308 may be omitted. Instead of this, the circumferential face shall be scanned completely by angle-beam scanning in both circumferential directions using a 35° angle-beam probe.

(4) During straight-beam scanning from the circumferential surface all echo heights shall be recorded which correspond to a circular disk diameter equal to or greater than 2.0 mm. Indications up to 6 dB in excess of the recording level and up to a maximum length equal to the bar diameter are permitted.

(5) When scanning in circumferential direction all echo heights shall be recorded which correspond to a circular disk diameter equal to or greater than 3.0 mm. Indication attaining or exceeding the recording level are not permitted.

11.9.3.2 Tests and examinations on finished parts

The requirements of clause 11.9.2.2 shall apply.

11.9.4 Bolts and nuts made by hot or cold forming and then quenched and tempered

The requirements of clause 11.9.2.2 shall apply.

11.9.5 Bolts and nuts of strength classes or steel grades

Bolts shall be tested and evaluated to DIN EN 26157-3, nuts shall be tested and evaluated to DIN EN ISO 6157-2. For the lot size, extent of spot-check samples and acceptance criteria the following applies:

a) for ferritic steels the stipulations of AD 2000-Merkblatt W 7,
b) for austenitic steels of test class A 1 and A 2 the stipulations in sub-clause 11.9.2.2 (1),
c) for austenitic steels of test class A 3 the stipulations of AD 2000-Merkblatt W 2.

11.10 Product forms of steels for special loads

11.10.1 Forgings, bars and rolled rings

The Sections 11.1.8 and 11.4 shall apply to the non-destructive tests and examinations.

11.10.2 Castings

Section 11.8 shall apply to the non-destructive tests and examinations on castings.

11.11 Heat-exchanger tubes

11.11.1 Type, extent and time of testing

11.11.1.1 Straight heat-exchanger tubes

(1) Each tube to Section 10.1, 10.3, 10.5 or 10.6 shall be tested over its entire length and full cross section. The type, extent and point of time of non-destructive tests and examinations can be found in **Table 11-8**.

(2) The test shall be performed by means of automated test equipment. The test equipment shall be capable of distinguishing between tubes that have passed the test and tubes being suspect by means of a trigger/alarm level in connection with a marking system. A recording device shall make assignment of measured values to their exact location possible. The authorized inspector shall have inspected the test equipment. Ends that have not been tested shall either be cut off or be tested manually on the basis of the same requirements applied before.

(3) Eddy-current tests shall be performed to Section 11.11.2, ultrasonic tests to Section 11.11.3 and magnetic flux leakage tests to Section 11.11.4.

11.11.1.2 Bent heat-exchanger tubes

(1) In the case of seamless bent heat-exchanger tubes of ferritic steels to Section 10.2 a visual inspection and a magnetic-particle test of the inside surface shall be performed on two cut-open elbows from the series of tubes with the smallest bend radius.

(2) In the case of seamless bent heat-exchanger tubes of austenitic steels to Section 10.4 a visual inspection and a penetrant test of the inside surface shall be performed on two cut-open elbows from the series of tubes with the smallest bend radius.

(3) The stipulations in Section 11.1.5 shall apply to the performance of testing.

(4) For the evaluation of the test results obtained the following shall apply: no abnormalities or indications are permitted.

Type of tubes Manufacture/material	Point in time of testing	Nominal thickness in mm	Diameter in mm	Extent of testing in %		Test method		
				H	S	ET	UT	MT [1]
Longitudinally welded austenitic tubes, stretch-reduced by roll drawing [2] and heat-treated, straight or bent	on straight tube	≤ 2.0	≤ 38.0	100	St. [3]	X alternatively	X	—
Seamless austenitic tubes, straight or cold bent	on straight tube	≤ 3.6	≤ 42.4			X alternatively	X	—
Seamless ferritic tubes, straight or cold bent	on straight tube	≤ 4.0	≤ 38.0			X [4]	X alternatively	X

1) Magnetic flux leakage technique

2) Total deformation > 20 %

3) St. : In test classes A1 and A2 the authorized inspector shall check the test system during his spot attendance on the test.

4) Where s ≤ 2 mm the test for transverse defects may be performed by ET alternatively to UT or MT.

H : Manufacturer
S : Authorized inspector
UT : Ultrasonic testing
ET : Eddy current testing

Table 11-8: Extent of testing and test methods

11.11.2 Eddy-current testing

11.11.2.1 Procedural prerequisites

11.11.2.1.1 General

The eddy-current testing shall be performed to DIN EN ISO 10893-2 using concentric coil technique in combination with the particulars of the following subsections.

11.11.2.1.2 Testing system

Encircling coils shall be employed for the test

a) using differential probes for testing seamless tubes

b) using differential and absolute probes for testing longitudinally welded tubes,

The tubes shall pass concentrically through the test coils. The coils shall be constructed such that the test sensitivity required in subsection 11.11.2.1.4 is achieved at the chosen excitation frequency. The value of the amplitude of the signals caused by indications shall be evaluated.

11.11.2.1.3 Excitation frequency

(1) To define appropriate excitation frequencies as a function of material, tube size and fabrication condition, a reference tube of the same test-relevant characteristics and the same dimensions as the tubes to be tested shall be used. Sharp-edged notches with a length of 20 mm, a width of smaller than or equal to 0.5 mm and a depth of less than or equal to 20 % of the nominal wall thickness but at least 0.15 mm shall be produced on the outside and inside in the longitudinal axis of this reference tube.

(2) The notches shall be made such that they do not cause changes of the microstructural characteristics of the material that influence the eddy-current distribution.

(3) The geometry, shape and dimension of the notches shall be verified.

(4) The excitation frequency shall be selected such that the notch on the surface distant from the probe is verified with a distance to the noise level of at least 6 dB. When selecting the excitation frequency particular consideration shall be given to the physical parameters of the tube (e.g. conductivity, permeability, wall thickness).

Notes:

(1) For tubes of austenitic steels, excitation frequencies from 30 kHz up to 400 kHz are used for wall thicknesses not exceeding 1 mm, excitation frequencies from 20 kHz up to 80 kHz for wall thicknesses larger than 1 mm and up to and including 2 mm, excitation frequencies from 5 kHz up to 40 kHz for wall thicknesses larger than 2 mm and up to and including 4 mm.

(2) For tubes of ferritic steels, excitation frequencies from 15 kHz up to 100 kHz are used for wall thicknesses not exceeding 1 mm, excitation frequencies from 4 kHz up to 25 kHz for wall thicknesses larger than 1 mm and up to and including 2 mm, excitation frequencies from 1 kHz up to 15 kHz for wall thicknesses larger than 2 mm and up to and including 4 mm.

(5) The test parameters to be used shall be laid down in the test instruction.

11.11.2.1.4 Testing sensitivity

(1) Test tubes with identical test-related characteristics and the same dimensions as the tubes to be tested shall be used to set the testing sensitivity level. Three holes separated by 120 degrees and having 0.8 mm diameter shall be drilled in these tubes. The spacing of holes in the longitudinal direction of the tube should be sufficiently large that the holes yield separate and distinguishable signals. The smallest signal shall reach the response threshold of the indicating and recording instruments. The basic sensitivity setting shall be made at the testing speed planned for the test, using the hole of 0.8 mm diameter. This basic sensitivity setting shall be corrected by a tube-diameter-dependent dB value per **Figure 11.1-1**.

(2) If the theoretical load factor of the tube wall is equal to or smaller than 30 %, testing sensitivity II to **Figure 11.1-1** shall be employed. Otherwise testing sensitivity I shall be required.

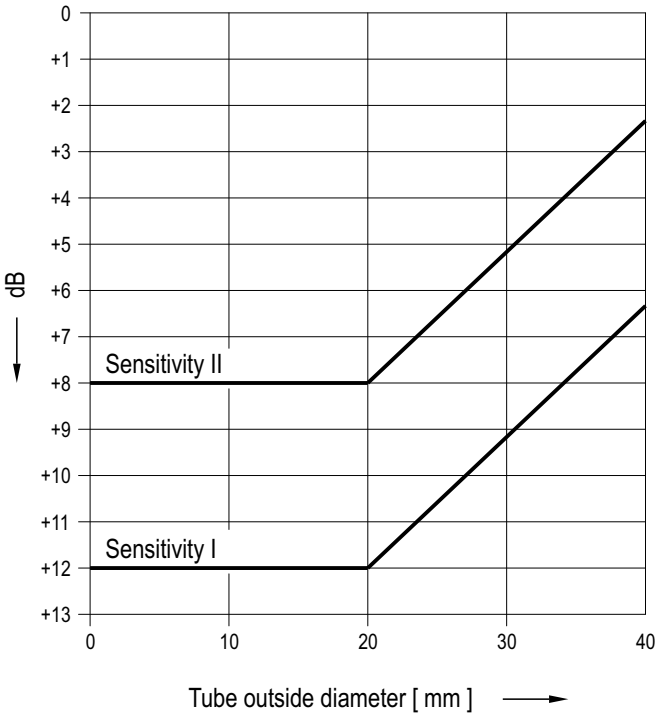


Figure 11.11-1: Testing sensitivity of eddy-current testing relative to a hole diameter of 0.8 mm

(3) The required testing sensitivity shall be specified in the purchase order.

(4) Prior to adjusting the testing sensitivity a running-in period of the eddy-current test device of at least half an hour shall be observed unless otherwise provided by the respective operating instruction.

11.11.2.2 Testing procedure and assessment of the results

11.11.2.2.1 Check of testing sensitivity

(1) Before starting the test, the testing sensitivity setting and the stability of the instrument settings shall be verified by at least three passes of the reference tube.

(2) After every 100 tubes tested or maximum four hours as well as after completing the test, the testing sensitivity shall be checked by another pass of the reference tube. If a loss of more than 2 dB in testing sensitivity is noted, the test shall be repeated on all tubes that were tested between the sensitivity setting to be corrected and the preceding sensitivity setting. The repetition of the test shall be performed using the corrected testing sensitivity setting.

11.11.2.2.2 Recording levels

All indications shall be recorded that reach or exceed the signal amplitude of the reference drill hole to clause 11.11.2.1.4 (1), corrected by the diameter dependent dB value to **Figure 11.11-1**.

11.11.2.2.3 Marking of indication sites

All sites on tubes with indications having amplitudes that reach or exceed the recording level shall be marked by a permanent marking.

11.11.2.2.4 Admissibility of indications

(1) All tubes or tube sections with indications that reach or exceed the recording level shall be sorted out being suspect.

(2) Indication sites on tubes being suspect that have been sorted out may be re-tested with a different non-destructive testing method (e.g., visual inspection, radiographic testing) for observation of defect type and size. Verification that the indications are not objectionable shall be required.

(3) Tubes being suspect may be mechanically reworked within the permissible dimensional tolerances, after which they shall be subjected to another test.

11.11.2.3 Test report

In addition to the information required according to DIN EN ISO 10893-2, the test report shall shall contain the following data:

a) relative motion of tube and probe unit (rotation frequency, translation velocity),
b) sorting and marking device,
c) adjustment and testing sensitivity level,
d) untested tube sites as well as
e) place of the test, test supervisory personnel and operators.

11.11.3 Ultrasonic testing

11.11.3.1 Procedural prerequisites

(1) Ultrasonic tests for longitudinal and transverse defects shall be performed. These tests shall be performed to (2) and (3) in combination with the particulars of the following subsections.

(2) Test for longitudinal defects

The test for longitudinal defects shall be performed to DIN EN ISO 10893-10, acceptance level U3 subclass A. The testing sensitivity adjustment shall be made on a reference tube with “N“ type notch at the outside and at the inside.

(3) Test for transverse defects

The test for transverse defects shall be performed to DIN EN ISO 10893-10, acceptance level U3 subclass A. The testing sensitivity adjustment shall be made on a reference tube with notches at the outside and at the inside, which shall be performed as partial circumferential or full circumferential notches.

(4) Tolerances on the notch depth

Deviating from the stipulations in DIN EN ISO 10893-10 the tolerance on the notch depth shall be ± 0.02 mm.

11.11.3.2 Test procedure and assessment of the results

11.11.3.2.1 Adjustment of the testing sensitivity

The testing sensitivity shall be set by adjusting the trigger/alarm level according to DIN EN ISO 10893-10, Section 7. In this case, the distance to the noise level derived from the respective reference reflector shall not be less than 6 dB.

11.11.3.2.2 Relative movement of tube and probe unit

(1) For the test the beam width, scanning pitch, pulse repetition frequency and test speed shall be tuned such as to ensure scanning of the entire tube surface without interruption. This is usually the case, if during tube surface scanning a 10% overlap of the scanned partial surface areas referred to the transducer diameter is ensured.

(2) Multiple transducers where the distance between the individual transducers is less than 1 mm, are considered to be one transducer.

11.11.3.2.3 Check of testing sensitivity

(1) Before the test is started, the testing sensitivity and stability of the device settings shall be verified by several passes of the reference tube.

(2) After every 2 hours, the testing sensitivity shall be checked by another pass of the reference tube. If a loss of more than 2 dB in testing sensitivity is noted, the test shall be repeated on all tubes that were tested between the sensitivity setting to be corrected and the preceding sensitivity setting. The repetition of the test shall be performed using the corrected testing sensitivity setting.

11.11.3.2.4 Recording levels

(1) All indications shall be recorded that reach or exceed the reference echo amplitude.

(2) The reference echo amplitude is the echo amplitude of the reference reflectors to clause 11.11.3.1.

11.11.3.2.5 Marking of indication sites

All sites on tubes with indications having amplitudes that reach or exceed the recording level shall be marked by a permanent marking.

11.11.3.2.6 Admissibility of indications

(1) All tubes or tube sections with indications that reach or exceed the recording level shall be sorted out being suspect.

(2) Indication sites on tubes being suspect that have been sorted out may be re-tested with a different non-destructive testing method (e.g., visual inspection, radiographic testing) for observation of defect type and size. Verification that the indications are not objectionable shall be required.

(3) Tubes being suspect may be mechanically reworked within the permissible dimensional tolerances, after which they shall be subjected to another test.

11.11.3.3 Test report

In addition to the information required according to DIN EN ISO 10893-10, the test report shall shall contain the following data:

a) relative motion of tube and probe unit (rotation frequency, translation velocity),
b) sorting and marking device,
c) adjustment and testing sensitivity level,
d) untested tube sites as well as
e) place of the test, test supervisory personnel and operators.

11.11.4 Magnetic flux leakage technique

11.11.4.1 General

The magnetic flux leakage testing shall be performed to DIN EN ISO 10893-3, acceptance level F2, in combination with the particulars of the following subsections for longitudinal and transverse defects.

11.11.4.2 Test system

For the test for longitudinal defects a technique with fixed or rotating magnetic field probes shall be used, and for the test for transverse defects a technique with multiple magnetic field probes.

11.11.4.3 Performance of test and evaluation of results

For the performance of the flux leakage test and the acceptance criteria the stipulations of DIN EN ISO 10893-3, acceptance class F2 apply. In addition, the following applies:

a) Each probe of the flux leakage test equipment shall be adjusted with the following reference notches for the test for both longitudinal and transverse defects:
   aa) reference notch on outer surface with a depth of 0.3 mm,
   ab) reference notch on the inner surface with a depth of 0.4 mm.

b) circular reference drill holes shall not be used for the adjustment of the test equipment

c) All locations on tubes where the trigger/alarm level is attained or exceeded, shall be identified with a permanent marking.

d) In addition to the information required according to DIN EN ISO 10893-3, the test report shall shall contain the following data:
   da) relative motion of tube and probe unit (rotation frequency, translation velocity),
   db) sorting and marking device,
   dc) adjustment and testing sensitivity level,
   dd) untested tube sites as well as
   de) place of the test, test supervisory personnel and operators.

Annex A

Material characteristic data

A 1 Ferritic steels of material group W I for flat products as well as parts made from flat products 69

A 2 Ferritic steels of material group W I for forgings, bars and rolled rings 77

A 3 Ferritic steels of material group W I for seamless pipes, seamless pipe elbows and seamless reducers 84

A 4 Castings for cases and bodies of ferritic cast steel of material group W I 89

A 5 High-tensile steels for quenching and tempering for bolts and nuts 91

A 6 Bars for bolts and nuts; additional stipulations 93

A 7 Castings of the martensitic steel G-X4 CrNi 13 4 (1.4317); additional stipulations 94

A 1 Ferritic steels of material group W I for flat products as well as parts made from flat products

A 1.1 General

Section A 1 defines the details for manufacture, chemical composition, characterizing mechanical and technological characteristics and heat treatment as well as for further processing of the following steel grades

a) 15 MnNi 6 3

b) 20 MnMoNi 5 5

c) 15 NiCuMoNb 5 S

d) WStE 255 S

e) WStE 285 S

f) WStE 315 S

g) WStE 355 S

for flat products and parts made from flat products.

A 1.2 Manufacture of the materials and delivery condition

A 1.2.1 Manufacture

(1) The steels shall be smelted by the basic oxygen process or in the electric furnace. If other processes are used, proof of equivalence shall be furnished.

(2) The steels shall be made in particularly killed condition.

A 1.2.2 Delivery condition

(1) The usual delivery condition for the steel grades is as follows:

a) 15 MnNi 6 3	normalized
b) 20 MnMoNi 5 5	quenched and tempered in liquid
c) 15 NiCuMoNb 5 S	normalized and tempered
d) WStE 255 S	normalized
e) WStE 285 S	normalized
f) WStE 315 S	normalized
g) WStE 355 S	normalized

(2) If the governing heat treatment is performed during further processing, the flat products to be supplied in normalized condition may also be delivered in rolled condition, and the flat products to be supplied in quenched and tempered condition may also be delivered in normalized or tempered condition or, in special cases, even in rolled condition.

(3) In special cases, a tempering treatment may be necessary for steel grades 15 MnNi 6 3 and WStB 355 S. This tempering treatment shall be indicated in the certificate.

A 1.3 Material characteristic values

A 1.3.1 Chemical composition

The values stipulated in **Table A 1-1** shall apply to the chemical composition per the ladle and product analyses.

A 1.3.2 Mechanical and technological characteristics

(1) The characteristic values of the mechanical and technological characteristics in the room-temperature tensile test are stipulated in **Table A 1-2.**

(2) The characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test are stipulated in **Table A 1-3**. The test temperatures for carrying out the elevated-temperature tensile test shall be as follows:

a) 15 MnNi 6 3	300 °C
b) 20 MnMoNi 5 5	350 °C
c) 15 NiCuMoNb 5 S	350 °C
d) WStE 255 S	300 °C
e) WStE 285 S	300 °C
f) WStE 315 S	300 °C
g) WStE 355 S	300 °C

(3) The characteristic values of impact energy and lateral expansion are stipulated in **Table A 1-4.**

(4) The data for impact energy and lateral expansion shall apply to standard specimens with a specimen width of 10 mm.

(5) The mechanical and technological characteristics shall be verified on specimens subjected to simulated stress-relief annealing. Unless otherwise agreed in the purchase order, the conditions for simulated stress-relief annealing shall be as follows:

a) holding time: 900 minutes,

b) annealing temp.: 560 °C to 580 °C,
600 °C to 620 °C for steel grades
20 MnMoNi 5 5 and 15 NiCuMoNb 5 S.

(6) The characteristic values shall apply to specimens taken and tested as per the stipulations in the Sections relating to product forms. The stipulations of **Table A 1-5** shall be taken into consideration for flat products.

A 1.3.3 Grain size

(1) The ferrite grain size at least shall comply with the following grain size index to DIN EN ISO 643:

a) 15 MnNi 6 3 grain size index 6,

b) 20 MnMoNi 5 5 grain size index 5,

c) 15 NiCuMoNb 5 S grain size index 6,

d) WStE 255 S grain size index 6,

e) WStE 285 S grain size index 6,

f) WStE 315 S grain size index 6,

g) WStE 355 S grain size index 6.

(2) For steels with contents of bainitic structure, the requirements shall apply only to the microstructural proportions of polygonal ferrite.

A 1.3.4 Physical characteristics

Reference values for the physical characteristics can be found in **Annex AP**.

A 1.4 Data on heat treatment

Reference values for heat treatment are presented in **Table A 1-6.**

A 1.5 Forming

A 1.5.1 Hot forming

Note:

Hot forming shall designate forming at temperatures above the highest temperature permissible for stress-relief annealing, even if the product forms are heated to the corresponding temperature only locally, in the forming zone. The term hot forming shall also include adaptation and straightening work at the corresponding temperatures.

(1) For hot forming, the flat products shall be heated above the lower limit temperature for normalization but not above 1050 °C. Grain coarsening due to excessively long times or to overheating shall be avoided.

(2) After hot forming, the complete product forms shall be subjected to renewed heat treatment as per the data in **Table A 1-6.**

(3) If the complete product form was heated above the lower limit temperature for normalization but not above 1000 C in the case of one-time hot forming or before the last step of hot forming in the case of hot forming in several steps, and if the forming process was completed above 750 °C, or above 700 °C in the case that the degree of forming in the last step did not exceed 5 %, subsequent normalization is not required for steel grades 15 MnNi 6 3, WStE 255 S, WStE 285 S, WStE 315 S and WStE 355 S; steel grade 15 NiCuMoNb 5 S shall merely require to be tempered. However, hot forming in several steps is subject to the condition that, before being heated for the last step, the product form in the case of steel grades 15 MnNi 6 3, WStE 255 S, WStE 285 S, WStE 315 S und WStE 355 S be cooled to a temperature below 550 °C and in the case of steel grade 15 NiCuMoNb 5 S be cooled to a temperature below 350 °C.

(4) The temperature control program shall be monitored.

(5) If the procedures employed differ from stipulations (1) to (3), e.g., in the case of forming with local heating without subsequent heat treatment of the complete product form, proof of equivalence shall be furnished.

A 1.5.2 Cold forming

Note:

Cold forming shall designate forming at room temperature or with heating up to the highest temperature permissible for stress-relief annealing.

(1) Heat treatment is not required after cold forming with degrees of forming smaller than or equal to 2 %.

(2) Stress-relief annealing shall be required after forming with degrees of cold forming between 2 % and smaller than or equal to 5 %,

(3) The governing heat treatment shall be performed after cold forming with degrees of forming larger than 5 %.

(4) For flat products with a degree of cold forming not exceeding 10 %, stress-relief annealing may be performed instead of the governing heat treatment if it is proved on a case-by-case basis that the stipulations for mechanical and technological characteristics are met.

(5) If different procedures are employed, proof of equivalence shall be furnished.

A 1.6 Thermal cutting and welding

A 1.6.1 Thermal cutting

SEW 088 shall be taken into consideration for thermal cutting. Recommended preheating temperatures are presented in **Table A 1-7**.

A 1.6.2 Welding

(1) Use of the following welding methods has been appraised as suitable for the steel grades to this Annex:

a) manual arc welding with basic-flux-coated rod electrodes,

b) submerged-are welding with basic fluxes,

c) inert-gas-shielded welding with wire electrodes or with basic-flux-cored wire electrodes.

(2) The examined work areas for welding are listed in **Table A 1-7**. Other work areas for welding are permitted, provided procedure qualification tests per KTA 3211.3 have been performed.

(3) The stipulations for welding per SEW 088 shall be observed. Basic coated rod electrodes or fluxes of basic characteristics shall preferably be used. Moreover, welding filler metals with the following diffusible hydrogen content shall be provided for steels if $R_{p0.2RT}$ is equal to or greater than 370 N/mm^2:

a) rod electrode weld metal:
equal to or smaller than 5 ml/100 g in the molten weld metal (H 5 to DIN EN ISO 2560);

b) submerged arc weld metal:
equal to or smaller than 5 ml/100 g in the molten weld metal (H 5 to DIN EN ISO 14174).

(4) Post-weld stress-relief annealing may be required, depending on wall thickness and geometry of the parts. The limit wall thickness values up to which stress-relief annealing may be waived are listed in **Table A 1-7**.

(5) Post-weld non-destructive examinations shall be performed after a waiting time of at least 48 hours after completion of the welding work. The waiting time may be waived for welds that are subjected to stress-relief annealing, hydrogen degassing or delayed cooling, or that were welded under shield gas.

Steel grade	Verification by	Limit value	Content by mass, % [1) 2)]															
			C	Si	Mn	P	S	Al_{total}	N	As	Cu	Cr	Mo	Nb	Ni	Sn	Ti	V
15 MnNi 6 3	Ladle analysis	min.	0.12	0.15	1.20			0.020							0.50			
		max.	0.18	0.35	1.65	0.015	0.005	0.055	0.015	0.015	0.06	0.15	0.05	0.004	0.85	0.010	0.020	0.020
	Product analysis	min.	0.10	0.15	1.15			0.015							0.50			
		max.	0.20	0.37	1.70	0.017	0.007	0.065	0.016	0.016	0.07	0.20	0.05	0.004	0.90	0.013	0.020	0.020
20 MnMoNi 5 5	Ladle analysis	min.	0.17	0.15	1.20			0.010					0.40		0.50			
		max.	0.23	0.30	1.50	0.012	0.008	0.040	0.013	0.025	0.12	0.20	0.55		0.80	0.011		0.020
	Product analysis	min.	0.15	0.10	1.15			0.010					0.40[3)]		0.45			
		max.	0.25	0.35	1.55	0.012[3)]	0.012[3)]	0.050	0.013[3)]	0.025	0.12[3)]	0.20	0.55		0.85	0.011[3)]		0.020
15 NiCuMoNb 5 S	Ladle analysis	min.		0.25	0.80			0.015			0.50		0.25	0.015	1.00			
		max.	0.17	0.50	1.20	0.016	0.005		0.020		0.80	0.30	0.40	0.025	1.30		0.020	0.020
	Product analysis	min.		0.21	0.75			0.010			0.45		0.20	0.010	0.95			
		max.	0.19	0.54	1.25	0.020	0.006		0.022		0.85	0.35	0.45	0.030	1.35		0.020	0.020
WStE 255 S	Ladle analysis	min.			0.40			0.020										
		max.	0.18	0.40	1.30	0.020	0.015		0.020		0.18[4)]	0.30[4)]	0.08[4)]	0.005	0.30		0.020	0.020
	Product analysis	min.			0.30			0.015										
		max.	0.20	0.45	1.40	0.025	0.020		0.022		0.25[4)]	0.34[4)]	0.11[4)]	0.005	0.35		0.020	0.020
WStE 285 S	Ladle analysis	min.			0.50			0.020										
		max.	0.18	0.40	1.40	0.020	0.015		0.020		0.18[4)]	0.30[4)]	0.08[4)]	0.005	0.30		0.020	0.020
	Product analysis	min.			0.40			0.015										
		max.	0.20	0.45	1.50	0.025	0.020		0.022		0.25[4)]	0.34[4)]	0.11[4)]	0.005	0.35		0.020	0.020
WStE 315 S	Ladle analysis	min.			0.60			0.020										
		max.	0.18	0.45	1.50	0.020	0.015		0.020		0.18[4)]	0.30[4)]	0.08[4)]	0.005	0.30		0.020	0.020
	Product analysis	min.			0.50			0.015										
		max.	0.20	0.50	1.60	0.025	0.020		0.022		0.25[4)]	0.34[4)]	0.11[4)]	0.005	0.35		0.020	0.020
WStE 355 S	Ladle analysis	min.		0.10	0.90			0.020										
		max.	0.20	0.50	1.65	0.020	0.015		0.020		0.18[4)]	0.30[4)]	0.08[4)]	0.005	0.30[5)]		0.020	0.020
	Product analysis	min.		0.05	0.80			0.015										
		max.	0.22	0.55	1.75	0.025	0.020		0.022		0.25[4)]	0.34[4)]	0.11[4)]	0.005	0.35[5)]		0.020	0.020

1) The differences that the tabulated values indicate between chemical compositions per the ladle and product analyses are sometimes smaller than would be expected from the metallurgical relationship. The reason is that the limit values for chemical composition per the product analysis are in this case based only on the heats covered by the appraisal. Thus the values will be reviewed once additional documents become available.

2) If the indicated limit contents per the ladle analysis are exceeded, the limit contents per the product analysis shall govern.

3) If these values are exceeded and allowance must be made in the product analysis for contents up to $P \leq 0.015$ %, $S \leq 0.015$ %, $Mo \leq 0.63$ %, $Cu \leq 0.18$ %, $Sn \leq 0.016$ % and $N_{total} \leq 0.015$ %, the authorized inspector shall check, until further information becomes available, as to whether welding simulation tests and if necessary tangential microsection examinations are necessary. If intermediate annealing at 550 °C is planned during further processing, the permissibility of this annealing temperature shall be verified during the said tests or examinations. The scope and conduct of these tests shall be agreed with the authorized inspector. The tests may be waived if so stipulated in the material appraisal.

4) The sum of the contents of chromium, copper and molybdenum shall not exceed 0.45 % in the ladle analysis or 0.50 % in the product analysis.

5) Depending on the authorized inspector's appraisal relative to the individual manufacturer, the maximum permissible nickel content shall be 0.85 % in the ladle analysis and 0.90 % in the product analysis.

Table A 1-1: Chemical composition of steel grades per the ladle and product analyses

Steel grade	Nominal thickness s mm	Tensile strength R_m N/mm²	Yield point [1] R_{eH} N/mm² at least	Elongation at fracture A % at least	Specimen direction	Reduction of area at fracture Z % (individual value) at least
15 MnNi 6 3	5 < s ≤ 38	510 to 630	370	22	longitudinal or transverse	45
	38 < s ≤ 50	510 to 630	350			
	50 < s ≤ 80	490 to 610	330			
	80 < s ≤ 100	470 to 600	320			
	100 < s ≤ 150	470 to 650	310			
15 MnNi 6 3 normalized and stress-relief-annealed	5 < s ≤ 38	490 to 610	330	22	longitudinal or transverse	45
	38 < s ≤ 50	490 to 610	330			
	50 < s ≤ 80	490 to 610	330			
	80 < s ≤ 100	470 to 600	320			
	100 < s ≤ 150	470 to 600	310			
20 MnMoNi 5 5	30 < s ≤ 70	590 to 730	450	18	longitudinal or transverse	45 [2]
	70 < s ≤ 150	570 to 710	430			45
	150 < s ≤ 600	560 to 700	390			45
15 NiCuMoNb 5 S	s ≤ 35	610 to 780	440	16		
	35 < s ≤ 50	610 to 780	440			
	50 < s ≤ 70	600 to 760	430			
	70 < s ≤ 85	600 to 760	430			
	85 < s ≤ 100	600 to 760	430			
	100 < s ≤ 125	600 to 750	420			
	125 < s ≤ 150	590 to 740	410			
WStE 255 S	s ≤ 35	360 to 480	255	25		
	35 < s ≤ 50	360 to 480	245			
	50 < s ≤ 70	360 to 480	235			
	70 < s ≤ 85	350 to 470	225			
	85 < s ≤ 100	340 to 460	215			
	100 < s ≤ 125	330 to 450	205			
	125 < s ≤ 150	320 to 440	195			
	150 < s ≤ 250	310 to 430	185	23		
WStE 285 S	s ≤ 35	390 to 510	285	24		
	35 < s ≤ 50	390 to 510	275			
	50 < s ≤ 70	390 to 510	265			
	70 < s ≤ 85	380 to 500	255			
	85 < s ≤ 100	370 to 490	245			
	100 < s ≤125	360 to 480	235			
	125 < s ≤ 150	350 to 470	225			
	150 < s ≤ 250	340 to 470	215	22		
WStE 315 S	s ≤ 35	440 to 560	315	23		
	35 < s ≤ 50	440 to 560	305			
	50 < s ≤ 70	440 to 560	295			
	70 < s ≤ 85	430 to 550	285			
	85 < s ≤ 100	420 to 540	275			
	100 < s ≤ 125	410 to 530	265			
	125 < s ≤ 150	400 to 520	255			
	150 < s ≤ 250	390 to 520	245	21		
WStE 355 S	s ≤ 35	490 to 630	355	22		
	35 < s ≤ 50	490 to 630	345			
	50 < s ≤ 70	490 to 630	335			
	70 < s ≤ 85	480 to 620	325			
	85 < s ≤ 100	470 to 610	315			
	100 < s ≤ 125	460 to 600	305			
	125 < s ≤ 150	450 to 590	295			
	150 < s ≤ 250	440 to 590	285	20		

[1] If the yield point is not emphasized, the values shall be applicable for the 0.2 % proof stress.

[2] For the steel grade 20 MnMoNi 5 5, the reduction of area at fracture shall additionally be subject to a smallest individual value of 35 % and a mean value of 45 % on perpendicular specimens.

Table A 1-2: Characteristic values of the mechanical and technological characteristics in the room-temperature tensile test on longitudinal and transverse specimens

Steel grade	Test temperature °C	Tensile strength R_m N/mm² at least			0.2 % proof stress $R_{p0.2}$ N/mm² at least				Elongation at fracture A % at least
		for nominal thicknesses in mm			for nominal thicknesses in mm				
		≥ 5 ≤ 50	> 50 ≤ 80	> 80 ≤ 150	≥ 5 ≤ 50	> 50 ≤ 80	> 80 ≤ 100	> 100 ≤ 150	
15 MnNi 6 3 normalized	100	470	460	440	340	315	305	295	
	145	450	440	420	320	290	280	270	
	200	440	430	410	290	260	250	240	
	250	440	430	410	270	250	240	230	
	300	440	430	410	250	230	220	210	
	350	440	430	410	230	210	200	190	
15 MnNi 6 3 normalized and stress-relief-annealed	100	420	420	420	300	300	290	280	
	145	410	410	410	290	290	280	270	
	200	410	410	410	260	260	250	240	
	250	400	400	400	250	250	240	230	
	300	400	400	400	230	230	220	210	
	350	400	400	400	210	210	200	190	
20 MnMoNi 5 5		for nominal thicknesses in mm			for nominal thicknesses in mm				
		≥ 30 ≤ 70	> 70 ≤ 150	> 150 ≤ 600	> 30 ≤ 70	> 70 ≤ 150	> 150 ≤ 200	> 200 ≤ 320	> 320 ≤ 600	
	100	550	530	520	431	412	382	370	370	17
	200	530	510	505	412	392	371	360	350	16
	300	530	510	505	392	371	353	350	330	16
	350	530	510	505	382	363	343	343	315	16
	375	530	505	505	377	358	338	330	300	16
	400	530	500	490	371	353	333	320	290	16

Table A 1-3: Characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test on longitudinal and transverse specimens (Part 1)

Steel grade	Test temperature °C	Tensile strength R_m, N/mm² at least						0.2 % proof stress $R_{p0.2}$, N/mm² at least							Elongation at fracture A % at least
		for nominal thicknesses in mm						for nominal thicknesses in mm							
		≤ 70	> 70 ≤ 85	> 85 ≤ 100	> 100 ≤ 125	> 125 ≤ 150	> 150 ≤ 250	≤ 35	> 35 ≤ 70	> 70 ≤ 85	> 85 ≤ 100	> 100 ≤ 125	> 125 ≤ 150	> 150 ≤ 250	
15 NiCuMoNb 5 S	100	540	540	540	530	520		402	402	402	402	392	382		
	150	530	530	530	520	510		392	392	392	392	382	373		
	200	520	520	520	510	500		383	383	383	383	373	363		
	250	520	520	520	510	500		373	373	373	373	363	353		
	300	520	520	520	510	500		363	363	363	363	353	343		
	350	510	510	510	500	490		353	353	353	353	343	333		
	400	500	500	500	490	480		333	333	333	333	323	313		
WStE 255 S	100	335	325	315	305	300	290	226	216	206	196	186	177	167	
	150	315	305	295	285	280	270	206	196	186	177	167	157	147	
	200	300	290	280	270	265	255	186	186	177	167	157	147	137	
	250	290	280	270	260	255	245	167	167	157	147	137	127	117	
	300	290	280	270	260	255	245	137	137	127	118	108	98	88	
	350	280	270	260	250	245	235	118	118	108	98	88	78	68	
	400	270	260	250	240	235	225	108	108	98	88	78	69	59	
WStE 285 S	100	360	350	340	330	320	310	255	245	235	226	216	206	196	
	150	345	335	325	315	305	295	235	226	216	206	196	186	176	
	200	330	320	310	300	290	280	206	206	196	186	177	167	157	
	250	320	310	300	290	280	270	186	186	177	167	157	147	137	
	300	320	310	300	290	280	270	157	157	147	137	127	118	108	
	350	305	295	285	275	270	265	137	137	127	118	108	98	88	
	400	295	285	275	265	260	255	118	118	108	98	88	78	68	
WStE 315 S	100	400	390	380	370	360	350	275	265	255	245	235	226	216	
	150	385	375	365	355	345	335	255	245	235	226	216	206	196	
	200	370	360	350	340	330	320	226	226	216	206	196	186	176	
	250	360	350	340	330	320	310	206	206	196	186	177	167	157	
	300	360	350	340	330	320	310	177	177	167	157	147	137	127	
	350	350	340	330	320	310	300	157	157	147	137	127	118	108	
	400	340	330	320	310	300	290	137	127	118	118	108	98	88	
WStE 355 S	100	430	420	410	400	390	380	304	294	284	275	265	255	245	
	150	420	410	400	390	380	370	284	275	265	255	245	235	225	
	200	410	400	390	380	370	360	255	255	245	235	226	216	206	
	250	400	390	380	370	360	350	235	235	226	216	206	196	186	
	300	400	390	380	370	360	350	216	216	206	196	186	177	167	
	350	390	380	370	360	350	340	196	196	186	177	167	157	147	
	400	380	370	360	350	340	330	167	167	157	147	137	127	117	

Table A 1-3: Characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test on longitudinal and transverse specimens (continued)

Steel grade	Nominal thickness s mm	Nature of value [1]	Impact energy in J at the temperature, °C at least						Lateral expansion in mm at the temperature, °C at least			
			-20	0	5	20	33	Upper shelf [2]	-20	5	33	Upper shelf [2]
15 MnNi 6 3	5 ≤ s 0≤ 150	MW	80	110	130	130	130	130				
		EW	68	90	100	100	100	100	0.9	1.3	1.3	1.3
20 MnMoNi 5 5	30 ≤ s ≤ 600 [4]	MW		41								
		EW		34			68 [3]	100			0.9 [3]	1.3
15 NiCuMoNb 5 S	10 ≤ s ≤ 150	MW		41								
		EW		34			68 [3]	100			0.9 [3]	1.3
WStE 255 S WStE 285 S WStE 315 S WStE 355 S	10 ≤ s ≤ 150	MW	21	41								
		EW	15	34			68 [3]	100			0.9 [3]	1.3
	150 ≤ s ≤ 250 [4]	MW	16	41								
		EW	11	34			68 [3]	100			0.9 [3]	1.3

[1] MW : mean value of 3 specimens, EW : individual value.

[2] The test is generally performed at 80 °C. The test may be waived if the requirements were already verified to be met at a lower temperature.

[3] If agreed in the purchase order, this requirement shall also apply at lower temperature, but not below 0 °C.

[4] For nominal thicknesses exceeding 150 mm, the smallest individual value of impact energy (transverse specimens) at the middle of the wall thickness at 80 °C shall not be less than 68 J.

Table A 1-4: Characteristic values of impact energy and lateral expansion in the notched-bar impact bend test on transverse specimens

Steel grade	Nominal thickness in mm	Delivered product length l in m per rolled plate	Sampling and location of the test coupons relative to the product width b
15 MnNi 6 3	all nominal thicknesses	l < 7	at one end at b/4
		l > 7	at both ends at b/4
20 MnMoNi 5 5	≥ 30 to ≤ 600	all lengths	at both ends at b/2 [1]
WStE 255 S WStE 285 S WStE 315 S WStE 355 S 15 NiCuMoNb 5 S	all nominal thicknesses	l < 7	at one end at b/4
		l > 7	at both ends at b/4

[1] The test cross sections shall be located by at least half the product thickness under the end and side surfaces from the edges straightened for the heat treatment. Notwithstanding the foregoing, the test sections from flat products with nominal thicknesses > 320 mm for pipe elbows shall be located at least 80 mm under the end and side surfaces from the edges straightened for the heat treatment.

Table A 1-5: Sampling and location of the test coupons (sampling locations)

Steel grade	Normalization °C	Temperature range in °C for		
		Quenching and tempering		Stress-relief annealing
		Austenitization	Tempering	
15 MnNi 6 3	880 to 960 [1]			530 to 580 [2]
20 MnMoNi 5 5		870 to 930 [2] [3]	630 to 690 [2]	580 to 620 [2] [4]
15 NiCuMoNb 5 S		900 to 980 [1]	640 to 680 [2]	580 to 620 [2]
WStE 255 S	900 to 950 [1]			530 to 580 [2]
WStE 285 S	900 to 950 [1]			530 to 580 [2]
WStE 315 S	890 to 940 [1]			530 to 580 [2]
WStE 355 S	880 to 940 [1]			530 to 580 [2]

[1] Cooling in stationary air after the temperature has been reached over the entire cross section.

[2] The heating and cooling rate, the temperature and the holding time shall be defined by the manufacturer and processor as a function of dimensions of the part, chemical composition and preceding heat treatments such that the requirements for mechanical and technological characteristics are met even allowing for subsequent heat treatments for the final condition of the complete part. Claddings shall also be taken into consideration (corrosion resistance, ductility).

[3] Water cooling.

[4] For multiple stress-relief annealing steps, the indicated temperature range shall be applicable for the last stress-relief annealing step. Preceding stress-relief annealing steps can be performed at 530 °C to 570 °C.

Table A 1-6: Data for heat treatment

Steel grade	Nominal thickness s mm	Thermal cutting Preheating temperature T_V	Welding [2]			Limit wall thickness for waiving stress-relief annealing after welding in mm
			Preheating temperature T_V and interpass temperature T_Z	Holding temperature [1] T_H	Cooling time $t_{8/5}$ sec.	
15 MnNi 6 3	$s \leq 15$	Room temp. $\leq T_V$	Room temp. $\leq T \leq 150$ °C	Room temp. $\leq T_H$	8 to 25	38 [3]
	$15 < s \leq 30$	Room temp. $\leq T_V$	80 °C $\leq T \leq$ 180 °C	Room temp. $\leq T_H$		
	$30 < s \leq 50$	100 °C $\leq T_V$	100 °C $\leq T \leq$ 220 °C	Room temp. $\leq T_H$		
	$50 < s \leq 150$	120 °C $\leq T_V$	120 °C $\leq T \leq$ 220 °C	Room temp. $\leq T_H$		
20 MnMoNi 5 5	$s > 15$	150 °C $\leq T_V \leq$ 250 °C	150 °C $\leq T \leq$ 250 °C	150 °C $\leq T_H \leq$ 250 [5]	7 to 25	Stress-relief annealing shall always be required
			120 °C $\leq T \leq$ 180 °C [4]	120 °C $\leq T_H \leq$ 180 [4] [5]		
15 NiCuMoNb 5 S	$s \leq 15$	Room temp. $\leq T_V$	Room temp. $\leq T \leq 150$ °C	Room temp. $\leq T_H$	8 to 35	
	$15 < s \leq 30$	Room temp. $\leq T_V$	80 °C $\leq T \leq$ 180 °C	Room temp. $\leq T_H$		
	$30 < s \leq 50$	70 °C $\leq T_V$	100 °C $\leq T \leq$ 220 °C	200 °C $\leq T_H$		
	$s > 50$	120 °C $\leq T_V$	120 °C $\leq T \leq$ 220 °C	120 °C $\leq T_H$		
WStE 255 S	$s \leq 15$	Room temp. $\leq T_V$	RT $\leq T \leq$ 150 °C	Room temp. $\leq T_H$	8 to 28	38 [3]
WStE 285 S	$15 < s \leq 50$	Room temp. $\leq T_V$	RT $\leq T \leq$ 180 °C	Room temp. $\leq T_H$		
WStE 315 S	$30 < s \leq 50$	Room temp. $\leq T_V$	80 °C $\leq T \leq$ 200 °C	80 °C $\leq T_H$		
	$s > 50$	120 °C $\leq T_V$	120 °C $\leq T \leq$ 220 °C	120 °C $\leq T_H$		
WStE 355 S	$s \leq 15$	Room temp. $\leq T_V$	RT $\leq T \leq$ 150 °C	Room temp. $\leq T_H$	8 to 25	38 [3]
	$15 < s \leq 30$	Room temp. $\leq T_V$	80 °C $\leq T \leq$ 180 °C	Room temp. $\leq T_H$		
	$30 < s \leq 50$	100 °C $\leq T_V$	100 °C $\leq T \leq$ 220 °C	200 °C $\leq T_H$		
	$s > 50$	120 °C $\leq T_V$	120 °C $\leq T \leq$ 220 °C	120 °C $\leq T_H$		

[1] See DIN EN ISO 13 916 for definition.

[2] If welding tests per KTA 3211.3 prove that the characteristics required for the application are also achieved with adequate safety under conditions other than those listed here, those conditions may be employed.

[3] In the case of simple geometric form and 100 % non-destructive examination of the welds, it is permitted to increase to ≤ 50 mm the limit wall thickness up to which post-welded stress-relief annealing may be waived.

[4] For weld cladding.

[5] The part shall be subjected to post-weld heating at about 280 °C from the heat of welding for more than 2 hours or to delayed cooling, unless stress-relief annealing is performed directly from the heat of welding or inert-gas-shielded welding is employed.

Table A 1-7: Particulars of thermal cutting and welding, together with limit wall thicknesses for stress-relief annealing

A 2 Ferritic steels of material group W I for forgings, bars and rolled rings

A 2.1 General

Section A 2 defines the details for manufacture, chemical composition, characterizing mechanical and technological characteristics and heat treatment as well as for further processing of the following steel grades

a) 15 MnNi 6 3

b) 20 MnMoNi 5 5

c) 15 NiCuMoNb 5 S

d) C 22.8 S

e) WStE 355 S

for forgings, bars and rolled rings.

A 2.2 Manufacture of the materials and delivery condition

A 2.2.1 Manufacture

(1) The steels shall be smelted by the basic oxygen process or in the electric furnace. If other processes are used, proof of equivalence shall be furnished.

(2) The steels shall be made in particularly killed condition.

A 2.2.2 Delivery condition

(1) The usual delivery condition for the steel grades is as follows:

a) 15 MnNi 6 3	normalized
b) 20 MnMoNi 5 5	quenched and tempered in liquid
c) 15 NiCuMoNb 5 S	normalized and tempered (quenched and tempered in air) or quenched and tempered in liquid
d) C 22.8 S	normalized, or also quenched and tempered in liquid for nominal thicknesses ≥ 150 mm
e) WStE 355 S	normalized or quenched and tempered

A 2.3 Material characteristic values

A 2.3.1 Chemical composition

The values stipulated in **Table A 2-1** shall apply to the chemical composition per the ladle and product analyses.

A 2.3.2 Mechanical and technological characteristics

(1) The characteristic values of the mechanical and technological characteristics in the room-temperature tensile test are stipulated in **Table A 2-2**.

(2) The characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test are stipulated in **Table A 2-3**. The test temperatures for carrying out the elevated-temperature tensile test for the various steel grades shall be as follows:

15 MnNi 6 3	300 °C
20 MnMoNi 5 5	350 °C
15 NiCuMoNb 5 S	350 °C
C 22.8 S	300 °C
WStE 355 S	300 °C

(3) The characteristic values of impact energy and lateral expansion are stipulated in **Table A 2-4**.

(4) The data for impact energy and lateral expansion shall apply to standard specimens with a specimen width of 10 mm.

(5) The mechanical and technological characteristics shall be verified on specimens subjected to simulated stress-relief annealing. For product forms of steel 20 MnMoNi 5 5 with nominal thicknesses up to and including 50 mm that are to be welded, the mechanical and technological characteristics shall be verified in the delivery condition.

(6) For simulated stress-relief annealing the requirements of **Table A 2-7** shall apply.

(7) The characteristics shall apply to specimens taken and tested as per the stipulations in the Sections relating to product forms.

A 2.3.3 Grain size

(1) The ferrite grain size at least shall comply with the following grain size index to DIN EN ISO 643:

a) 15 MnNi 6 3	grain size index 6,
b) 20 MnMoNi 5 5	grain size index 5,
c) 15 NiCuMoNb 5 S	grain size index 6,
d) C 22.8 S	grain size index 4,
e) WStE 355 S	grain size index 6.

(2) For steels with contents of bainitic structure, the requirements shall apply only to the microstructural proportions of polygonal ferrite.

A 2.3.4 Physical characteristics

Reference values for the physical characteristics can be found in **Annex AP**.

A 2.4 Data on heat treatment

Reference values for heat treatment are presented in **Table A 2-5.**

A 2.5 Forming

A 2.5.1 Hot forming

Note:

Hot forming shall designate forming at temperatures above the highest temperature permissible for stress-relief annealing, even if the product forms are heated to the corresponding temperature only locally, in the forming zone. The term hot forming shall also include adaptation and straightening work at the corresponding temperatures.

(1) For hot forming, the forgings shall be heated to at least 750 °C but not above 1050 °C. For hot forming, the forgings of 15 MnNi 6 3 shall be heated to at least 750 °C but not above 1100 °C. Grain coarsening due to excessively long times or to overheating shall be avoided. Hot forming of tubular forgings, e.g., for the manufacture of pipe elbows, shall be subject to the stipulations in Section A 3.

(2) After hot forming, the complete product forms shall be subjected to renewed heat treatment per the data in **Table A 2-5.**

(3) If the procedures employed differ from stipulations (1) and (2), e.g., in the case of forming with local heating without subsequent heat treatment of the complete product form, proof of equivalence shall be furnished.

(4) The temperature control program shall be monitored.

A 2.6 Thermal cutting and welding

A 2.6.1 Thermal cutting

SEW 088 shall be taken into consideration for thermal cutting. Recommended preheating temperatures are presented in **Table A 2-6.**

A 2.6.2 Welding

(1) Use of the following welding methods has been appraised as suitable for the steels per this Annex:

a) manual arc welding with basic-flux-coated rod electrodes,

b) submerged-arc welding with basic fluxes,

c) inert-gas-shielded welding with wire electrodes or with basic-flux-cored wire electrodes.

(2) The examined work areas for welding are listed in **Table A 2-6**. Other work areas for welding are permitted, provided procedure qualification tests per KTA 3211.3 have been performed.

(3) The stipulations for welding per SEW 088 shall be observed. Basic coated rod electrodes or fluxes of basic characteristics shall preferably be used. Moreover, welding filler metals with the following diffusible hydrogen content shall be provided for steels if $R_{p0.2RT}$ is equal to or greater than 370 N/mm^2:

a) rod electrode weld metal:
   equal to or smaller than 5 ml/100 g in the molten weld metal (H 5 to DIN EN ISO 2560);

b) submerged arc weld metal:
   equal to or smaller than 5 ml/100 g in the molten weld metal (H 5 to DIN EN ISO 14174).

(4) Post-weld stress-relief annealing may be required, depending on wall thickness and geometry of the parts. The nominal thicknesses at which stress-relief annealing may be waived are listed in **Table A 2-6**.

(5) Post-weld non-destructive examinations shall be performed after a waiting time of at least 48 hours after completion of the welding work. The waiting time may be waived for welds that are subjected to stress-relief annealing, hydrogen degassing or delayed cooling, or that were welded under shield gas.

Steel grade	Verification by	Limit value	Content by mass, % [1) 2)]															
			C	Si	Mn	P	S	Al_{total}	N	As	Cu	Cr	Mo	Nb	Ni	Sn	Ti	V
15 MnNi 6 3	Ladle analysis	min.	0.12	0.15	1.20			0.020							0.50			
		max.	0.18	0.35	1.65	0.015	0.005	0.055	0.015	0.015	0.06	0.15	0.05	0.004	0.85	0.010	0.020	0.020
	Product analysis	min.	0.10	0.15	1.15			0.015							0.50			
		max.	0.20	0.37	1.70	0.017	0.007	0.065	0.016	0.016	0.07	0.20	0.05	0.004	0.90	0.013	0.020	0.020
20 MnMoNi 5 5	Ladle analysis	min.	0.17	0.15	1.20			0.010					0.40		0.50			
		max.	0.23	0.30	1.50	0.012	0.008	0.040	0.013	0.025	0.12	0.20	0.55		0.80	0.011		0.020
	Product analysis	min.	0.15	0.10	1.15			0.010					0.40		0.45			
		max.	0.25	0.35	1.55	0.012[3)]	0.012[3)]	0.050	0.013[3)]	0.025	0.12 [3)]	0.20	0.55 [3)]		0.85	0.011[3)]		0.020
15 NiCuMoNb 5 S	Ladle analysis	min.	0.10	0.25	0.80			0.015			0.50		0.25	0.015	1.00			
		max.	0.17	0.50	1.20	0.016	0.005	0.035	0.020		0.80	0.30	0.40	0.025	1.30			0.020
	Product analysis	min.	0.08	0.21	0.75			0.010			0.45		0.20	0.010	0.95			
		max.	0.19	0.54	1.25	0.020	0.006	0.040	0.022		0.85	0.35	0.45	0.030	1.35			0.020
C 22.8 S	Ladle analysis	min.	0.18	0.15	0.40			0.015										
		max.	0.23	0.35	0.90	0.016	0.010	0.050			0.15	0.30						0.020
	Product analysis	min.	0.16	0.10	0.36			0.010										
		max.	0.25	0.40	0.95	0.020	0.015	0.055			0.18	0.35						0.020
WStE 355 S	Ladle analysis	min.		0.10	0.90			0.020										
		max.	0.20	0.50	1.65	0.020	0.015	0.070	0.020		0.18 [4)]	0.30 [4)]	0.08[4)]	0.005	0.30 [5)]		0.020	0.020
	Product analysis	min.		0.05	0.84			0.015										
		max.	0.22	0.55	1.75	0.025	0.020	0.075	0.022		0.25 [4)]	0.34 [4)]	0.11[4)]	0.006	0.35 [5)]		0.020	0.020

[1)] The differences that the tabulated values indicate between chemical compositions per the ladle and product analyses are sometimes smaller than would be expected from the metallurgical relationship. The reason is that the limit values for chemical composition per the product analysis are in this case based only on the heats covered by the appraisal. Thus the values will be reviewed once additional documents become available.

[2)] If the indicated limit contents per the ladle analysis are exceeded, the limit contents per the product analysis shall govern.

[3)] If these values are exceeded and allowance must be made in the product analysis for contents up to $P \leq 0.015$ %, $S \leq 0.015$ %, $Mo \leq 0.63$ %, $Cu \leq 0.18$ %, $Sn \leq 0.016$ % and $N_{total} \leq 0.015$ %, the authorized inspector shall check, until further information becomes available, as to whether welding simulation tests and if necessary tangential microsection examinations are necessary. If intermediate annealing at 550 °C is planned during further processing, the permissibility of this annealing temperature shall be verified during the said tests or examinations. The scope and conduct of these tests shall be agreed with the authorized inspector. The tests may be waived if so stipulated in the material appraisal.

[4)] The sum of the contents of chromium, copper and molybdenum shall not exceed 0.45 % in the ladle analysis or 0.50 % in the product analysis.

[5)] Depending on the authorized inspector's appraisal relative to the individual manufacturer, the maximum permissible nickel content shall be 0.85 % in the ladle analysis and 0.90 % in the product analysis.

Table A 2-1: Chemical composition of steel grades per the ladle and product analyses

Steel grade	Heat-treatment wall thickness s mm	Tensile strength R_m N/mm²	Yield point [1] R_{eH} N/mm² at least	Specimen direction	Elongation at fracture A % at least	Reduction of area at fracture Z %	
						Individual value	Mean value
15 MnNi 6 3	s ≤ 70	470 to 590	320	longitudinal / transverse	22	45	—
	70 < s ≤ 100	470 to 590	310	longitudinal / transverse	22	45	—
	100 < s ≤ 150	470 to 590	300	longitudinal / transverse	22	45	—
	150 < s ≤ 250	440 to 580	285	longitudinal / transverse	22	45	—
	250 < s ≤ 350	440 to 580	275	longitudinal / transverse	22	45	—
				perpendicular	—	35	45
20 MnMoNi 5 5	s ≤ 1000	560 to 700	390	longitudinal / transverse	19	45	—
				perpendicular	—	35	45
15 NiCuMoNb 5 S	s ≤ 400	580 to 740	430	longitudinal	20	—	—
				transverse	18	—	—
C 22.8 S	s ≤ 150	410 to 540	230	longitudinal	25	45	—
				transverse	20	45	—
	150 < s ≤ 320	400 to 520	210	longitudinal	25	45	—
				transverse	19	45	—
	320 < s ≤ 500	400 to 520	200	longitudinal	25	45	—
				transverse	19	45	—
WStE 355 S	s ≤ 100	490 to 630	335	longitudinal	23	—	—
				transverse	21	—	—
	100 < s ≤ 250	470 to 630	295	longitudinal	21	—	—
				transverse	19	—	—
	250 < s ≤ 400	470 to 630	275	longitudinal	21	—	—
				transverse	19	—	—

[1] If the yield point is not emphasized, the values shall be applicable for the 0.2 % proof stress.

Table A 2-2: Characteristic values of the mechanical and technological characteristics in the room-temperature tensile test

Steel grade	Test temperature °C	Tensile strength R_m N/mm² at least	0.2 % proof stress $R_{p0.2}$ N/mm² at least					Elongation at fracture A % at least (longitudinal or transverse)
		for heat-treatment wall thicknesses in mm						
		≤ 350	≤ 70	> 70 ≤ 100	> 100 ≤ 150	> 150 ≤ 250	> 250 ≤ 350	
15 MnNi 6 3	100	420	290	280	270	245	235	
	145	410	280	270	260	225	215	
	200	400	250	240	230	205	195	
	250	400	240	230	220	185	175	
	300	400	220	210	200	165	155	
	350	400	200	190	180	145	135	

Steel grade	Test temperature °C	for heat-treatment wall thicknesses in mm				
		≤ 1000	≤ 320	> 320 ≤ 1000	≤ 320	> 320 ≤ 1000
20 MnMoNi 5 5	100	520	370	370	17	16
	200	505	360	350	16	16
	300	505	350	330	16	15
	350	505	343	315	16	14
	375	505	330	300	16	14
	400	490	320	290	16	14

Steel grade	Test temperature °C	for heat-treatment wall thicknesses in mm		
		≤ 400	≤ 400	
15 NiCuMoNb 5 S	100	540	402	
	150	530	389	
	200	520	376	
	250	510	363	
	300	500	350	
	350	490	337	
	400	480	324	

Steel grade	Test temperature °C	for heat-treatment wall thicknesses in mm				
		≤ 500	≤ 150	> 150 ≤ 320	> 320 ≤ 500	
C 22.8 S	100	360	220	200	190	
	150	350	200	180	170	
	200	340	175	160	155	
	250	335	155	140	135	
	300	335	135	125	115	
	350	335	115	105	100	
	400	300	90	85	80	

Steel grade	Test temperature °C	for heat-treatment wall thicknesses in mm				
		≤ 400	≤ 100	> 100 ≤ 250	> 250 ≤ 400	
WStE 355 S	100	410	294	255	235	
	150	400	275	235	215	
	200	390	255	216	197	
	250	380	235	196	179	
	300	380	216	177	160	
	350	370	196	157	142	
	400	360	167	127	117	

Table A 2-3: Characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test

Steel grade	Nominal thickness s mm	Nature of value [1]	Impact energy at the temperature, °C at least						Lateral expansion in mm at the temperature, °C at least			
			- 20	0	+ 5	+20	+33	Upper shelf [2]	- 20	+ 5	+ 33	Upper shelf [2]
15 MnNi 6 3	s ≤ 150	MW	80	110	130	130	130	130				
		EW	68	90	100	100	100	100	0,9	1,3	1,3	1,3
	150 < s ≤ 350	MW	70	90	110	130	130	130				
		EW	56	72	88	100	100	100	0,9	1,3	1,3	1,3
20 MnMoNi 5 5	s ≤ 1000	MW		41								
		EW		34			68 [3]	100			0,9 [3]	1,3
15 NiCuMoNb 5 S	s ≤ 400	MW	60	80		95						
		EW	42	56		66	68 [3]	100			0,9 [3]	1,3
C 22.8 S	s ≤ 500	MW		41		49						
		EW		34		42	68 [3]	100			0,9 [3]	1,3
WStE 355 S	s ≤ 400	MW		41								
		EW		34			68 [3]	100			0,9 [3]	1,3

[1] MW : mean value of 3 specimens, EW : individual value.

[2] The test is generally performed at 80 °C. The test may be waived if the requirements were already verified to be met at a lower temperature.

[3] If agreed in the purchase order, this requirement shall also apply at lower temperature, but not below 0 °C.

Table A 2-4: Characteristic values of impact energy and lateral expansion in the notched-bar impact bend test on transverse specimens

Steel grade	Normalization °C	Temperature range for		
		Quenching and tempering		Stress-relief annealing [3]
		Austenitization °C	Tempering °C	°C
15 MnNi 6 3	880 to 960 [1]			530 to 580
20 MnMoNi 5 5 [5]		870 to 940 [2]	630 to 680	580 to 620
15 NiCuMoNb 5 S		900 to 980 [1]	640 to 670	580 to 620
		880 to 930 [4]	640 to 690 [4]	580 to 620
C 22.8 S	880 to 920 [1]	870 to 910 [2]	640 to 660	530 to 600
WStE 355 S	880 to 920 [1]	880 to 940 [4]	610 to 680	530 to 580

[1] Cooling in stationary air after the temperature has been reached over the entire cross section.

[2] Cooling in water.

[3] For multiple stress-relief annealing steps, the indicated temperature range shall be applicable for the last stress-relief annealing step. Preceding stress-relief annealing steps can be performed at 530 °C to 570 °C.

[4] Cooling in oil or water. This treatment shall be employed for relatively large heat-treatment wall thicknesses, in order to be able to maintain the minimum temperature of 640 °C for tempering.

[5] Two-stage quenching and tempering are permitted, depending on the authorized inspector's appraisal.

Table A 2-5: Data for heat treatment

Steel grade	Nominal thickness s mm	Thermal cutting Preheating temperature T_V	Welding [2] Preheating temperature T_V and interpass temperature T_Z	Welding [2] Holding temperature T_H [1]	Welding [2] Cooling time $t_{8/5}$ seconds	Limit wall thickness for waiving stress-relief annealing after welding mm
15 MnNi 6 3	s ≤ 15	Room temp. ≤ T_V	Room temp. ≤ T ≤ 150 °C	Room temp. ≤ T_H	8 to 25	38 [5]
	15 < s ≤ 30	Room temp. ≤ T_V	80 °C ≤ T ≤ 180 °C	Room temp. ≤ T_H		
	30 < s ≤ 50	100 °C ≤ T_V	100 °C ≤ T ≤ 220 °C [3]	100 °C ≤ T_H		
	50 < s ≤ 150	120 °C ≤ T_V	120 °C ≤ T ≤ 220 °C [3]	120 °C ≤ T_H		
20 MnMoNi 5 5	s > 15	150 °C ≤ T_V ≤ 250 °C	150 °C ≤ T ≤ 250 °C [3]	150 °C ≤ T_H ≤ 250 °C	7 to 25	Stress-relief annealing shall always be required
				120 °C ≤ T_H ≤ 180 °C [4]		
15 NiCuMoNb 5 S	s ≤ 15	Room temp. ≤ T_V	80 °C ≤ T ≤ 180 °C	Room temp. ≤ T_H	10 to 25	Stress-relief annealing shall always be required
	15 < s ≤ 30	Room temp. ≤ T_V	100 °C ≤ T ≤ 180 °C	100 °C ≤ T_H		
	30 < s ≤ 50	100 °C ≤ T_V	120 °C ≤ T ≤ 220 °C	120 °C ≤ T_H		
	s > 50	120 °C ≤ T_V	120 °C ≤ T ≤ 220 °C			
C 22.8 S	s ≤ 30	Room temp. ≤ T_V	80 °C ≤ T ≤ 150 °C	Room temp. ≤ T_H	8 to 25	30
	30 < s ≤ 50	Room temp. ≤ T_V	80 °C ≤ T ≤ 200 °C [3]	Room temp. ≤ T_H		
	s > 50	120 °C ≤ T_V	120 °C ≤ T ≤ 220 °C [3]	120 °C ≤ T_H		
WStE 355 S	s ≤ 15	Room temp. ≤ T_V	Room temp. ≤ T ≤ 150 °C	Room temp. ≤ T_H	8 to 25	38 [5]
	15 < s ≤ 30	Room temp. ≤ T_V	80 °C ≤ T ≤ 180 °C	Room temp. ≤ T_H		
	30 < s ≤ 50	100 °C ≤ T_V	100 °C ≤ T ≤ 220 °C [3]	100 °C ≤ T_H		
	s > 50	120 °C ≤ T_V	120 °C ≤ T ≤ 220 °C [3]	120 °C ≤ T_H		

1) See DIN EN ISO 13 916 for definition.

2) If welding tests per KTA 3211.3 prove that the characteristics required for the application are also achieved with adequate safety under conditions other than those listed here, those conditions may be employed.

3) At most 180 °C for weld cladding.

4) The part shall be subjected to post-weld heating at about 280 °C from the heat of welding for more than 2 hours or to delayed cooling, unless stress-relief annealing is performed directly from the heat of welding or inert-gas-shielded welding is employed.

5) In the case of simple geometric form and 100 % non-destructive examination of the welds, it is permitted to increase the limit wall thickness to ≤ 50 mm, unless special requirements of heat-treatment condition are imposed.

Table A 2-6: Particulars of thermal cutting and welding, together with limit wall thicknesses for stress-relief annealing

Steel grade	Verification necessary	Simulated stress-relief annealing Temperature in °C	Simulated stress-relief annealing Holding time [1] in minutes
15 MnNi 6 3	yes [2]	560 to 580	900
20 MnMoNi 5 5		600 to 620	
15 NiCuMoNb 5 S		600 to 620	
C 22.8 S		580 to 600	
WStE 355 S		560 to 580	

1) These data shall apply only if no other particulars were required in the purchase order.

2) See clause A 2.3.2 (5) for verification of product forms of the steel 20 MnMoNi 5 5.

Table A 2-7: Necessity for verification of mechanical characteristics in the simulated stress-relief-annealed condition, and performance of the simulated stress-relief annealing process

A 3 Ferritic steels of material group W I for seamless pipes, seamless pipe elbows and seamless reducers

A 3.1 General

Section A 3 defines the details for manufacture, chemical composition, characterizing mechanical and technological characteristics and heat treatment as well as for further processing of the following steel grades

a) 15 MnNi 6 3

b) 20 MnMoNi 5 5

c) 15 NiCuMoNb 5 S

for seamless pipes, seamless pipe elbows and seamless reducers.

A 3.2 Manufacture of the materials and delivery condition

A 3.2.1 Manufacture

(1) The steels shall be smelted by the basic oxygen process or in the electric furnace. If other processes are used, proof of equivalence shall be furnished.

(2) The steels shall be made in particularly killed condition.

A 3.2.2 Delivery condition

(1) The usual delivery condition for the steel grades is as follows:

a)	15 MnNi 6 3	normalized
b)	20 MnMoNi 5 5	quenched and tempered in liquid
c)	15 NiCuMoNb 5 S	normalized and tempered (quenched and tempered in air) or quenched and tempered in liquid

(2) If the governing heat treatment is performed during further processing, the pipes to be supplied in normalized condition may also be delivered in rolled condition, and the pipes to be supplied in quenched and tempered condition may also be delivered in normalized or tempered condition or, in special cases, even in rolled condition.

A 3.3 Material characteristic values

A 3.3.1 Chemical composition

The values stipulated in **Table A 3-1** shall apply to the chemical composition per the ladle and product analyses.

A 3.3.2 Mechanical and technological characteristics

(1) The characteristic values of the mechanical and technological characteristics in the room-temperature tensile test are stipulated in **Table A 3-2**.

(2) The characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test are stipulated in **Table A 3-3**. The test temperature for carrying out the elevated-temperature tensile test for the various steel grades shall be as follows:

15 MnNi 6 3	300 °C
20 MnMoNi 5 5	350 °C
15 NiCuMoNb 5 S	350 °C

(3) The characteristic values of impact energy and lateral expansion are stipulated in **Table A 3-4**.

(4) The data for impact energy and lateral expansion shall apply to standard specimens with a specimen width of 10 mm.

(5) The mechanical and technological characteristics shall be verified on specimens subjected to simulated stress-relief annealing (see **Table A 3-5**). For product forms of steel 20 MnMoNi 5 5 with nominal thicknesses up to and including 50 mm that are to be welded, the mechanical and technological characteristics shall be verified in the delivery condition.

A 3.3.3 Grain size

(1) The ferrite grain size at least shall comply with the following grain size index to DIN EN ISO 643:

a)	15 MnNi 6 3	grain size index 6,
b)	20 MnMoNi 5 5	grain size index 5,
c)	15 NiCuMoNb 5 S	grain size index 6.

(2) For steels with contents of bainitic structure, the requirements shall apply only to the microstructural proportions of polygonal ferrite.

A 3.3.4 Physical characteristics

Reference values for the physical characteristics can be found in **Annex AP**.

A 3.4 Data on heat treatment

Reference values for heat treatment are presented in **Table A 3-6**.

A 3.5 Forming

A 3.5.1 Hot forming

Note:

Hot forming shall designate forming at temperatures above the highest temperature permissible for stress-relief annealing, even if the product forms are heated to the corresponding temperature only locally, in the forming zone. The term hot forming shall also include adaptation and straightening work at the corresponding temperatures.

(1) For hot forming, the pipes shall be heated to at least 750 °C but not above 1050 °C. For hot forming, the pipes of steel 15 MnNi 6 3 shall be heated to at least 750 °C but not above 1100 °C. Forging and upsetting shall be performed in the upper portion of the temperature range at 1100 °C to 900 °C. Hot bending of pipes and similar forming work shall be performed in the lower portion of the temperature range. Grain coarsening due to excessively long times or to overheating shall be avoided.

(2) After hot forming, the complete product forms shall be subjected to renewed heat treatment as per the data in **Table A 3-5**.

(3) If the procedures employed differ from stipulations (1) to (2), e.g., in the case of forming with local heating without subsequent heat treatment of the complete product form, proof of equivalence shall be furnished.

(4) The temperature control program shall be monitored.

A 3.5.2 Cold forming and cold bending

Note:

Cold forming and cold bending shall designate forming at room temperature or with heating up to the highest temperature permissible for stress-relief annealing.

(1) Heat treatment is not required after cold forming with degrees of forming smaller than or equal to 2 %.

(2) Stress-relief annealing shall be required after forming with degrees of cold forming between 2 % and smaller than or equal to 5 %.

(3) The governing heat treatment shall be performed after cold forming with degrees of forming larger than 5 %.

(4) If different procedures are employed, proof of equivalence shall be furnished.

(5) For cold-bending processes, heat treatment after cold bending may be waived if appropriate proof is furnished. Weld-on work and straightening work shall not be permitted in the zone of cold bends.

Note:

Cold bends shall be defined as machine-made cold bends of pipes with $\leq$ DN *150 and with bend radii* $R_m > 2.5 \cdot D_a$.

A 3.6 Thermal cutting and welding

A 3.6.1 Thermal cutting

SEW 088 shall be taken into consideration for thermal cutting. Recommended preheating temperatures are presented in **Table A 3-7**.

A 3.6.2 Welding

(1) Use of the following welding methods has been appraised as suitable:

a) manual arc welding with basic-flux-coated rod electrodes,

b) submerged-arc welding with basic fluxes,

c) inert-gas-shielded welding with wire electrodes or with basic-flux-cored wire electrodes

(2) The examined work areas for welding are listed in **Table A 3-7**. Other work areas for welding are permitted, provided procedure qualification tests per KTA 3211.3 have been performed.

(3) The stipulations for welding per SEW 088 shall be observed. Basic coated rod electrodes or fluxes of basic characteristics shall preferably be used. Moreover, welding filler metals with the following diffusible hydrogen content shall be provided for steels if $R_{p0.2RT}$ is equal to or greater than 370 N/mm^2:

a) rod electrode weld metal:
   equal to or smaller than 5 ml/100 g in the molten weld metal (H 5 to DIN EN ISO 2560);

b) submerged arc weld metal:
   equal to or smaller than 5 ml/100 g in the molten weld metal (H 5 to DIN EN ISO 14174).

(4) Post-weld stress-relief annealing may be required, depending on nominal thickness and geometry of the parts. The nominal thicknesses at which stress-relief annealing may be waived are listed in **Table A 3-7**.

(5) Post-weld non-destructive examinations shall be performed after a waiting time of at least 48 hours after completion of the welding work, The waiting time may be waived for welds that are subjected to stress-relief annealing, hydrogen degassing or delayed cooling, or that were welded under shield gas.

Steel grade	Verification by	Limit value	Content by mass, % [1) 2)]															
			C	Si	Mn	P	S	Al_{total}	N	As	Cu	Cr	Mo	Nb	Ni	Sn	Ti	V
15 MnNi 6 3	Ladle analysis	min.	0.12	0.15	1.20			0.020							0.50			
		max.	0.18	0.35	1.65	0.015	0.005	0.055	0.015	0.015	0.06	0.15	0.05	0.004	0.85	0.010	0.020	0.020
	Product analysis	min.	0.10	0.15	1.15			0.015							0.50			
		max.	0.20	0.37	1.70	0.017	0.007	0.065	0.016	0.016	0.07	0.20	0.05	0.004	0.90	0.013	0.020	0.020
20 MnMoNi 5 5	Ladle analysis	min.	0.17 [4)]	0.15	1.20			0.010					0.40		0.50			
		max.	0.23	0.30	1.50	0.012	0.008	0.040	0.013	0.025	0.12	0.20	0.55		0.80	0.011		0.020
	Product analysis	min.	0.15 [4)]	0.10	1.15			0.010					0.40		0.45			
		max.	0.25	0.35	1.55	0.012[3)]	0.012[3)]	0.050	0.013[3)]	0.025	0.12 [3)]	0.20	0.55 [3)]		0.85	0.011[3)]		0.020
15 NiCuMoNb 5 S	Ladle analysis	min.	0.10	0.25	0.80			0.015			0.50		0.25	0.15	1.00			
		max.	0.17	0.50	1.20	0.016	0.005	0.035	0.020		0.80	0.30	0.40	0.025	1.30			0.020
	Product analysis	min.	0.08	0.21	0.75			0.010			0.45		0.20	0.010	0.95			
		max.	0.19	0.54	1.25	0.020	0.006	0.040	0.022		0.85	0.35	0.45	0.030	1.35			0.020

1) The differences that the tabulated values indicate between chemical compositions per the ladle and product analyses are sometimes smaller than would be expected from the metallurgical relationship. The reason is that the limit values for chemical composition per the product analysis are in this case based only on the heats covered by the appraisal. Thus the values will be reviewed once additional documents become available.

2) If the indicated limit contents per the ladle analysis are exceeded, the limit contents per the product analysis shall govern.

3) If these values are exceeded and allowance must be made in the product analysis for contents up to $P \leq 0.015$ %, $S \leq 0.015$ %, $Mo \leq 0.63$ %, $Cu \leq 0.18$ %, $Sn \leq 0.016$ % and $N_{total} \leq 0.015$ %, the authorized inspector shall check, until further information becomes available, as to whether welding simulation tests and if necessary tangential microsection examinations are necessary. If intermediate annealing at 550 °C is planned during further processing, the permissibility of this annealing temperature shall be verified during the said tests or examinations. The scope and conduct of these tests shall be agreed with the authorized inspector. The tests may be waived if so stipulated in the material appraisal.

4) For quenched and tempered wall thicknesses smaller than or equal to 30 mm, the following C contents shall be permissble: larger than or equal to 0.14 % and smaller than or equal to 0.18 % for the ladle analysis; and larger than or equal to 0.12 % and smaller than or equal to 0.20 % for the product analysis.

Table A 3-1: Chemical composition of steel grades per the ladle and product analyses

Steel grade	Heat-treatment wall thickness mm	Tensile strength R_m N/mm²	Yield point [1] R_{eH} N/mm² at least	Specimen direction	Elongation at fracture A % at least	Reduction of area at fracture Z % at least	
						Individual value	Mean value
15 MnNi 6 3	≤ 70	490 to 610	330	longitudinal	24	45	—
				transverse	22	45	—
	> 70 ≤ 130	470 to 590	310	transverse	22	45	—
				longitudinal	24	45	—
				perpendicular	—	35	45
20 MnMoNi 5 5	≥ 15 ≤ 100	570 to 710	430	longitudinal / transverse	19	45	—
	< 100 ≤ 200	560 to 700	390	longitudinal / transverse	19	45	—
				perpendicular	—	35	45
15 NiCuMoNb 5 S	≤ 60	610 to 760	440	longitudinal	19	—	—
				transverse	17	—	—
				perpendicular	—	25	35

[1] If the yield point is not emphasized, the values shall be applicable for the 0.2 % proof stress.

Table A 3-2: Characteristic values of the mechanical and technological characteristics in the room-temperature tensile test

Steel grade	Test temperature °C	Tensile strength R_m N/mm² at least		0.2 % proof stress $R_{p0.2}$ N/mm² at least		Elongation at fracture A % at least (longitudinal or transverse)
		for heat-treatment wall thicknesses in mm				
		≤ 70	> 70 ≤ 130	≤ 70	> 70 ≤ 130	
15 MnNi 6 3	100	420	400	285	260	
	145	415	375	275	240	
	200	400	375	245	220	
	250	400	375	220	200	
	300	400	375	210	190	
	350	390	375	190	170	
		for heat-treatment wall thicknesses in mm				
		≥15 ≤ 100	> 100 ≤ 200	≥ 15 ≤ 100	> 100 ≤ 200	
20 MnMoNi 5 5	100	530	530	412	370	16
	200	513	510	392	360	
	300	513	510	371	350	
	350	513	510	363	343	
	375	505	505	358	330	
	400	500	500	353	320	
		for heat-treatment wall thicknesses in mm				
		≤ 60		≤ 60		
15 NiCuMoNb 5 S	100	540		422		
	150	530		412		
	200	520		402		
	250	520		392		
	300	520		382		
	350	510		373		
	400	500		343		

Table A 3-3: Characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test

Steel grade	Nominal wall thickness s mm	Nature of value [1]	Impact energy in J at the temperature, °C at least						Lateral expansion in mm at the temperature. °C at least			
			-20	0	+5	+20	+33	Upper shelf [2]	-20	+5	+33	Upper shelf [2]
15 MnNi 6 3	≤ 130	MW	80	110	130	130	130	130				
		EW	68	90	100	100	100	100	0,9	1,3	1,3	1,3
20 MnMoNi 5 5	≤ 200	MW		41 [4]								
		EW		34 [4]			68 [3]	100			0,9	1,3
15 NiCuMoNb 5 S	≤ 60	MW	60	80		95						
		EW	42	56		66	68 [3]	100			0,9	1,3

[1] MW : mean value of 3 specimens, EW : individual value.

[2] The test is generally performed at 80 °C. The test may be waived if the requirements were already verified to be met at a lower temperature.

[3] If agreed in the purchase order, this requirement shall also apply at lower temperature, but not below 0 °C.

[4] For longitudinal specimens the minimum mean value shall be 60 J and the minimum individual value shall be 51 J.

Table A 3-4: Characteristic values of impact energy and lateral expansion in the notched-bar impact bend test on transverse specimens

Steel grade	Verification necessary	Simulated stress-relief annealing	
		Temperature in °C	Holding time [1] in minutes
15 MnNi 6 3	yes	560 to 580	900
20 MnMoNi 5 5	yes	600 to 620	900
15 NiCuMoNb 5 S	yes	600 to 620	900

[1] These data shall apply only if no other particulars were required in the purchase order.

Table A 3-5: Necessity for verification of mechanical characteristics in the simulated stress-relief-annealed condition, and performance of the simulated stress-relief annealing process

Steel grade	Normalization °C	Temperature range for quenching and tempering		Stress-relief annealing [3] °C
		Austenitization °C	Tempering °C	
15 MnNi 6 3	880 to 960 [1]			530 to 580
20 MnMoNi 5 5		870 to 930 [2]	630 to 690	580 to 620
15 NiCuMoNb 5 S		900 to 980 [1]	640 to 680	580 to 620
		880 to 930 [4]	640 to 690 [4]	580 to 620

[1] Cooling in stationary air after the temperature has been reached over the entire cross section.

[3] Cooling in water.

[3] For multiple stress-relief annealing steps, the indicated temperature range shall be applicable for the last stress-relief annealing step. Preceding stress-relief annealing steps can be performed at 530 °C to 570 °C.

[4] Cooling in oil or water. This treatment shall be employed for relatively large heat-treatment wall thicknesses, in order to be able to maintain the minimum temperature of 640 °C for tempering.

Table A 3-6: Data for heat treatment

Steel grade	Nominal wall thickness s mm	Thermal cutting Preheating temperature T_V	Welding [1] Preheating temperature T_V and interpass temperature T_Z	Welding [1] Holding temperature [2] T_H	Cooling time $t_{8/5}$ seconds	Limit wall thickness for waiving stress-relief annealing after welding mm
15 MnNi 6 3	$s \le 15$	Room temp. $\le T_V$	Room temp. $\le T \le 150$ °C	Room temp. $\le T_H$	8 to 25	38 [5]
	$15 < s \le 30$	Room temp. $\le T_V$	80 °C $\le T \le$ 180 °C	Room temp. $\le T_H$		
	$30 < s \le 50$	100 °C $\le T_V$	100 °C $\le T \le$ 220 °C [3]	100 °C $\le T_H$		
	$s > 50$	120 °C $\le T_V$	120 °C $\le T \le$ 220 °C [3]	120 °C $\le T_H$		
20 MnMoNi 5 5	$s \ge 15$	150 °C $\le T_V \le$ 250 °C	150 °C $\le T \le$ 250 °C [3]	150 °C $\le T_H \le$ 250 °C [4]	7 to 25	Stress-relief annealing shall always be required
				120 °C $\le T_H \le$ 180 °C [6]		
15 NiCuMoNb 5 S	$s \le 15$	Room temp. $\le T_V$	80 $\le T \le$ 150 °C	Room temp. $\le T_H$	10 to 30	
	$15 < s \le 30$	Room temp. $\le T_V$	100 °C $\le T \le$ 180 °C	100 °C $\le T_H$		
	$30 < s \le 50$	100 °C $\le T_V$	120 °C $\le T \le$ 220 °C [3]	120 °C $\le T_H$		
	$s > 50$	120 °C $\le T_V$	120 °C $\le T \le$ 220 °C [3]	120 °C $\le T_H$		

1) If welding tests per KTA 3211.3 prove that the characteristics required for the application are also achieved with adequate safety under conditions other than those listed here, those conditions may be employed.

2) See DIN EN ISO 13916 for definition.

3) At most 180 °C for weld cladding.

4) The part shall be subjected to post-weld heating at about 280 °C from the heat of welding for more than 2 hours or to delayed cooling, unless stress-relief annealing is performed directly from the heat of welding or inert-gas-shielded welding is employed.

5) In the case of simple geometric form and 100 % non-destructive examination of the welds, it is permitted to increase the limit wall thickness to ≤ 50 mm, unless special requirements of heat-treatment condition are imposed.

6) For weld cladding.

Table A 3-7: Particulars of thermal cutting and welding, together with limit wall thicknesses for stress-relief annealing

A 4 Castings for cases and bodies of ferritic cast steel of material group W I

A 4.1 General

Section A 4 defines the details for manufacture, chemical composition, characterizing mechanical and technological characteristics and heat treatment as well as for further processing of the following cast-steel grade

GS-C 25 S

for cases and bodies.

Note:

The following stipulations are provisional, since the supplementary appraisal of cast-steel grade GS-C 25 S with regard to meeting the requirements beyond those for cast-steel grade GP240GH (material number 1.0619) to DIN *10213 have not yet been completed and an individual appraisal is required.*

A 4.2 Manufacture of the steels

The steels shall be smelted by the basic oxygen process or in the electric furnace. If other processes are used, proof of equivalence shall be furnished.

A 4.3 Material characteristic values

A 4.3.1 Chemical composition

The values stipulated in **Table A 4-1** shall apply to the chemical composition per the ladle and product analysis.

A 4.3.2 Mechanical and technological characteristics

(1) The characteristic values of the mechanical and technological characteristics in the room-temperature tensile test, including the minimum values of elongation at fracture, are stipulated in **Table A 4-2**.

(2) The characteristic values of the mechanical and technological characteristics at elevated temperatures are stipulated in **Table A 4-3**. Verification shall be required only if the design temperature is higher than 100 °C for cast-steel grade GS-C 25 S, unless otherwise stipulated in the authorized inspector's appraisal.

(3) The characteristic values of impact energy are stipulated in **Table A 4-4**.

(4) The data for impact energy shall apply to standard specimens with a specimen width of 10 mm.

(5) The mechanical and technological characteristics shall be verified as per **Table A 4-6**.

A 4.3.3 Physical characteristics

Reference values for the physical characteristics can be found in **Annex AP**.

A 4.4 Data on heat treatment

Reference values for heat treatment are presented in **Table A 4-5**.

Steel grade	Verification by	Limit value	Content by mass, %													
			C	Si	Mn	P	S	Al_{total}	N	As	Cr	Cu	Mo	Ni	Sn	V
GS-C 25 S	Ladle analysis	min.	0.18	0.30	0.50	—	—	0.020	—	—	—	—	—	—	—	—
		max.	0.22	0.60	1.10	0.015	0.010	0.070	0.015	—	0.30	0.18	—	—	—	0.02
	Product analysis	min.	0.18	0.30	0.50	—	—	0.020	—	—	—	—	—	—	—	—
		max.	0.22	0.60	1.10	0.015	0.012	0.070	0.015	—	0.30	0.18	—	—	—	0.02

Table A 4-1: Chemical composition per the ladle and product analyses

Steel grade	Nominal thickness in mm maximum	0.2 %-proof stress $R_{p0.2}$, N/mm² at least	Tensile strength R_m, N/mm²	Elongation at fracture A, % at least
GS-C 25 S	100	245	440 up to 590	22

Table A 4-2: Characteristic values of the mechanical and technological characteristics in the room-temperature tensile test

Steel grade	0.2 %-proof stress [1] $R_{p0.2}$, N/mm² at least at temperature, °C						Tensile strength [1] R_m, N/mm² at least at temperature, °C						Elongation at fracture [1] A, % at least at temperature, °C					
	100	200	250	300	350	400	100	200	250	300	350	400	100	200	250	300	350	400
GS-C 25	(205)	175	(160)	145	135	130	(410)	(400)	(400)	(390)	(375)	(355)	(21)	(20)	(19)	(18)	(20)	(25)

[1] The values in parentheses must still be substantiated by statistics.

Table A 4-3: Characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test

Stahlsorte	Impact energy in J at least			Upper shelf [2] of the impact energy in J at least
	at 0 °C		at 33 °C [1]	
	Mean value of 3 specimens	Individual value	Mean value of 3 specimens	Individual value
GS-C 25 S	41	34	68	100

[1] If agreed in the purchase order, this requirement shall also apply at lower temperature, but not below + 5 °C.

[2] The test is generally performed at 80 °C.

Table A 4-4: Characteristic values of impact energy

Steel grade	Quenching and tempering		Preheating	Stress-relief annealing [3]
	Hardening °C	Tempering °C	°C	°C
GS-C 25 S	900 to 940 [1]	650 to 700	100 to 250 [2]	580 to 620

[1] Quenching in oil or water.

[2] Preheating may be waived if adequate experience is available.

[3] If applicable, higher temperatures up to 30 K below the actually employed tempering temperatures may be permissible for stress-relief annealing.

Table A 4-5: Particulars of preweld heat treatment and preheating, of thermal cutting and of stress-relief annealing

Steel grade	Verification necessary	Simulated stress-relief annealing	
		Temperature °C	Holding time minutes
GS-C 25 S	yes	600 to 620	900

Table A 4-6: Necessity for verification of mechanical and technological characteristics in the simulated stress-relief-annealed condition, and performance of the simulated stress-relief annealing process

A 5 High-tensile steels for quenching and tempering for bolts and nuts

A 5.1 General

Section A 5 defines the details for manufacture, chemical composition, characterizing mechanical and technological characteristics and heat treatment as well as for further processing of high-tensile steels for quenching and tempering for bolts and nuts. These stipulations shall apply not only to rolled or forged bars but also to the bolts and nuts made from the bars.

A 5.2 Manufacture of the steels and delivery condition

A 5.2.1 Manufacture

Note:

The steels shall be high-tensile steels for quenching and tempering with stipulated minimum values of elevated-temperature strength characteristics.

(1) The steels shall be smelted by the basic oxygen process or in the electric furnace. If other processes are used, proof of equivalence shall be furnished. Steel grades 26 NiCrMo 14 6 and 34 CrNiMo 6 S shall be subjected to metallurgical ladle post-treatment or remelted in vacuum or by the electroslag refining process.

(2) The steels shall be made in particularly killed condition.

A 5.2.2 Delivery condition

The steels shall be delivered in the quenched and tempered condition or in the quenched and tempered plus stress-relief-annealed condition.

A 5.3 Material characteristic values

A 5.3.1 Chemical composition

The values stipulated in **Table A 5-1** shall apply to the chemical composition per the ladle analysis. **Table A 5-2** presents the allowable deviations of chemical composition per the product analysis from the limit values of chemical composition per the ladle analysis.

A 5.3.2 Mechanical and technological characteristics

(1) The mechanical and technological characteristics shall apply to the delivery condition. The values shall be verified on longitudinal specimens from the sampling locations as per Section 8.

(2) The characteristic values of the mechanical and technological characteristics in the room-temperature tensile test, including the minimum values of reduction of area at fracture, are stipulated in **Table A 5-3**.

(3) The characteristic values of the mechanical and technological characteristics in the elevated-temperature tensile test are stipulated in **Table A 5-4**.

(4) The characteristic values of impact energy and lateral expansion are stipulated in **Table A 5-5**.

A 5.3.3 Physical characteristics

Reference values for the physical characteristics can be found in **Annex AP**.

A 5.4 Data on heat treatment

Data for heat treatment are presented in **Table A 5-6**.

A 5.5 Further processing

Only machining is permitted.

Note:

No provisions shall be made for hot or cold forming (thread rolling shall not qualify as cold forming).

Steel grade	Limit value	Content by mass in %									
		C	Si	Mn	P	S	Cr	Mo	Ni	V	Al_{total}
20 NiCrMo 14 5	min.	0.18	0.15	0.30	—	—	1.20	0.25	3.40	—	0.020
	max.	0.25	0.40	0.50	0.020	0.010	1.50	0.50	4.00	—	0.050
26 NiCrMo 14 6	min.	0.25	—	0.20	—	—	1.20	0.35	3.30	—	0.020
	max.	0.30	0.30	0.50	0.020	0.010	1.70	0.55	3.80	0.08 [1)]	0.050
34 CrNiMo 6 S	min.	0.30	0.15	0.40	—	—	1.40	0.15	1.40	—	—
	max.	0.38	0.40	0.70	0.020	0.010	1.70	0.35	1.70	—	—

[1)] Values larger than 0.08 and smaller than or equal to 0.12 % may be approved by appraisals on a case-by-case basis.

Table A 5-1: Chemical composition per the ladle analysis of high-tensile steels for quenching and tempering for bolts and nuts

Element	Allowable limit deviation [1)] of values per the product analysis Content by mass, %
C	± 0.02
Si	± 0.03
Mn	± 0.04
P	+ 0.005
S	+ 0.005
Al	± 0.005
Cr	± 0.05
Mo	± 0.04
Ni	± 0.05 [2)]
V	+ 0.02

[1)] If several product analysis are performed for one heat and deviations of chemical composition per the product analysis are found from the permissible values of chemical composition per the ladle analysis, these deviations for a given element shall be allowable only if they are either all above or all below the limit values as per **Table A 5-1**.

[2)] For permissible nickel contents of 2.00 to 4.00 % per the ladle analysis, deviations of ± 0.07% Ni in the values per the product analysis shall be allowable.

Table A 5-2: Allowable deviations of chemical composition per the product analysis from the limit values of chemical composition per the ladle analysis

Steel grade	Diameter (bars) mm	0.2% proof stress $R_{p0.2}$, N/mm^2 at least	Tensile strength R_m N/mm^2	Elongation at fracture A, % at least	Reduction of area at fracture Z, % at least
20 NiCrMo 14 5 (I)	≤ 130	940	1040 to 1240	14	55
20 NiCrMo 14 5 (II)		980	1080 to 1280	14	55
26 NiCrMo 14 6		940	1040 to 1240	14	50
34 CrNiMo 6 S		830	930 to 1130	16	45

Table A 5-3: Characteristic values of the mechanical and technological characteristics in the room-temperature tensile test

Steel grade	Diameter (bars)	0.2% proof stress $R_{p0.2}$, N/mm^2 at		Tensile strength R_m, N/mm^2 at		Elongation at fracture A, % at		Reduction of area at fracture Z, % at	
	mm	300 °C	350 °C	300 °C	350 °C	300 °C	350 °C	300 °C	350 °C
20 NiCrMo 14 5 (I)	≤ 130	785	735	860	840	14	14	55	55
20 NiCrMo 14 5 (II)		830	785	900	880	14	14	55	55
26 NiCrMo 14 6		790	785	860	820	14	14	45	45
34 CrNiMo 6 S		630	560	760	735	16	16	45	45

Table A 5-4: Minimum values of the mechanical and technological characteristics in the elevated-temperature tensile test

Steel grade	Diameter (bars) mm	Impact energy J		Lateral expansion mm
		Mean value	Individual value	Individual value
20 NiCrMo 14 5 (I)	≤ 130	76	61	0.65
20 NiCrMo 14 5 (II)		76		
26 NiCrMo 14 6		72		
34 CrNiMo 6 S		76		

Table A 5-5: Characteristic values of impact energy and lateral expansion on longitudinal specimens at 20 °C

Steel grade	Temperature range, °C for austenitization	Cooling fluid	Temperature range, °C for	
			Tempering	Stress-relief annealing
20 NiCrMo 14 5 (I)	840 to 900	Water or oil	520 to 600	430 to 470
20 NiCrMo 14 5 (II)	800 to 900		500 to 580	430 to 470
26 NiCrMo 14 6	840 to 870		530 to 580	450 to 500
34 CrNiMo 6 S	820 to 870		550 to 640	450 to 500

Table A 5-6: Data for heat treatment of high-tensile steels for quenching and tempering for bolts and nuts

A 6 Bars for bolts and nuts; additional stipulations

A 6.1 General

Section A 6 shall apply additionally for the steel grades listed in **Table A 6-1** when used for bolts and nuts within the scope of validity of this safety standard.

(2) The stipulations shall apply to rolled or forged bars and to the bolts and nuts made from it.

A 6.2 Dimensional limits

The steel grades listed in **Table A 6-1** may be used up to the dimensional limits indicated therein.

A 6.3 Notched-bar impact bend test

Table A 6-1 presents the values of impact energy and lateral expansion to be verified in the notched-bar impact bend test at 20 °C with longitudinal specimens, taking the stipulations of section 8.3 into consideration.

A 6.4 Elevated-temperature tensile test

Table A 6-1 also presents the values of tensile strength at elevated temperatures.

Steel grade			Diameter mm	Impact energy in J (longitudinal specimens)		Lateral expansion mm	Tensile strength R_m, N/mm² at least	
Abbreviated name	Heat-treatment condition	Requirements in addition to		at room temperature			at the temperature of	
				Mean value, at least	Individual value, at least	Individual value, at least	300 °C	350 °C
C35E	+QT	DIN EN 10269	≤ 60	55	39	0.60	400	390
25CrMo4	+QT		≤ 100	60	42	0.60	460	440
21CrMoV5-7	+QT		≤ 100	63	52	0.60	590	560
X22CrMoV12-1	+QT1		≤ 60	52	36	—	620	600
X 8 CrNiMoBNb 16 -16 + wk	+ wk	VdTÜV material sheet 113/2	≤ 80	52	36	—	530	505

Table A 6-1: Limits of permissible dimensions and additional stipulations for steels for bolts and nuts

A 7 Castings of the martensitic steel G-X4 CrNi 13 4 (1.4317); additional stipulations

A 7.1 General

Section A 7 shall apply in addition to the requirements of VdTÜV material sheet 452 when castings of the martensitic steel G-X4 CrNi 13 4 (1.4317) are within the scope of validity of this safety standard.

A 7.2 Chemical composition

(1) Deviating from the values given in VdTÜV material sheet 452 the restricted values specified in **Table A 7-1** shall apply to the ladle and product analyses.

(2) In the case of operating temperatures exceeding 300 °C during continuous operation, the ratio chrom equivalent to nickel equivalent shall be set less than 2.0.

Cr equivalent = % Cr + % Mo + 1.5 · % Si

Ni equivalent = % Cr + % Mo + 1.5 · % Si

Element	Ladle analysis max. weight-%	Product analysis max. weight-%
P	0.020	0.025
S	0.015	0.020

Table A 7-1: Restricted values for the chemical composition as compared to the VdTÜV material sheet 452

A 7.3 Mechanical and technological characteristics

In test group A 1 deviating from the values given in VdTÜV material sheet 452 the minimum requirements for the impact energy to be verified in the notched-bar impact bend test specified in **Table A 7-2** shall apply, however only one individual value of the specimen set below the specified mean value shall be permitted.

Test area	Mean value of three specimens J	Smallest individual value J
Base metal, Heat-affected zone [1)]	70	50
Weld metal [1)] (quenched and tempered)	70	50
Weld metal [1)] (tempered/stress relief heat treated)	50	35

[1)] Proof has to be provided in the course of welding procedure qualifications or production control tests.

Table A 7-2: Impact energy at room temperature verified in the notched-bar impact bend test (minimum requirements) for castings in test group A 1

Annex AP

Reference data on physical characteristics

AP 1 Scope of application

This Annex contains reference data on

a) specific density,

b) dynamic modulus of elasticity,

c) mean coefficient of linear thermal expansion,

d) mean specific heat capacity and

e) thermal conductivity

for the steel grades cited in Sections A 1 through A 5.

AP 2 Characteristic values

AP 2.1 General

The characteristic values listed in **Table AP-1** for physical characteristicfs are reference data compiled on the basis of measurements on individual heats and of literature data [3].

AP 2.2 Determination of characteristic values

At present a standardized method has not been defined for determination of the characteristic values presented here for physical characteristics.

AP 2.3 Scatter band of characteristic values

(1) Changes in chemical composition and heat treatment lead to a certain scatter band of physical characteristics. Any grain orientation has a particularly strong influence on the values of modulus of elasticity.

(2) Differences between the measurement methods employed may lead to additional scattering.

(3) The documents available at present are not adequate for statistical evaluation of reliability.

(4) The statements on the scatter band of characteristic values in footnotes 1 to 5 of **Table AP-1** were taken from the literature. They relate to the average scatter band of the measured values acquired there.

Steel grade	Specific density [1] 10^6 g/m^3	Dynamic modulus of elasticity [2] 10^3 N/mm^2 at temperature in °C						Mean coefficient of linear thermal expansion [3] 10^{-6} K^{-1} between 20 °C and the temperature in °C					Mean specific heat capacity [4] in J g^{-1} K^{-1} between 20 °C and the temperature in °C					Thermal conductivity [5] W m^{-1} K^{-1} at the temperature in °C					
	at 20 °C	20	100	200	300	350	400	100	200	300	350	400	100	200	300	350	400	20	100	200	300	350	400
15 MnNi 6 3	7.85	211	206	198	191	187		12.4	12.9	13.3	13.6							42	43	42	41	40	
15 NiCuMoNb 5 S	7.84	210	206	199	191		183	12.4	13.0	13.6		14.1						44	44	43	42		40
20 MnMoNi 5 5	7.86	211	206	199	192		184	12.7	13.2	13.6		14.0						44	44	43	41		39
20 NiMoCr 14 5	7.84	205	200	191	182			11.2	11.6	12.1	12.2							29	30	31	31		31
26 NiMoCr 14 6	7.84	205	200	191	182			11.2	11.6	12.1	12.2							29	30	31	31		31
34 CrNiMo 6 S	7.84	205	200	191	182			12.5	13.2	13.7		14.2						34	36	37	37		36
C 22.8 S	7.80	212	205	200	192		183	12.5	13.1	13.6		14.0	0.46	0.49	0.51	0.52	0.53	43	43	42	41		39
GS-C 25 S	7.83	211	204	196	186		177	12.2	12.9	13.4		13.9						43	43	42	41		39
WStE 255 S	7.85	212	207	200	192		184	12.3	12.8	13.3		13.8						42	43	43	42		40
WStE 285 S	7.85	212	207	200	192		184	12.3	12.8	13.3		13.8						42	43	43	42		40
WStE 315 S	7.84	212	207	200	192		184	12.3	12.8	13.3		13.8						42	43	43	42		40
WStE 355 S	7.83	212	207	200	192		184	12.3	12.8	13.3		13.8						42	43	43	42		40

[1] Average bandwidth of dispersion of measured values ± 0.05 · 10^6 g/m^3.

[2] Average bandwidth of dispersion of measured values ± 5 · 10^3 N/mm^2.

[3] Average bandwidth of dispersion of measured values ± 0.8 · 10^{-6} K^{-1}.

[4] Average bandwidth of dispersion of measured values ± 0.01 J g^{-1} K^{-1}.

[5] Average bandwidth of dispersion of measured values ± 3.5 W m^{-1} K^{-1} for ferritic steels, ± 1.5 W m^{-1} K^{-1} for austenitic steels.

Table AP-1: Reference data on specific density, dynamic modulus of elasticity and mean coefficient of linear thermal expansion of the steel grades as per Sections A 1 through A 5

Annex B

Production welds of steel castings

B 1 General

This Annex shall apply in addition to the stipulations of DIN EN 1559-2 and DIN EN ISO 11970 for production welds on steel castings.

Note:

Production welds shall be employed only if the defect cannot be repaired in another way without reducing the thickness below the nominal value.

B 2 Prerequisites

(1) The general requirements per Section 3 shall be met.

(2) Production welds as well as their examination and documentation shall be classified as per the production scheme of **Figure 5.7-1** in the process of casting manufacture. The individual production steps shall be completed in the described sequence. In the event of deviations from the standard production sequence, a design approval of the sequence of production steps shall be required. A distinction shall be made between Procedure 1 (production welding with subsequent quenching and tempering or solution annealing and quenching) on the one hand, and Procedure 2 (production welding without subsequent quenching and tempering or solution annealing and quenching) on the other hand.

(3) If the castings are not quenched and tempered or solution-annealed and quenched after production welding, for example, because of the machining condition, the authorized inspector's consent regarding production welding shall be obtained if required in Section 11.8. In this case the production welds shall be documented as per **Figure 5.7-1**.

(4) Each area prepared for welding shall be assumed to be a “relatively large production weld” if its depth exceeds 40 % of the wall thickness or the following values:

a) for welding ends and cast bodies: 25 mm,

b) for adjoining zones: 40 mm.

(5) For relatively large production welds that will subsequently be quenched and tempered or solution-annealed and quenched, the authorized inspector shall be given adequate advance notification of the welding work. Suspension of the production sequence is not required.

(6) For small production welds that will subsequently be quenched and tempered or solution-annealed and quenched, it is not required to notify the authorized inspector.

B 3 Weld filler metals and welding consumables

The weld filler metals and welding consumables shall meet the requirements of KTA 1408.1, KTA 1408.2 and KTA 1408.3 Section 3.

B 4 Heat supply during welding and post-weld heat treatment

(1) The appropriately defined preheating temperature shall be met for welding as well as for all cutting and joining work.

(2) The welding conditions and welding parameters for ferritic and martensitic cast-steel grades shall be selected such that the lowest possible hardness values are achieved for the particular material. Work specimens shall be taken to verify that hardness values of 350 HV 10 are not exceeded.

(3) Production welds shall be heat-treated as per **Figure 5.7-1**.

(4) Correlation of the castings with the heat-treatment lot shall be ensured.

B 5 Welding procedure qualifications

(1) For all materials to be welded and for all welding methods, a welding procedure qualification as per DIN EN ISO 11970 and per the following stipulations shall be performed before the start of production welding for each planned heat treatment, welding position and wall thickness.

(2) The welding procedure qualification for a particular steel shall also be applicable for other steels within the limits set in KTA 3211.3.

(3) The duration of validity of a welding procedure qualification shall be 24 months after successful completion of the welding procedure qualification. This period shall begin with the date of the written opinion of the authorized inspector. If production is started within these 24 months and production control tests to Section C 6 have been performed, the initial period shall be extended by a further 24 months, counting from the start of validity of the production control test.

(4) If production is not started within 24 months after successful completion of the welding procedure qualification or is interrupted for longer than 24 months, the first production control test prior to starting or resuming production shall be treated as a repeat of the welding procedure qualification. The stipulations of the original welding procedure qualification shall govern the scope of this production control test, with regard to both the start of validity and the duration of validity.

(5) Before the welding procedure qualification is performed, a welding procedure sheet and, if necessary, a heat-treatment plan shall be submitted to the authorized inspector.

(6) It shall not be necessary to use for the welding procedure qualification the same heats of base metal or the same batches of weld filler metals and welding consumables as are used for welding of parts.

(7) The welding shall be performed under constraint conditions.

(8) Welding records of welding procedure qualifications shall be kept. Blank forms per KTA 3211.3 or sheets with identical information content shall be used for this purpose.

(9) The scope of the welding procedure qualification as per DIN EN ISO 11970 is stipulated in **Table B-1**. **Table B-2** additionally contains stipulations on the technological bend test.

(10) Welding procedure qualifications that are still valid but are not fully in conformity with the stipulations of **Table B-1** regarding the scope of testing may be added to by supplementary tests in a preliminary production control test.

B 6 Production control tests

(1) Depending on scope of validity of the welding procedure qualification, the manufacturer shall be required to perform one production control test per year during production in the presence of the authorized inspector. KTA 3211.3 Section 5 shall apply in addition to the stipulations of this section.

(2) Production control tests on a steel of material group W I shall also cover production control tests on the same steel for use in material group W II.

(3) The test coupons for production control tests shall be taken from one of the heats involved.

(4) The weld filler metals and welding consumables shall be taken from one of the manufacturing lots involved.

(5) The test coupons shall be welded by welders who participate in production.

(6) Production control tests shall be performed as full-penetration welds. They shall cover all partial penetration weldings.

(7) The test pieces shall be subjected to simulated heat treatment jointly with the authorized inspector or shall be traveller pieces subjected to the same heat treatment as the casting.

(8) The extent of examination and requirements are stipulated in **Table B-3**.

B 7 Documentation

The documentation of welding procedure qualification and production control tests, including the associated design approval documents, shall be organized per the stipulations set forth for welding procedure qualification in DIN EN ISO 11970, and shall be attached to the inspection certificate.

Type of examination	Number of specimens, specimen location, requirements
Non-destructive tests and examinations	100 % surface inspection 100 % volumetric testing, test procedure and requirements as per the stipulations of Section 11.8.
Tensile test (DIN EN ISO 4136 and DIN EN ISO 6892-1)	a) Base metal (DIN EN ISO 6892-1) 1 specimen (DIN 50125) at room temperature Requirements to Sections 5.7, 6.7, 7.7 or 9.2 b) Welded joint (DIN EN ISO 4136) 2 specimens (DIN EN ISO 4136, Figure 2a or 2b, parallel length L_c = weld width + at least 60 mm) at room temperature. R_m and fracture location shall be tested (tensile-strength requirement as for the base metal). c) All-weld metal (DIN EN ISO 6892-1) 1 specimen (DIN 50125, $L_0 = 5 \cdot d_0$) at room temperature. Requirements for $R_{p0.2}$, R_m, A, Z, as well as $R_{p1.0}$ for austenite, stipulated as for the weldability test.
Notched-bar impact bend test (DIN EN ISO 148-1)	**Ferritic steels of material group W I** One specimen set of base metal at 0 °C. One specimen set each of weld metal and heat-affected zone at 0 °C, 33 °C and 80 °C. Specimen location as per **Figure B-1**. See clause 4.3.1 for requirements. If the temperature at which 68 J (smallest individual value) and 0.9 mm lateral expansion (smallest individual value) is reached lies between 0 °C and 33 °C, the exact value of this temperature may be determined by interpolation and used as the lowest permissible loading temperature. The ductile fracture percentage of the fractured area shall be determined. **Ferritic steels of material group W II** One specimen set of base metal at 0 °C (20 °C permissible if the lowest loading temperature exceeds 20 °C and the weld metal as well as the heat affected zone are tested at 20 °C). One specimen set each of weld metal and heat-affected zone at 0 °C (20 °C permissible if the lowest loading temperature exceeds 20 °C). Specimen location as per **Figure B-1**. See clause 4.3.2 for requirements. The ductile fracture percentage of the fractured area shall be determined. **Austenitic steels** One specimen set each of weld metal at room temperature. Specimen location as per **Figure B-1**. See clause 4.3.3 for requirements. **Martensitic steels** One specimen set of base metal at room temperature. Requirements as per Sections 5.7 or 9.2. One specimen set each of weld metal and heat-affected zone at room temperature. Specimen location as per **Figure B-1**. Requirements as for the base metal.
Technological bend test (DIN EN ISO 5173)	One specimen each with root and cover pass on the tension side; see **Table B-2** for bending-mandrel diameter and requirements.
Chemical composition	Weld metal Not required for unalloyed steels. Elements to be verified per weldability test of the weld filler metals.

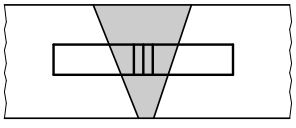
Table B-1: Extent of examination and stipulations for procedure qualification for production welds on steel castings
(continued on next page)

Type of examination	Number of specimens, specimen location, requirements
Metallographic examinations with photographic documentation	a) Macrograph To be evaluated: Weld buildup, penetration, slag, pores. Requirements: Satisfactory weld buildup, satisfactory penetration; isolated slag inclusions and pores are permitted. b) Micrograph, magnification at least 100 : 1 (not required for unalloyed steels). To be evaluated: Microstructure. For austenite, delta ferrite content in the weld metal shall additionally be determined. Requirement: A ferrite content of 4 to 10 % should be targeted; a closed lattice structure is not permitted.
HV 10 hardness test (DIN EN ISO 6507-1 and DIN EN ISO 6507-4)	as per DIN EN ISO 11970
Verification of intergranular corrosion resistance (DIN EN ISO 3651-2)	Austenitic steels Specimen location: root side without additional sensitization. Requirement: freedom from cracks.

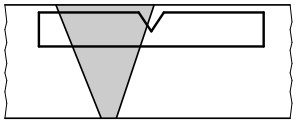
Table B-1: Extent of examination and stipulations for welding procedure qualification for production welds on steel castings (continued)

Steel group	Tensile strength R_m in N/mm²	Bending mandrel diameter	Bend angle in degrees	Allowable deviation
Ferritic and martensitic steels	$R_m < 430$	2 · specimen thickness a	180	Cracks shall not be longer than 1.6 mm. Bursting open due to pores or lack of fusion are permitted.
	$430 \leq R_m < 460$	2.5 · specimen thickness a	180	
	$R_m \geq 460$	3 · specimen thickness a	180	As for ferritic and martensitic steels with $R_m < 460$ N/mm², but in addition: - If the specimen breaks at a bend angle ≥ 90°, the elongation of the gauge length (L_0 = weld width + wall thickness) shall reach the minimum value of elongation at fracture A of the base metal. - If the specimen breaks at a bend angle < 90°, the elongation over the weld width shall reach at least 30 %. The fracture surface appearance shall be free of defects.
Austenitic steels		3 · specimen thickness a	180	

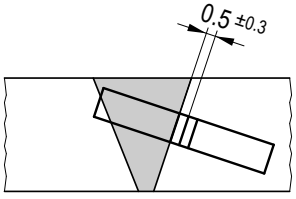
Table B-2: Bending-mandrel diameter for the technological bend test to DIN EN ISO 5173 in connection with welding procedure qualification for production welds on cast steel



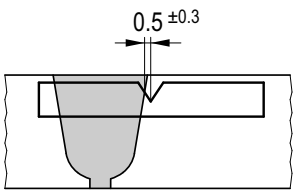
a) Specimen location in the weld metal



c) Specimen location in the HAZ or transition



b) Specimen location in the HAZ or transition



d) only if b) is not feasible

Figure B-1: Location of the notch in notched-bar impact bend-test specimens

Type of examination	Number of specimens, specimen location, requirements
Non-destructive tests and examinations	100 % surface inspection 100% volumetric testing, test procedure and requirements as per the stipulations for the base metal (see Section 11.8.
Tensile test (DIN EN ISO 4136, DIN EN ISO 6892-1 and DIN EN ISO 6892-2)	a) Welded joint (DIN EN ISO 4136) 2 specimens (DIN EN ISO 4136, Figure 2a or 2b, parallel length L_c = weld width + at least 60 mm) at room temperature. R_m and fracture location shall be tested (tensile-strength requirement as for the base metal). b) All-weld metal (DIN EN ISO 6892-1 and DIN EN ISO 6892-2) 1 specimen (DIN 50 125, $L_0 = 5 \cdot d_0$) at room temperature and design temperature [1)]. Requirements for $R_{p0.2}$, R_m, A, Z, as well as $R_{p1.0}$ for austenite, stipulated as for the weldability test.
Notched-bar impact bend test (DIN EN ISO 148-1) on Charpy-V specimens	**Ferritic steels of material group W I** One specimen set each of weld metal and heat-affected zone at 0 °C and at the lowest loading temperature or at 33 °C, if correlation with a particular component is not possible. Specimen location per **Figure B-1**. See clause 4.3.1 for requirements. If the temperature at which 68 J (smallest individual value) and 0.9 mm lateral expansion (smallest individual value) is reached lies between 0 °C and 33 °C, the exact value of this temperature may be determined by interpolation and used as the lowest permissible loading temperature. If the requirement for minimum values of impact energy and lateral expansion at the lowest operating temperature is already met at 0 °C, the test at higher temperature is not required. The ductile fracture percentage of the fractured area shall be determined. **Ferritic steels of material group W II** One specimen set each of weld metal and heat-affected zone at 0 °C or at 20 °C, if the lowest loading temperature exceeds 20 °C. Specimen location as per **Figure B-1**. See clause 4.3.2 for requirements. The ductile fracture percentage of the fractured area shall be determined. **Austenitic steels** One specimen set each of weld metal and heat-affected zone at room temperature. Specimen location as per **Figure B-1**. See clause 4.3.3 for requirements. **Martensitic steels** One specimen set each of weld metal and heat-affected zone at room temperature. Specimen location as per **Figure B-1**. Requirements as for the base metal.
Metallographic examinations with photographic documentation	a) Macrograph To be evaluated: Weld buildup, penetration, slag, pores. Requirements: Satisfactory weld buildup, satisfactory penetration; isolated slag inclusions and pores are permitted. b) Micrograph, magnification at least 100 : 1 (not required for unalloyed steels). To be evaluated: Microstructure. For austenite, delta ferrite content in the weld metal shall additionally be determined. Requirement: A ferrite content of 4 to 10 % should be targeted; a closed lattice structure is not permitted.
HV 10 hardness test (DIN EN ISO 6507-1)	Ferritic steels One hardness profile through base metal, heat-affected zone and weld metal, as close as possible under the surface. Requirement: 350 HV 10 shall not be exceeded.
Verification of intergranular corrosion resistance (DIN EN ISO 3651-2)	Austenitic steels Specimen location: root side without additional sensitization. Requirement: freedom from cracks.

[1)] The elevated-temperature tensile test shall be required if the operating temperature is higher than 200 °C (test groups A 1 and A 2) or higher than 300 °C (test group A 3). In these cases, the elevated-temperature tensile test shall be performed at 350 °C for ferritic steels, at 400 °C for austenitic steels and at 320 °C for martensitic steels.

Table B-3: Extent of examination and stipulations for production control tests for production welds on steel castings

Annex C

Procedure for determining the delta ferrite content

C 1 General

This annex specifies details for the procedures required for the determination of the products' delta ferrite content under clause 4.4.6.9 (1).

C 2 Metallographic determination on castings in the as-delivered condition

(1) A test specimen shall be taken from the product at the specified sampling location, be ground and polished in the usual way and etched in accordance with Murakami [4]. The etched surface shall have an area of at least 10 mm by 10 mm.

(2) The evaluation shall be performed at a magnification of 100:1.

(3) A representative location of the etched surface shall be documented as photograph at a magnification of 100:1.

(4) With regard to the quantitative evaluation it is recommended to compare the micrograph with a corresponding delta ferrite reference sheet and classify it accordingly. Alternatively, the procedure of a quantitative microstructure analysis may be employed.

(5) The test report shall state:

a) the shape, size and direction of the test specimen as well as the sampling location,

b) the heat treatment condition,

c) the delta ferrite content in %.

A micrograph shall be contained in the test report.

C 3 Metallographic analysis of the bead-on-plate test specimen

(1) A test specimen of the following size shall be taken from the product form at the specified sampling location:

length 200 mm, thickness 25 mm up to 30 mm, width 40 mm.

(2) A melt run with a length of at least 180 mm shall be deposited on the test specimen with a TIG burner without weld filler metals, using the following weld parameters (guidance values):

voltage about 20 V,

current about 160 A,

feed rate about 20 cm/min.

(3) In the case of product forms that do not allow taking of test specimens with a size as specified under (1) and where the weld parameters as specified under (2) cannot be applied, the specimen shape and heat input shall be adjusted as closely as possible to the welding to be performed later on the product.

(4) A disc shall be taken from the middle of the melt run perpendicular to the surface of the test specimen and to the weld run axis; one side of this cross-section shall be ground and polished in the usual way and etched in accordance with Murakami [4].

(5) The evaluation shall be performed at a magnification of 1000:1.

(6) A representative location of the surface-deposited weld zone on the etched surface shall be documented as photograph at a magnification of 1000:1.

(7) With regard to the quantitative evaluation it is recommended to compare the micrograph with a corresponding delta ferrite reference sheet [5] and classify it accordingly. Alternatively, the procedure of a quantitative microstructure analysis may be employed.

(8) The test report shall state:

a) the shape, size and direction of the test specimen as well as the sampling location,

b) the actual values of the welding parameters,

c) the delta ferrite content in %.

A micrograph with a specification of its location shall be added to the test report.

C 4 Metallographic determination for weld material (during the procedure qualification and production control test for production weldings on castings)

(1) A slice through the entire cross-section shall be taken from the weld. For the metallographic examination, the slice shall be ground and polished for on one side in the usual way, as well as etched in accordance with Murakami [4].

(2) An overall photograph shall be taken of the entire weld cross section.

(3) The evaluation shall be performed at a magnification of 1000:1.

(4) With regard to the quantitative evaluation it is recommended to compare the micrograph with a corresponding delta ferrite reference sheet [5] and classify it accordingly. Alternatively, the procedure of a quantitative microstructure analysis may be employed.

(5) Micrographs at a magnification of 1000:1 shall be made of at least three zones representative of the delta ferrite content.

(6) The test report shall state:

a) the sampling location,

b) the heat treatment condition,

c) the delta ferrite content in %.

(7) The overall photograph as per (2) and the micrographs as per (5) shall be attached to the test report. The location of the zones as per (5) shall be marked in the overall photograph.

C 5 Mathematical estimation according to De Long

Note:

Figure C-1 *in accordance with De Long [4] is used for the mathematical estimation of the delta ferrite content. In this graph the delta ferrite content is shown in relation to the chemical composition, however, not in terms of its volumetric ratio but rather on the basis of a special calibration (cf. DIN EN ISO 8249), in terms of the characteristic "ferrite number (FN)". In the range of small ferrite numbers up to FN 7, the ferrite number is identical to the delta ferrite content in %.*

(1) The nickel equivalent Ni_E shall be calculated from the chemical composition of the base metal (content by mass) according to the equation

$$Ni_E = \% Ni + 30 \cdot (\% C + \% N) + 0.5 \cdot \% Mn \qquad (C\ 5\text{-}1)$$

and the chrome equivalent Cr_E according to the equation

$$Cr_E = \% Cr + \% Mo + 1.5 \cdot \% Si + 0.5 \cdot \% Nb \qquad (C\ 5\text{-}2)$$

(2) The calculated values of the nickel equivalent and chrome equivalent are the coordinates of a point in **Figure C-1**. The corresponding ferrite number is read from the graph. Where required, the values can be interpolated between the straight lines of constant ferrite numbers.

(3) The documentation of the mathematical estimation shall contain the following:

a) the chemical composition of the base metal,

b) the value of the nickel equivalent,

c) the value of the chrome equivalent,

d) the delta ferrite content in terms of the ferrite number.

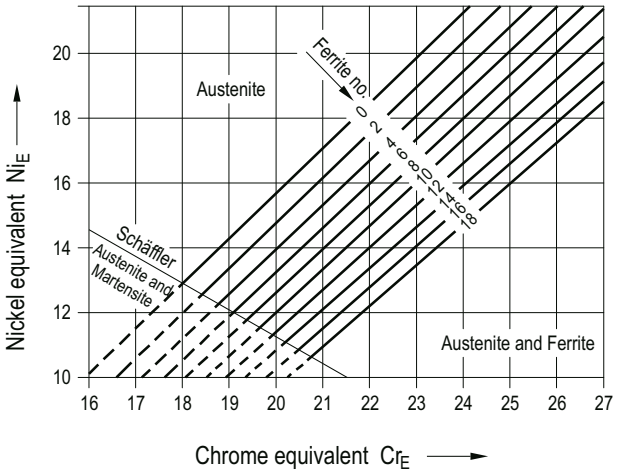


Figure C-1: Relationship between chemical composition and ferrite numbers of molten base metal or weld material (according to W.T. De Long [4])

Annex D

Performance of manual ultrasonic testing

D 1	General requirements	103
D 2	Definitions, symbols, formulae	103
D 2.1	Definitions	103
D 2.2	Symbols	103
D 2.3	Formulae	103
D 3	Requirements to be met by the test object	104
D 4	Requirements to be met by the testing system	104
D 4.1	Test equipment	104
D 4.2	Calibration blocks, reference blocks and reference reflectors	105
D 5	Optimization of the testing technique for ultrasonic testing of austenitic steels or nickel alloys	106
D 6	Adjustment of test system	106
D 6.1	Range adjustment	106
D 6.2	Adjustment of the testing level when applying the DGS method	106
D 6.3	Adjustment of the testing level for the reference block method and DAC method	107
D 6.4	Corrections of testing level adjustment	108
D 6.5	Setting of the ultrasonic instrument	108
D 7	Creeping wave method	110
D 7.1	Description of method	110
D 7.2	Reference block	110
D 7.3	Testing level adjustment	110
D 7.4	Adaptation of probes	111
D 8	Wave conversion method I (secondary creeping wave)	111
D 8.1	Description of method	111
D 8.2	Probe	111
D 8.3	Range calibration	112
D 8.4	Testing level adjustment	112
D 8.5	Corrections during testing level adjustment	113
D 8.6	Performance of testing	113
D 9	Wave conversion method II (LLT technique)	114
D 9.1	General	114
D 9.2	Probes, scanning zones, reference blocks, LLT sensitivity diagrams	114
D 9.3	Range adjustment	114
D 9.4	Testing level adjustment	114
D 9.5	Transfer correction	115
D 9.6	Performance of testing	115
D 10	Performance of testing	117
D 10.1	Overlap	117
D 10.2	Rate of probe movement	117
D 10.3	Adjustment and check of the test system	117
D 11	Description of indications	117
D 11.1	Echo amplitude	117
D 11.2	Extension of indications	117
D 11.3	Indications due to geometric discontinuities	118

D 1 General requirements

(1) This Annex covers the performance of manual ultrasonic testing.

(2) In this Annex, stipulations have been laid down for the calibration of ultrasonic equipment for the pulse-echo method used in the multiple-echo or through transmission technique and for the description of indications.

D 2 Definitions, symbols, formulae

D 2.1 Definitions

The definitions of DIN EN ISO 5577 apply.

D 2.2 Symbols

In this Annex the following symbols are used:

Symbol	Variable or designation	Unit
A	Sound path length related to near field length in the general DGS diagram	—
a	Projected surface distance	mm
a'	Reduced projected surface distance	mm
a_{LLT}	Reduced projected surface distance in the case of LLT-technique	mm
AVG	Distance / gain / size	—
α_{LW}	Angle of refraction of longitudinal wave	degree
α_{TW}	Angle of incidence of transverse wave on scanning surface of test object	degree
C	Required width of the reference block	mm
c_{LW}	Sound velocity of longitudinal wave	m/s
c_{TW}	Sound velocity of transverse wave	m/s
D_{eff}	Effective transducer dimension according to probe data sheet	mm
D_{FBB}	Diameter of the flat bottom hole	mm
D_{Kon}	Diameter of contact surface of a straight beam probe	mm
D_{KSR}	Diameter of disc shaped reflector	mm
D_Q	Effective transducer dimension perpendicular to the scanning direction	mm
$D_{S\text{-}6dB}$	Beam width for 6 dB decrease of sound pressure relating to central beam	mm
$D_{S\text{-}20dB}$	Beam width for 20 dB decrease of sound pressure relating to central beam	mm
D_z	Diameter of side-drilled hole	mm
d	Curvature diameter of the scanning surface on the test object	mm
d_{ref}	Curvature diameter of opposite surface on the test object	mm
Δf	Band width (difference between upper and lower frequency limit) referred to 3 dB amplitude decrease	MHz
Δ_{SE}	Distance of points of incidence	mm
ES	Receiving transducer	—
f_N	Nominal frequency	MHz
ϕ_{LW}	Angle of incidence of longitudinal wave on reflector	degree
ϕ_{TW}	Angle of refraction of transverse wave on reflector	degree
G	Reflector diameter referred to effective transducer diameter	—
G_K	Instrument gain when setting the reference reflector for reference screen height level	dB
G_T	Instrument gain when setting the transmission indication for reference screen height level	dB
$\overline{G_T}$	Arithmetical average of G_T values	dB
G_R	Instrument gain setting for recording level	dB
γ_6	Beam spread angle at 6 dB limit	degree
H	Echo amplitude referred to screen height	—
HE	Main echo in testing using wave conversion technique	—
KSR	Diameter of disc shaped reflector	mm
κ	Sound attenuation coefficient (deviating from DIN EN ISO 5577; sound attenuation referred to sound path length)	dB/mm
L	Probe scanning surface dimension in direction of curvature	mm
LLT	„Long-Long-Trans" wave conversion technique	—
LW	Longitudinal wave	—
λ	Wave length	mm
N	Near field length	mm
NE1; NE2	Neighbour echoes in testing using wave conversion technique	—
n	Number of individually measured values	—
p	Projected surface distance for indirect scan	mm
p'	Projected surface distance in testing using wave conversion technique in the case of neighbour echo optimization	mm
p''	Projected surface distance in testing using wave conversion technique in the case of main echo optimization	mm
Ra	Arithmetical mean deviation of the assessed profile (average roughness) Ra to DIN EN ISO 4287	µm
R_L	Recording length	mm
R_{LK}	Corrected recording length	mm
S (with and without index)	Sound path length	mm
SEL	Transmitter-receiver longitudinal waves	—
SE	Transmitter - receiver	—
s	Wall thickness, nominal wall thickness	mm
s_j	Thickness of reference block	mm
S/N	Signal-to-noise ratio is the ratio of the echo amplitude of an ultrasonic signal from a reflector to the amplitude of the noise level (noise level means the 95 % value of the cumulative frequency of the heights of the noise signals in the tested volume free from defects)	—
TLL	„Trans-Long-Long" wave conversion	—
TW	Transverse wave	—

Symbol	Variable or designation	Unit
V	Gain in the general DGS diagram	dB
Y_{FBB}	Reflector depth position	mm
Y_s	Distance of scanning zone centre to scanning surface	mm
Z_H	Depth of scanning zone	mm
ΔV	Sensitivity correction	dB
ΔV_κ	Sound attenuation correction referred to a certain sound path length	dB
ΔV_{koppl}	Coupling correction	dB
ΔV_{LLT}	Echo height difference between reference level of front face and maximum of sensitivity curve	dB
ΔV_S	Divergence correction of back reflection curve	dB
$\Delta V^{\sim}$	Gain correction for considering transfer variations	dB
ΔV_T	Transfer correction	dB
ΔV_Z	Gain correction for considering different sound path travel distances when scanning a cylindrical hole	dB

D 2.3 Formulae

The variables to be calculated shall be determined by means of the following equations:

a) Required width of the reference block

$$C \geq D_{S\text{-}20dB} \qquad \text{(D-1)}$$

b) The beam width $D_{S\text{-}20dB}$ referred to a 20 dB echo amplitude decrease:

$$D_{S-20dB} = 2 \cdot \lambda \cdot \frac{S}{D_Q} \qquad \text{(D-2)}$$

c) Conversion of side-drilled hole echo amplitudes to disc shaped reflector echo amplitudes:

$$D_{KSR} = \sqrt{\frac{\sqrt{2}}{\pi} \cdot \lambda \cdot \sqrt{D_Z \cdot S}}\ , \qquad \text{(D-3)}$$

where $S > 1.5 \cdot N$ and $D_Z > 1.5 \cdot \lambda$.

d) The beam diameter $D_{S\text{-}6dB}$ referred to a 6 dB echo amplitude decrease:

$$D_{S\text{-}6dB} = 2 \cdot S \cdot \tan \gamma_6, \qquad \text{(D-4)}$$

e) Average value of instrument gain setting $\overline{G}_T$:

$$\overline{G}_T = \frac{\sum G_T}{n} = \frac{\text{sum of individual values}}{\text{number of individual values}}\ , \qquad \text{(D-5)}$$

f) Corrected recording length R_{LK}:

$$R_{LK} = R_L - D_{S-6dB} \cdot \left(1 - \frac{D_{S-6dB}}{R_L}\right) \qquad \text{(D-6)}$$

g) Sound path length without lateral wall influence:

$$S = \frac{s \cdot D_{eff}}{2 \cdot \lambda} \qquad \text{(D-7)}$$

h) Gain correction $\Delta V^{\sim}$:

$$\Delta V^{\sim} = 1.7 \cdot \sqrt{\frac{\sum G_T^2 - \frac{1}{n} \cdot \left(\sum G_T\right)^2}{n-1}} \qquad \text{(D-8)}$$

or

$$\Delta V^{\sim} = 1.7 \cdot \sqrt{\frac{\sum \left(G_T - \overline{G}_T\right)^2}{n-1}} \qquad \text{(D-9)}$$

i) Sensitivity correction ΔV_Z:

$$\Delta V_Z = 30 \cdot \lg \frac{S_2}{S_1} \qquad \text{(D-10)}$$

k) Resultant instrument sensitivity for adjustment of recording level:

$$G_R = G_K + \Delta V_T + \Delta V^{\sim} \qquad \text{(D-11)}$$

with

$$\Delta V_T = \Delta V_{koppl} + \Delta V_\kappa \qquad \text{(D-12)}$$

l) Zero point displacement at longitudinal wave dual-element probes:

$$S = 1.5 \cdot s + a \qquad \text{(D-13)}$$

m) Sound path travel distance to scanning zone centre with LLT probes:

$$S_{Just} = S_{LW} + 2 \cdot S_{TW} \qquad \text{(D-14)}$$

$$\text{with } S_{LW} = \frac{2 \cdot s - Y_s}{\cos \alpha_{LW}} \qquad \text{(D-15)}$$

$$\text{and } S_{TW} = \frac{Y_s}{\cos \alpha_{TW}} \qquad \text{(D-16)}$$

or approximated for steel

$$S_{Just} = 2 \cdot \frac{s + Y_s}{\cos \alpha_{LW}} \qquad \text{(D-17)}$$

D 3 Requirements to be met by the test object

(1) The scanning surfaces of the test object and its reflecting surfaces shall be large enough to completely cover the examination volume.

(2) The scanning surfaces shall be free from disturbing unevenness and contaminants (e.g. notches, scale, weld spatters, machining grooves). Where the opposite surface is used as reflection surface, the same requirements as for the scanning surface apply to the reflection surface.

(3) The arithmetical mean deviation of the assessed profile (average roughness) Ra to DIN EN ISO 4287 shall not exceed 20 µm on the surfaces to be tested.

(4) In the case of waviness of the scanning surfaces the waviness shall be so little as to provide sufficient probe shoe contact. This is generally the case if the distance between probe shoe surface and scanning surface does not exceed 0.5 mm at any point.

(5) In relation to a reference surface of 40 mm x 40 mm, the deviation from the specified contour of the scanning surfaces shall not exceed 0.5 mm. When selecting other dimensions of reference surfaces, the allocated deviation from the specified contour shall be linearly converted in accordance with the side length of the reference surface selected.

D 4 Requirements to be met by the testing system

D 4.1 Test equipment

(1) The test equipment used including the required measuring instruments and auxiliary equipment shall show appropriate exactness and stability suited for the intended use.

(2) Test instruments and probes shall normally meet the requirements of DIN EN 12668-1 or DIN EN 12668-2. The requirements of DIN EN 12668-3 shall apply to checking the properties of the entire test equipment.

(3) The combination of equipment, cables and probes of various manufacturers is permitted if it is ensured (e.g. by

measurements on reference reflectors) that the exactness of results is not affected.

(4) Probes with sound fields shall be used which ensure the observance of the required testing level (recording level) in the area to be examined.

Note:

In general, a nominal frequency of 4 MHz and a transducer size D_Q of approx. 10 mm is used for nominal wall thicknesses equal to or less than 40 mm, and a nominal frequency of 2 MHz and a transducer size D_Q of approx. 20 mm is used for nominal wall thicknesses exceeding 40 mm.

(5) Straight-beam probes shall be selected such that the distance between the scanning surfaces of the probe and of the test object does not exceed 0.5 mm ($D_{Kon} < \sqrt{2d}$). By the use of protective foils the coupling of a straight-beam transceiver probe may be improved.

(6) The scanning surfaces of transverse wave angle-beam probes shall

a) always be contoured when scanning into concave test object scanning surfaces unless sufficient coupling can be obtained due to large radii of curvature,

b) be contoured when scanning into convex test object scanning surfaces if according to **Figure D-1** for test object diameters up to 200 mm the scanning surface dimension in the direction of curvature is L > d/10 and for diameters exceeding 200 this dimension is L > $\sqrt{2d}$.

(7) For adjustment of the time base range and the testing level as well as for testing the same couplant shall be used. Only such couplants shall be used which do not damage the object (e.g. corrosion). Upon testing, all couplant residues shall be removed from the test object.

(8) Test object, calibration block, reference block and probes shall approximately have the same temperature.

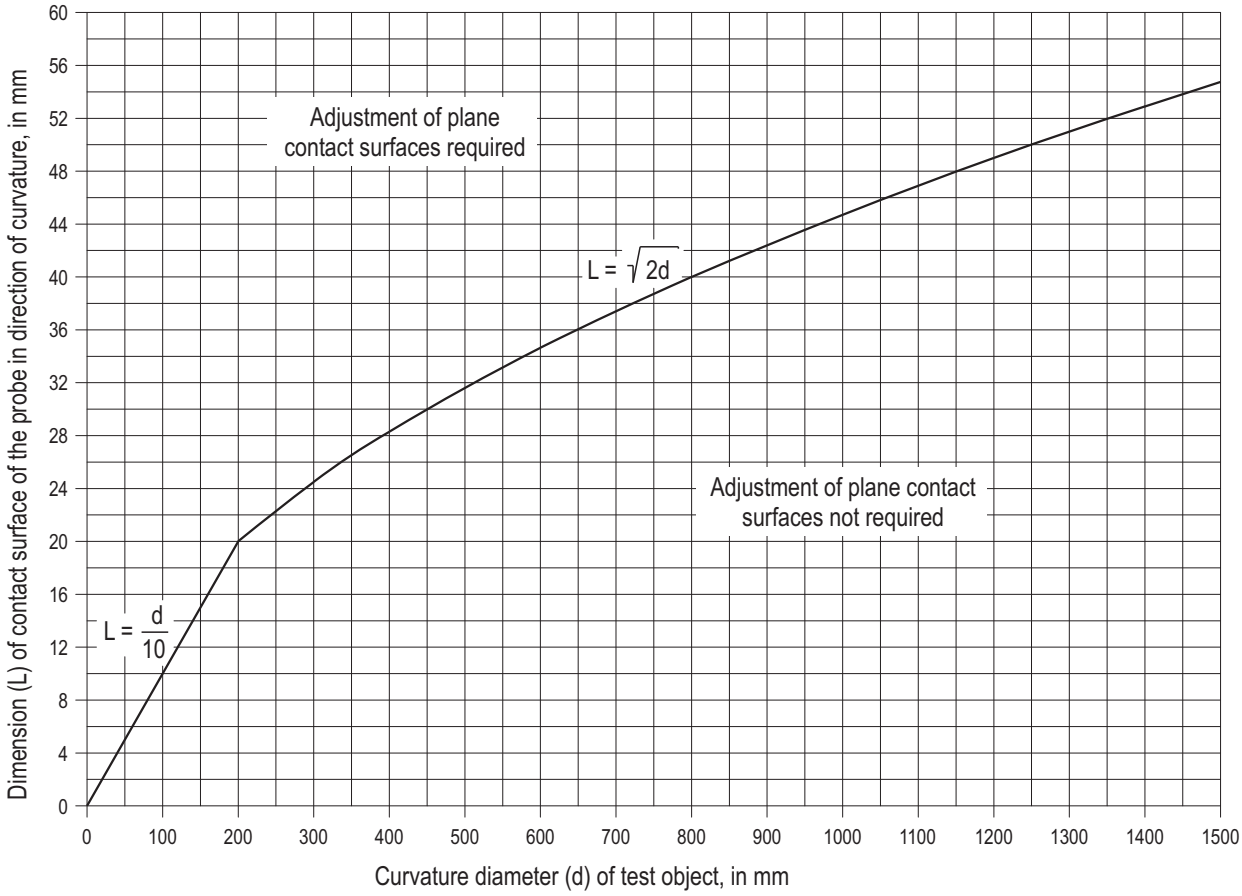


Figure D-1: Conditions for adjusting plane contact surfaces of angle-beam probes when scanning into convex scanning surfaces of the test object

D 4.2 Calibration blocks, reference blocks and reference reflectors

(1) When using differing materials for calibration block or reference block and test object the difference in sound velocities shall be taken into account for range adjustment and for the angular deviation in case of angle beam scanning.

(2) When calibration blocks No. 1 to DIN EN ISO 2400 or No. 2 to DIN EN ISO 7963 are not used for adjusting the testing level, the following applies:

a) to the reference block used:

aa) The reference block shall correspond to the test object as regards the test-relevant characteristics (material, design, shape, wall thickness, cladding if any, heat treatment). The wall thickness of the reference block shall deviate not more than 10 % from that of the component to be tested. When using contoured probes or if the curvature of the opposite surface impairs the reflection behaviour (ratio of wall thickness s to outer diameter d_a of the test objet to exceed 0.2), the deviation of the test object diameter shall not exceed 10 % of the diameter of the component to be tested. Deviating here from plane reference blocks may be used in case of pulse-echo probes if the test object diameter does not require the use of contoured probes, the reflection behaviour is not impaired by the curvature of the opposite surface (ratio of wall thickness s to outer diameter d_a of the test objet less than or equal to 0.2) and no wave conversion technique is used.

ab) Reference blocks for testing of welds on austenitic steels, on nickel alloys or dissimilar welds shall be

similar to the test object. The similar reference block (e.g. from a production control test piece), must correspond to the test object as regards geometry, material, weld design, welding process and surface condition.

ac) The sound beam shall not be impaired in its development, i.e. all dimensions vertical to the main beam path for sound paths up to twice the near field length (N) shall normally be greater than the transducer dimension perpendicular to the scanning direction (D_Q) Decisive for greater sound path travel distances than twice the near field length is the beam width $D_{S\text{-}20dB}$ at the reflector location. In this case, the reference object width is determined to the following formula:

$$C \geq 2 \cdot \lambda \cdot \frac{S_{max}}{D_Q}$$

Exempted from this rule are reference blocks used for testing the area with lateral wall influence on bars in axial direction. In this case, the width of the reference block shall be equal to the width of the test object.

ad) The dimensions of the scanning surface of the test object shall normally exceed 1.5 times the probe scanning surface.

ae) The location of the reference reflectors in the reference block shall be selected such that their echoes do no interfere with each other and cannot be confused with corner echoes.

b) to the reference reflector used:

ba) The back walls shall normally be plane and vertical to the main beam as well as have dimensions exceeding the beam width $D_{S\text{-}20dB}$, but not less than the transducer dimension.

bb) Side-drilled holes shall normally be vertical to the main beam and parallel to the scanning surface. The lengths of the side-drilled holes shall normally be greater than the sound beam width $D_{S\text{-}20dB}$, but not less than the transducer dimension. The diameter shall normally be 3 mm.

bc) The bottom of flat bottom holes shall normally be vertical to the main beam when applying the single-probe technique. Exempted from this rule are specifications for the use of flat-bottom holes when applying the wave conversion technique II and the creeping-wave technique.

bd) The notches shall have a rectangular cross-section. The notch edges shall be vertical to the surface. The notches shall normally have a width $\leq$ 1.0 mm and, if not specified for the respective product form, have a depth of 1.0 mm. The acoustically effective length of the notches shall normally be 20 mm.

be) Where the echo amplitudes of side-drilled holes are to be converted to echo amplitudes of D_{KSR}, the formula D-3 shall be considered.

D 5 Optimization of the testing technique for ultrasonic testing of austenitic steels or nickel alloys

(1) To maintain a sufficient distance (at least 6 dB) of the recording level to the noise level the test technique shall be optimised, e.g. by taking the following measures:

a) use of probes with low nominal frequency,

b) use of frequency-selective test instruments,

c) use of probes with composite transducers and test instruments suited for this purpose,

d) use of longitudinal waves for angle-beam scanning,

e) electrodynamically excited surface waves and horizontally polarised transverse waves.

(2) As far as the optimization of the testing technique as per (1) does not lead to a sufficient signal-to-noise ratio, testing techniques providing images of the test results shall be used to make evaluation possible, e.g.

a) sectorial and compound scanning with controlled phased arrays,

b) automated testing techniques, e.g. in connection with ALOK (transit-time and amplitude locus-curves).

D 6 Adjustment of test system

Note:
Sections D 7 to D 9 contain requirements for the test system adjustment as regards the use of wave conversion and creeping wave techniques.

D 6.1 Range adjustment

(1) The time base range shall normally be calibrated on the calibration block No. 1, the calibration block No. 2, the test object or on a similar reference block (e.g. to **Figure D-2**).

The time base range shall be adjusted by locating known reflectors.

(2) Where probes have to be contoured, the range shall first be calibrated with a non-contoured probe on a plane calibration or reference block. Hereafter, the contoured probe shall be positioned on a suitable shaped reference block to contain at least one reflector on a known time base range. By means of this reflector a zero-point correction shall be made.

(3) For longitudinal wave angle-beam probes a pre-adjustment of the time base range shall be carried out using a straight beam probe on the calibration blocks No. 1 or No. 2, on the test object or on the reference block. Subsequently a correction of zero point shall be effected by means of the angle-beam probe to consider the delay path.

D 6.2 Adjustment of the testing level when applying the DGS method

D 6.2.1 Application of the DGS method

(1) The DGS method may only be used for probes where probe-specific DGS diagrams are available.

(2) In the case of probes with adjusted contact surfaces, the DGS method shall basically not be used. When scanning with angle-beam probes which flat contact surfaces are adjusted the use of the DGS method is permitted on test objects with d exceeding 100 mm where scanning is performed on a concave scanning surface of the test object, if the condition $L < \sqrt{d}$ is satisfied.

(3) The following criteria apply to the use of the of the DGS method:

a) The evaluable sound path begins, for single transducer probe, approximately at $S = 0.7 \cdot N$ and for dual-element probes as well as for focussing probes at the beginning of the focal zone.

b) In the case of a lateral wall influence the DGS method may only be used up to the sound path travel distance given in Section D 2.3, equation D-7.

c) In the case of angle-beam scanning the DGS method can only be applied for wall thicknesses exceeding $5 \cdot \lambda$.

d) Probe-specific DGS diagrams for disc shaped reflectors shall be used to adjust the testing level.

e) In the case of attenuated probes the DGS method may only be used if the ratio of the band width (Δf) to the nominal frequency is less than 0.75.

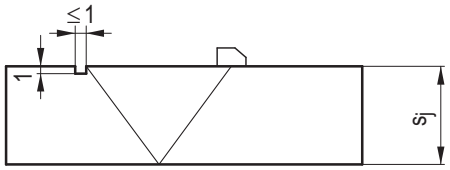
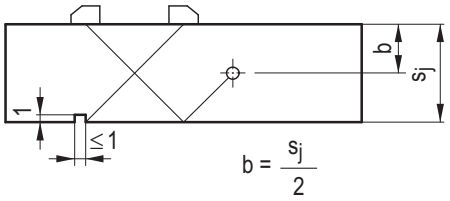
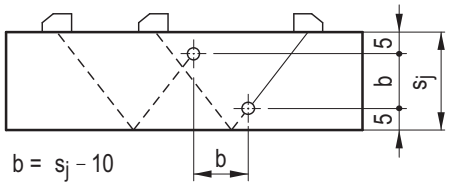
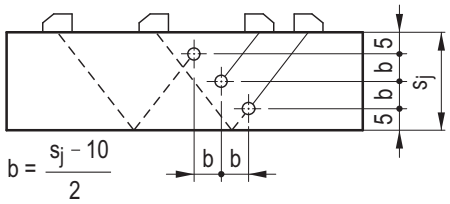
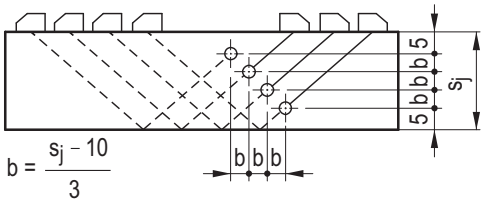
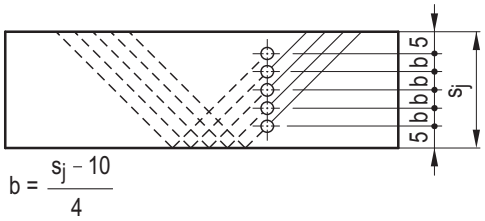
Wall thickness or nominal wall thickness of the test object in mm	Lateral view of the reference block
s ≤ 10	
10 < s ≤ 15	
15 < s ≤ 20	
20 < s ≤ 40	
40 < s ≤ 80	
s > 80	

Figure D-2: Reference blocks for adjusting the testing level for angle beam scanning

D 6.2.2 Reference reflectors to be used

(1) The reference echo heigth shall be determined on reference reflectors meeting the following requirements:

a) The reference reflector for straight beam probes shall be
   - aa) the back wall of the test object provided the back wall meets the requirements according to clause D 4.2 (2) ba),
   - ab) the back wall of the reference block provided the back wall meets the requirements according to clause D 4.2 (2) ba),
   - ac) the back wall of calibration block no. 1 with a thickness of 25 mm or the back wall of calibration block no. 2 with a thickness of 12.5 mm,
   - ad) a side-drilled hole or a flat bottom hole.

b) The reference reflector for angle-beam probes shall be
   - ba) the circular arc R100 of the calibration block no. 1,
   - bb) the circular arc R25 of the calibration block no. 2 taking the known or determined probe-specific correction values into account,
   - bc) a side-drilled hole or a flat bottom hole.

(2) The diameter of a flat bottom hole (D_{FBB}) corresponds to the diameter of the disc shaped reflector (D_{KSR}) provided that $D_{FBB} > 1.5 \cdot \lambda$.

(3) For the conversion of the echo amplitude of a side-drilled hole into the echo amplitude of a disc shaped reflector equation D-3 shall be used.

D 6.3 Adjustment of the testing level for the reference block method and DAC method

D 6.3.1 Reference block method

(1) In the reference block method the indication from the test object is directly compared to the reference reflector having nearly the same sound path length. This may be done with reference reflectors in the part or reference block.

(2) The testing level shall be adjusted by means of a reference reflector located at the end of the time base range. Where echoes of reflectors are detected in the test, further reference reflectors of the respective reference block may be used which have the same or next greater sound path length. Where different types of reference reflectors are used (see **Figure D-2**) the smaller echo height shall be used as reference level.

D 6.3.2 DAC method

(1) When applying the DAC method for simplifying the echo amplitude description it is recommended to generate a DAC curve by means of one or several equal reflectors located at different depths in reference blocks (e.g. step wedge or to **Figure D-2**) or by means of reference reflectors in the test object located at different distances. Clause D 4.2 (2) b) applies with regard to the requirements for reference reflectors.

(2) The DAC curve shall be generated by at least three responses from the reference reflectors (e.g. side-drilled holes) in various probe distances (see **Figure D-3**). The echo with the highest amplitude shall normally be adjusted for approximately 80 % of the screen height. The DAC curve constructed may be extrapolated by a maximum of 20 % beyond the time base range limited by the reference reflectors. The gain setting of the ultrasonic equipment shall be selected such that the DAC curve is within the time base range between 20 % and 80 % of the screen height. If this is not possible for the entire time base range, the DAC curve shall be staged as per **Figure D-4**.

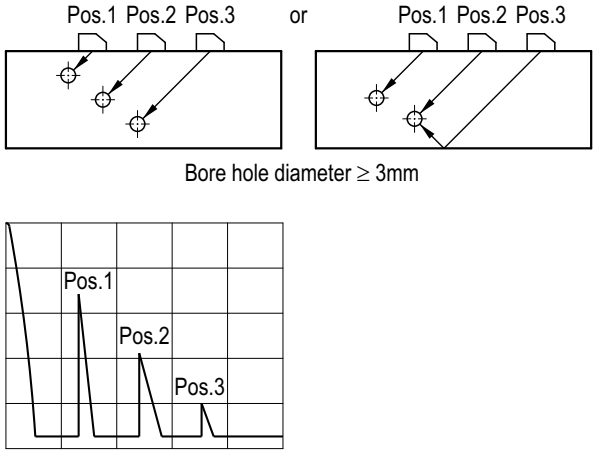


Figure D-3: Generation of reference echo heights from side-drilled holes located at different probe distances for angle beam scanning

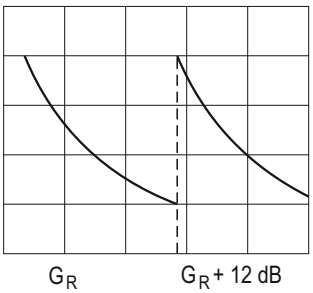


Figure D-4: Staged DAC curve

D 6.4 Corrections of testing level adjustment

D 6.4.1 Transfer correction

(1) The transfer correction shall normally be determined on at least 4 points of the test object in the intended direction of testing.

(2) The transfer correction shall normally be determined in accordance with **Figure D-5** by means of transmission on the calibration block and on the test object.

(3) To consider the transfer correction in angle-beam scanning ΔV_T of the V-transmission or W-transmission shall normally be used. Where ΔV_T exceeds this value by more than 2 dB, the testing level adjusted to D 6.2 of D 6.3 shall be corrected by the values obtained. In the case of ΔV_T values equal to or less than 2 dB these values shall generally be taken as 2 dB when adjusting the testing level.

D 6.4.2 Determination of the sound attenuation

(1) The sound attenuation for straight-beam scanning shall normally be determined as per **Figure D-6** and for angle-beam scanning as per **Figure D-7** at the same reference screen height level respectively in consideration of ΔV_S.

(2) The determination of the sound attenuation may be omitted if it is considered by a constant allowance independent from the sound path length (e.g. by transfer correction in accordance with clause D 6.4.1).

D 6.4.3 Coupling and sound attenuation variations

(1) For the transfer correction the average value of the transmission values obtained from the test object shall be used if the range of variation does not exceed 6 dB. Where the range exceeds 6 dB, the average value from 20 transmission values plus an allowance $\Delta\tilde{V} = 1.7 \cdot$ standard deviation to be calculated in accordance with clause D 2.3 h) shall be used as transfer correction.

(2) Where the $\Delta\tilde{V}$ value thus determined is greater than 6 dB, the test object shall be subdivided into testing sections where the transfer correction of each section shall be considered separately. This subdivision shall be such that in each section $\Delta\tilde{V}$ is equal to or smaller than 6 dB.

D 6.4.4 Consideration of corrections

(1) Taking the aforementioned corrections into account, the resultant instrument sensitivity for adjustment of recording level as per equation D-11 is obtained.

(2) Where sound attenuation in dependence of the sound path length is taken into account this shall be made with the attenuation portion ΔV_κ contained in ΔV_T as per **Figure D-8** when using the DGS method or as per **Figure D-9** when using the DAC method.

(3) If it is not necessary to consider the sound attenuation in dependence of the sound path length, ΔV_T shall contain a constant sound attenuation portion ΔV_κ independent of the sound path length.

(4) Where an additional correction for considering greater variations as per clause D 6.4.3 is required, this shall be done by means of $\Delta\tilde{V}$. Otherwise, the correction value $\Delta\tilde{V}$ in equation D-11 shall be omitted.

D 6.5 Setting of the ultrasonic instrument

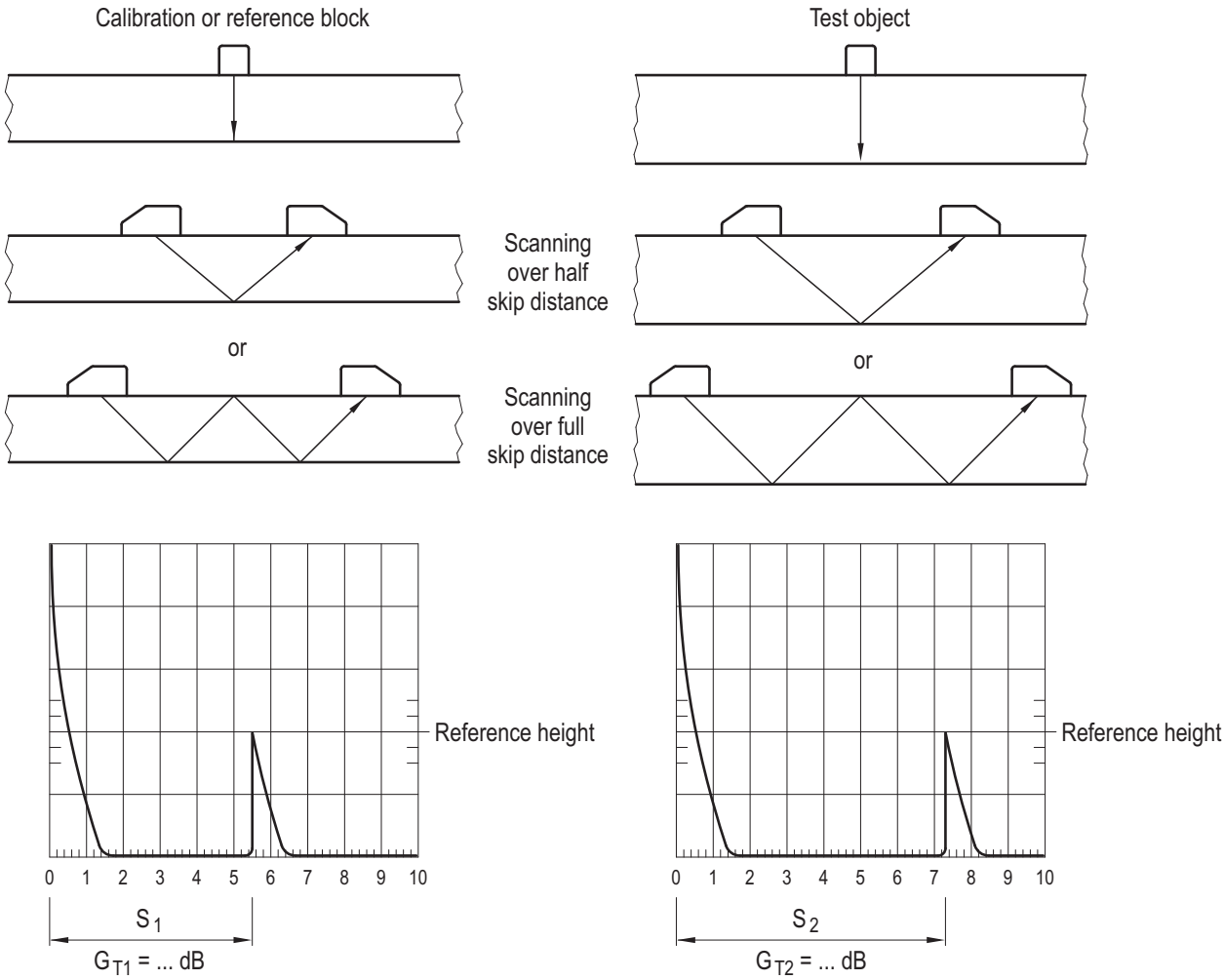
(1) Prior to adjusting the testing level it shall be ensured that

a) the amplifier suppression (“grass cutting”) is not used,
b) the amplifier is operated in the correct frequency range,
c) the filter is set such that optimum resolution is obtained,
d) the test instrument impedance, where required, is adapted such that a maximum echo height is obtained at constant resolution,
e) the energy for the transmitter pulse is set as low as possible in due consideration of the gain control reserve.

(2) The pulse repetition frequency shall be adjusted such that

a) the detection of all signals to be recorded is ensured,
b) the occurrence of so-called ghost echoes in case of long sound path lengths (especially in the case of materials with low sound attenuation) is avoided.

(3) Taking the corrections according to Section D 6.4 into account the instrument gain shall be adjusted such that all echoes exceeding the recording level attain at least 20 % of the screen height at the end of the respective time base range.



$\Delta V_T = G_{T2} - G_{T1} - \Delta V_S$
Transfer correction during straight and angle beam scanning [dB]

$\Delta V_S = V_{S_2} - V_{S_1}$
Divergence correction of back-wall echo curve of a DGS diagram

V_{S_1} = Gain value for transmission echo on calibration or reference block at reference level [dB]

V_{S_2} = Gain value for transmission echo on test object at reference level [dB]

G_{T1} = Instrument gain for transmission echo on calibration or reference block [dB]

G_{T2} = Instrument gain for transmission echo on test object [dB]

Back-wall echo curve of a DGS diagram

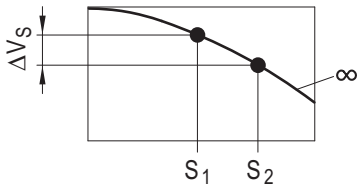
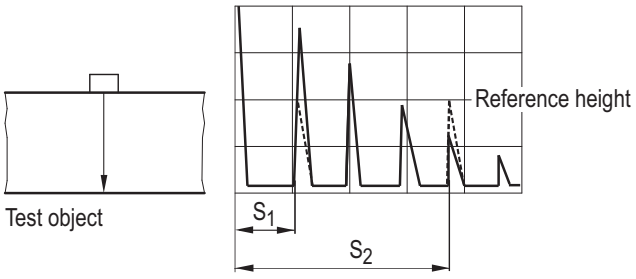


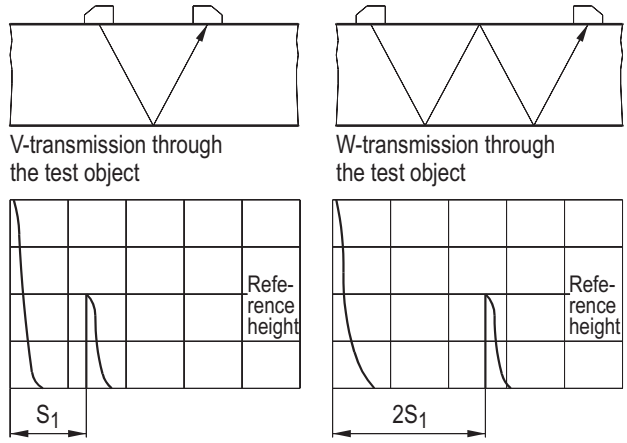
Figure D-5: Determination of transfer correction during straight and angle beam scanning performed as V or W-transmission



$$\kappa = \frac{G_{T2} - G_{T1} - V_S}{2 \cdot (S_2 - S_1)} \; [\mathrm{dB/mm}]$$

G_{T1} =...dB
G_{T2} =...dB

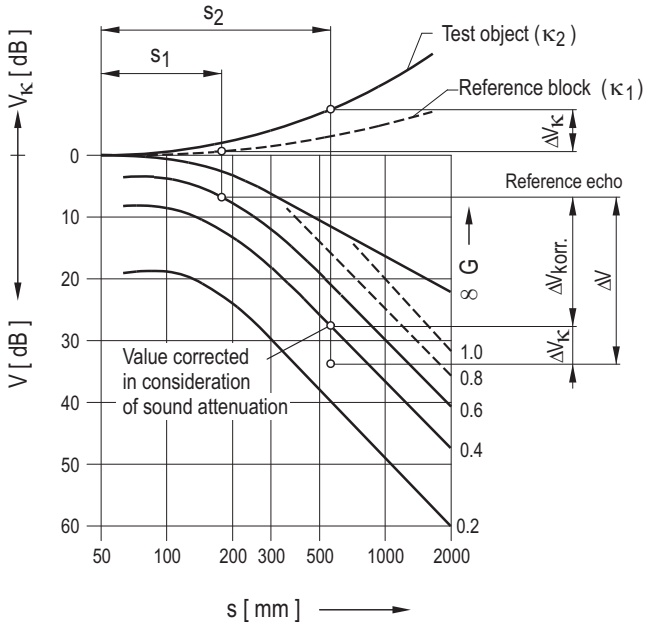
Figure D-6: Determination of sound attenuation for straight-beam scanning (example)



$G_{T1} = \ldots$ dB $\qquad G_{T2} = \ldots$ dB

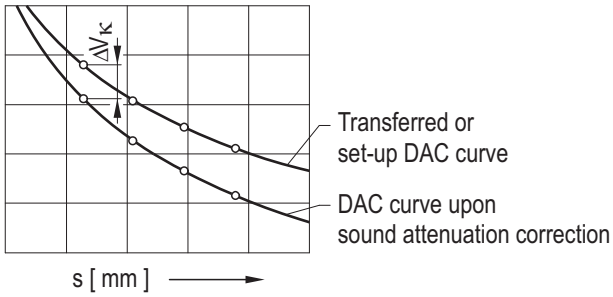
$$\kappa = \frac{G_{T2} - G_{T1} - \Delta V_S}{2 \cdot S_1} \; [\mathrm{dB/mm}]$$

Figure D-7: Determination of sound attenuation for angle-beam scanning



$$\Delta V_\kappa = 2 \cdot (S_2 \cdot \kappa_2 - S_1 \cdot \kappa_1) \; [\mathrm{dB}]$$

Figure D-8: Consideration of sound attenuation in the DGS diagram for $\kappa_2 > \kappa_1$ (example)



$$\Delta V_\kappa = 2 \cdot S \cdot (\kappa_2 - \kappa_1) \; [\mathrm{dB}]$$

Figure D-9: Consideration of sound attenuation for the DAC method for the case $\kappa_2 > \kappa_1$ (example)

D 7 Creeping wave method

D 7.1 Description of method

(1) Longitudinal wave probes with usual angles of incidence of 75 degrees to 80 degrees generate besides a sharp declined transverse wave additionally to the longitudinal main wave a longitudinal wave propagating in parallel to the scanning surface (primary creeping wave).

(2) By the propagation of the primary creeping wave along the scanning surface transverse waves are permanently radiated so that the intensity of the creeping wave rapidly decreases with the sound path length. For example the focal distance in the case of creeping wave dual-element probes with transducer dimensions of $D_0 \approx 6$ mm · 13 mm will be approximately 10 mm, by what a usable ultrasonic beam with a length of approximately 20 mm exists.

(3) Where, for geometric reasons, the primary creeping wave will dip into the volume, e.g. in the case of attachment welds, it will propagate as normal longitudinal wave without radiation. This leads to greater usable sound paths lengths of 30 mm to approximately 50 mm.

D 7.2 Reference block

(1) For the testing level adjustment of creeping wave probes the following reference blocks shall be taken:

a) for testing attachment welds or build-up weldings the reference block as shown in **Figure D-10**, which shall contain flat bottom holes with a diameter of 3 mm distributed over the maximum usable sound path length at equal distances of approximately 5 mm to 10 mm.

b) for testing near-surface areas the reference block as shown in **Figure D-11**, which shall contain a 1 mm deep notch with a length of 20 mm.

(2) When testing with contoured probes, the curvatures of the scanning surfaces of the reference block and the test object shall match.

D 7.3 Testing level adjustment

(1) For testing attachment welds or build-up weldings a DAC curve shall be generated to meet the requirements of Section D 6.3 by means of scanning the respective flat bottom holes in the reference block according to clause D 7.2 (1) a).

(2) For testing near-surface areas the reference echo height shall be the amplitude of the reference reflector according to clause D 7.2 (1) b).

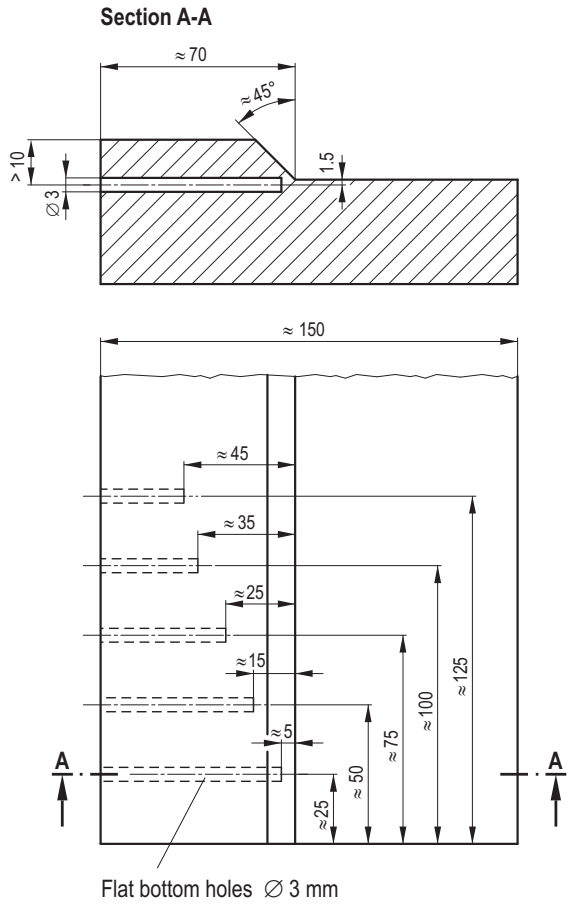


Figure D-10: Reference block for testing level adjustment when using the creeping wave technique (primary creeping wave)

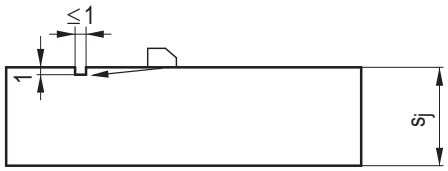


Figure D-11: Reference block for testing level adjustment when using the creeping wave technique (primary creeping wave) for testing near-surface areas

D 7.4 Adaptation of probes

(1) When testing on convex curved scanning surfaces of the test object, the probes shall be selected in accordance with **Figure D-12**.

(2) When testing on concave scanning surfaces of the test object, specific probes with properly contoured contact surfaces shall be used.

D 8 Wave conversion method I (secondary creeping wave)

D 8.1 Description of method

(1) **Figure D-13** shows the principle of reflection with wave conversion in scanning with a longitudinal wave angle-beam probe. When transverse waves in steel hit an opposite face at an angle less than 31 degrees, besides reflection of the transverse wave a wave conversion occurs. A longitudinal wave (secondary creeping wave) is generated at an angle of incidence of approximately 31 degrees which contains portions nearly parallel to the surface. The angle of incidence of approximately 31 degrees is obtained, in the case of test objects with parallel surfaces, by the accompanying transverse wave of a 70-degree longitudinal wave angle-beam probe (**Figure D-14**).

(2) Due to its near-surface linear propagation the secondary creeping wave is e.g. used to cover the root area of a welded joint without being significantly influenced by the excess penetration. In this case it shall be taken into account that

a) the intensity of the secondary creeping wave will rapidly decrease with the sound path subject to the permanent radiation of transverse waves,

b) the secondary creeping wave may be influenced by irregularities (e.g. edges, grooves) in the root area.

(3) During scanning with the longitudinal wave angle-beam probe on test objects having plane-parallel surfaces neighbour echoes are generated which are called NE 1 and NE 2 (**Figure D-15**). For the detection of reflectors the echo NE 2 is used. The echo NE 1 may be used for reflector depth estimation.

(4) When scanning thin test objects (wall thickness up to approximately 20 mm depending on the material) with the longitudinal wave probe (type 70 degree SEL) an analyzable echo amplitude is generated which contains both the longitudinal wave portion (main echo-HE) and the converted transverse wave portion (sequence of secondary echoes-NE) (**Figure D-16**).

Note:

Echoes due to geometric discontinuities may be generated due to the transverse wave generated simultaneously with the beam entry into the test object, since the transverse wave entering at a very steep angle is highly sensitive to irregularities of the probe-remote surface (e.g. gauge marks, identification markings) and reacts to deviations from shape. Therefore, it is especially important to

a) consider the probe position in relation to the centre of the welded joint,

b) know the sound velocities and the related angle of incidence of the transverse wave,

c) know the various echo dynamics.

When exactly allocating the indication to the welded joint and considering the fact that a reflector - contrary to the accompanying transverse wave - has a great dynamic effect when being scanned with 70 degree longitudinal waves, a distinction between such spurious echoes and real defects is possible.

*Scanning with secondary creeping waves in accordance with subpara (2) and (3) is purposeful beginning with a wall thickness exceeding 15 mm. In the case of wall thicknesses 8 mm < s ≤ 20 mm the examination shall be performed with longitudinal wave probes (Type 70 degree SEL). The presence of the main echo HE and the neighbour echo NE shows that the sound waves are reflected at deep material discontinuities. Indications of root notches of little depth are distinguished from deep defects due to the fact that secondary echoes are not obtained (**Figure D-16**).*

D 8.2 Probe

(1) In the case of plane-parallel surfaces of the test object single transducer or dual-element angle-beam longitudinal wave probes with beam angles of 70 degrees are used.

(2) For the testing test objects with none plane-parallel surfaces probes with beam angles shall be used, where the angle of incidence of the transverse wave on the opposite surface is approx. 31 degrees.

Note:

The wall thickness to be tested, the nominal frequency and the transducer dimension as well as the amplitudes of the echo NE 2 obtained from the different deep notches shall be decisive with regard to the selection of the probe.

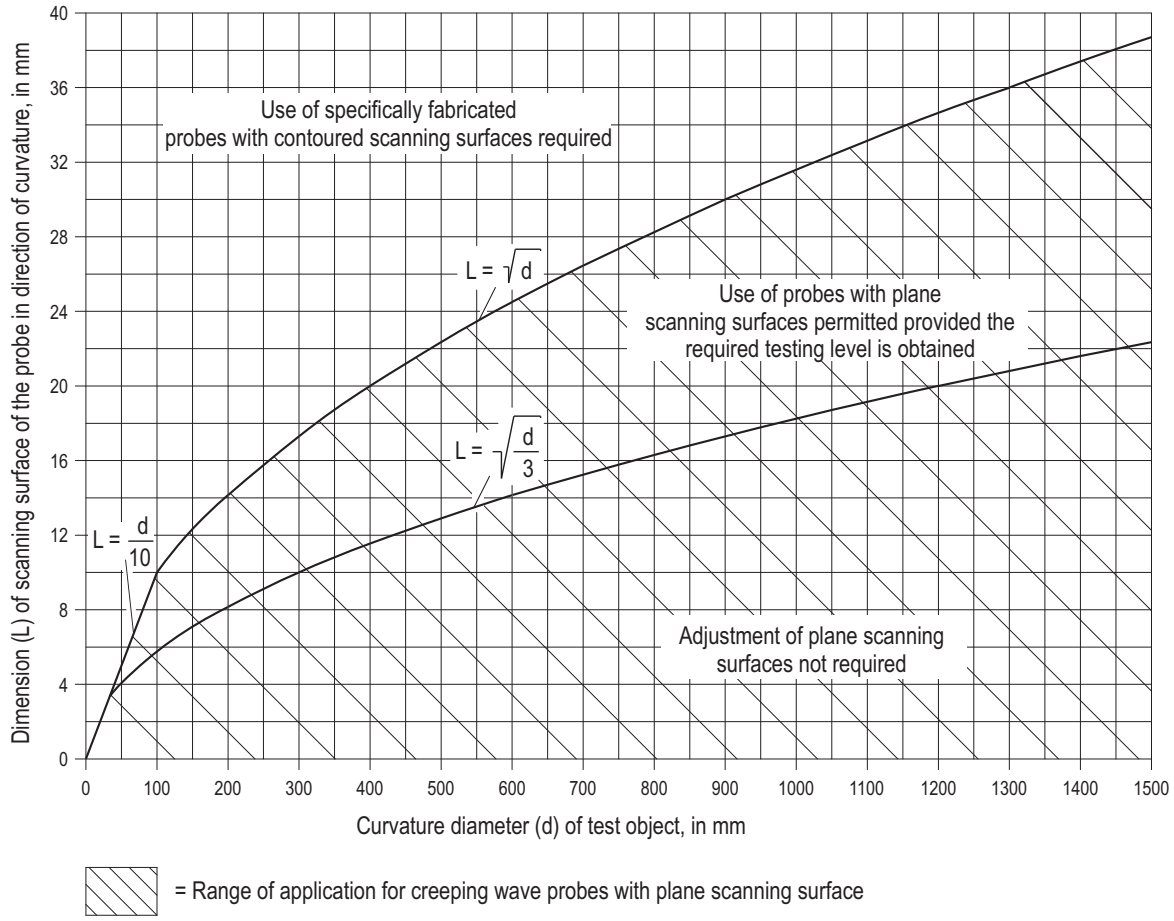


Figure D-12: Ranges of application of creeping wave probes with and without contouring of scanning surfaces for testing on convex test object scanning surfaces

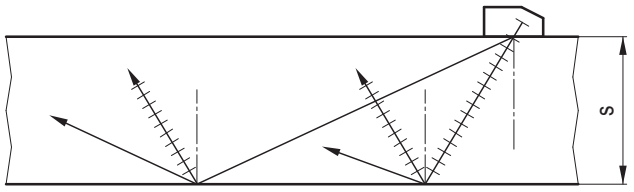


Figure D-13: Reflexion with wave conversion for longitudinal wave angle-beam probe

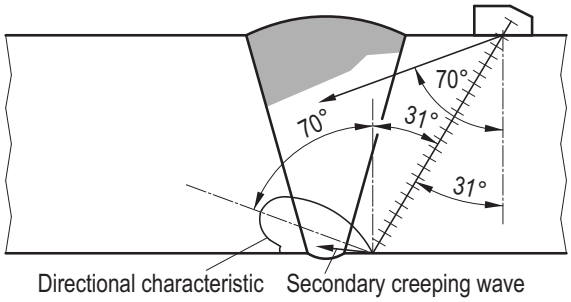


Figure D-14: Testing of internal near-surface area of welded joints by means of secondary creeping waves

D 8.3 Range calibration

(1) The time base range shall be pre-adjusted in accordance with D 6.1 (3).

(2) Hereafter, the zero-point correction for the longitudinal wave angle-beam probe shall be effected. In this case the following procedure may be followed, unless performed on the 100 mm circular arc profile (R100) of calibration block no.1:

A notch with rectangular cross-section provided on the reference block or test object shall be scanned (**Figure D-15**) in which case the transverse wave portion of the longitudinal wave angle-beam probe shall be included. The neighbour echo NE2 shall be optimised by displacing the probe. On the scanning surface the projected surface distance (p') from the point of incidence to the scanned notch shall be determined. By means of the following equation

$$S_{NE2} = 1.5 \cdot s + p'$$

the value of the sound path length of the angle beam probe shall be determined by approximation.

Note:

The neighbour echo NE 1 may be used for controlling the range calibration. The sound path position of the echo NE1 is determined by approximation by means of the formula $S_{NE1} = 2 \cdot s$ at a maximum value of the echo NE2.

D 8.4 Testing level adjustment

(1) The testing level shall be adjusted on a reference block.

(2) To generate a reference echo notches as per clause D 4.2 (2) bd) shall be used.

(3) By displacing the probe on the reference block the echo NE 2 reflected from the notch shall be optimized and thus the reference echo height be determined.

(4) In the case of testing as per clause D 8.1 (4) the testing level shall be adjusted on corresponding notches with rectangular cross-section using longitudinal waves. The recording level is the reference echo amplitude of the direct longitudinal wave minus 6 dB. The indication of the edge on the reference block shall exceed the recording level by at least 10 dB. Otherwise, the recording level shall be reduced accordingly.

D 8.5 Corrections during testing level adjustment

D 8.5.1 Transfer correction

The difference of the acoustic properties between the similar reference block and the test object shall be determined and be considered during testing. This may be done by a global transfer measurement.

D 8.5.2 Correction of sound attenuation caused by the weld metal

Different testing levels caused by the weld metal shall be determined by suitable means and be taken into account.

D 8.6 Performance of testing

(1) Range calibration according to the requirements of Section D 8.3

a) pre-adjustment with straight-beam probe,

b) zero-point correction with longitudinal wave angle-beam probe on the 100 mm circular arc profile (R100) of calibration block no.1,

c) determination of probe index point where required for the longitudinal wave angle-beam probe.

(2) Testing level adjustment according to the requirements of Section D 8.4

a) positioning of probe index point of the longitudinal wave angle-beam probe above the notch of the respective reference block,

b) determination of the distance p' in case of optimised NE2 to reference echo (see **Figure D-15**),

c) consideration of respective allowances for testing level.

(3) Displacement of the probe

The longitudinal wave angle-beam probe shall be displaced vertically to the weld so that the defined testing area is completely covered at the opposite surface.

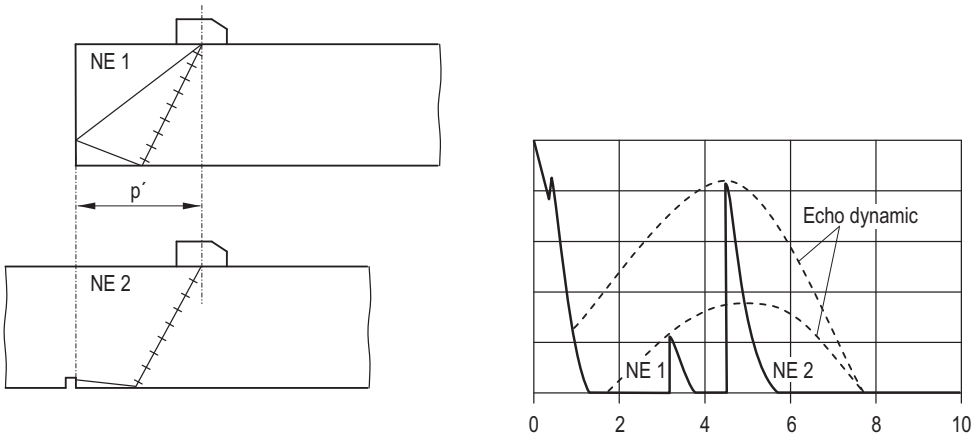
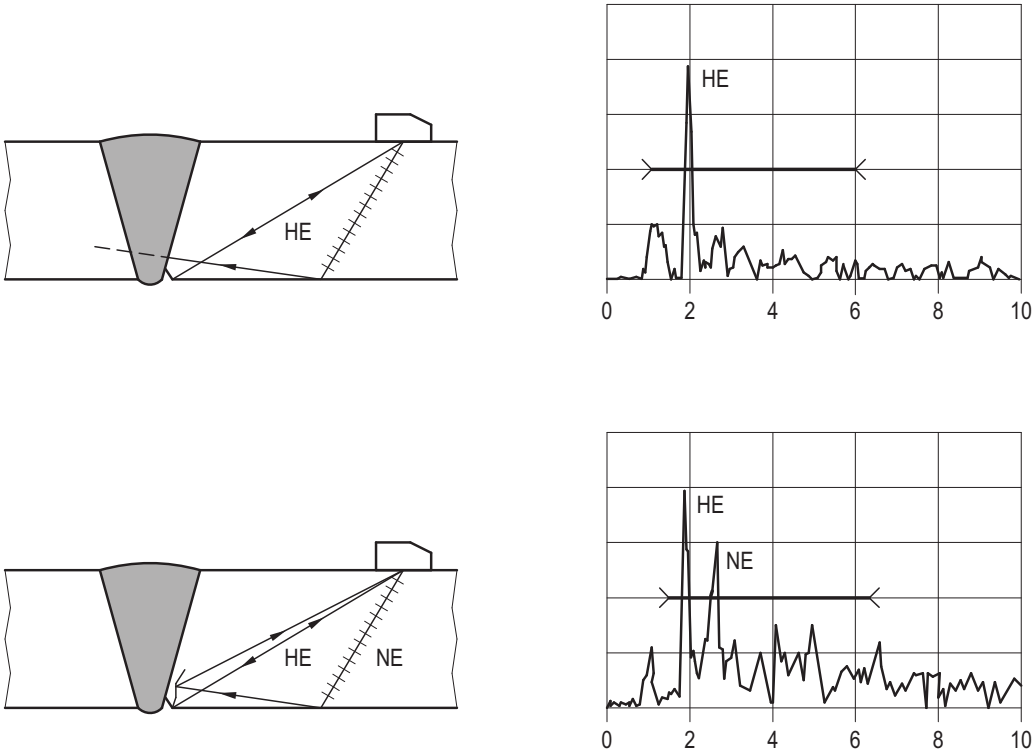


Figure D-15: Sound field geometry during transverse wave conversion



HE: Main echo, NE: Neighbour echo

Figure D-16: Testing of components with nominal wall thicknesses 8 mm < s ≤ 20 mm by means of longitudinal waves (70 degree SEL probe)

D 9 Wave conversion method II (LLT technique)

D 9.1 General

(1) The LLT technique is used to detect reflectors vertical or nearly vertical to the surface during volumetric testing of test objects with parallel or concentrically curved surfaces and up to a nominal wall thickness of 80 mm.

(2) The functional principle of the LLT technique is shown in **Figure D-17**. The transmitting transducer generates a longitudinal wave with an angle of α_{LW} ranging between 7 and 45 degrees. This wave is reflected on the test object back-wall and hits the vertical reflector. Here, the greatest portion of the wave energy is converted to form a transverse wave which is reflected at an angle α_{TW} and is received from the receiving transducer.

(3) The advantage of the LLT technique is the compact design of the LLT probes with the transmitting and receiving transducer being arranged in one housing.

D 9.2 Probes, scanning zones, reference blocks, LLT sensitivity diagrams

D 9.2.1 Use of probes

(1) Due to their specific arrangement of transmitting and receiving transducers the probes are designed for testing of a certain depth zone (scanning zone) at the respective wall thickness and curvature of the test object. The range of application shall be determined by means of probe-specific data sheets.

(2) LLT probes designed for the examination of flat test objects may be used in testing of surfaces concentrically curved in the direction of testing, where great radii of curvature (R exceeding 1000 mm) exist.

D 9.2.2 Probes and their scanning zones

D 9.2.2.1 Location and height of scanning zones

(1) LLT probes are sensitive only in a limited scanning zone (depth zone). The location of the scanning zone is determined by the beam angle α_{LW}, the angle of incidence α_{TW} and by the arrangement of the transducers.

(2) The scanning zone height is determined by the depth area (Z_{H_a}, Z_{H_b}, **Figure D-17**) where the sensitivity has decreased by half the value (-6 dB) compared to the maximum value in the scanning zone centre (Y_{S_a}, Y_{S_b}, **Figure D-17**). The height of the scanning zone depends on the wall thickness, the nominal frequency and the dimensions oft the transmitting and receiving transducer.

D 9.2.2.2 Subdivision of scanning zones

(1) The scanning zones shall cover the volume to be tested, and the scanning zones shall overlap.

Note:

The volume to be examined normally comprises the non-subsurface area as of a depth of 10 mm distanced from the probe-remote surface and probe-adjacent surface.

(2) The subdivision of scanning zones may be estimated based on probe-specific data sheets. Where no probe-specific data sheets are, the location and dimensions of the scanning zones shall be determined by means of measurements with the selected probes on reference blocks with flat bottom holes.

D 9.2.3 Reference blocks

(1) The reference block used for determining the scanning zone dimension and location shall correspond to the test object as regards the geometry and acoustic properties. The reference reflectors are flat bottom holes with the same size as the disc shaped reflectors to be recorded. The reference reflectors shall be provided on the front-face side in the centre of the scanning zone (depth location, distance Y_{S_a}, Y_{S_b}, **Figure D-17**) laid down by the given probe. To confirm proper subdivision of scanning zones, additional reference reflectors shall be provided in the overlapping areas of the zone edges.

(2) The distance of the reference reflectors to the front faces shall be at least 20 mm.

D 9.2.4 Establishment of LLT sensitivity diagrams

(1) With the aid of sensitivity diagrams the testing level adjustment may be simplified.

(2) The diagrams shall be established by means of measurements on flat bottom holes of the reference block in accordance with clause D 9.2.3 for the respective scanning zone. The echo heights (signal amplitudes) measured on the flat bottom holes shall be entered over the depth location (Y_{FBB}, **Figure D-18**). The reference height of the front face (maximum of front-face echo) shall also be entered in the diagram. The distance between the reference height of the front face and the peak of the sensitivity curve from the echo heights of the flat bottom holes defines the value ΔV_{LLT}.

(3) To generate a depth scale the reflector depth location shall be entered in a further diagram over the sound path travel distance (see **Figure D-19**). To this end, at least three flat bottom holes provided at the front-face side of the reference block are necessary.

D 9.3 Range adjustment

(1) The respective LLT probe shall be operated such that at first only the receiving transducer is activated in the pulse-echo mode to generate transverse waves. Range adjustment shall be made at the 100 mm circular arc profile of the calibration block No. 1. The range shall be adjusted such that the sound path travel distance to the centre of the scanning zone is located in the middle of the time base range (S_{Just}). The time base range shall be calculated and adjusted in accordance with formulae D-14 to D-17.

Hereafter, the transmitting transducer shall also be connected and the ultrasonic instrument shall change over to the dual-element mode.

(2) To estimate the depth location of reflectors a depth scale determined in accordance with clause D 9.2.4 shall be used.

D 9.4 Testing level adjustment

D 9.4.1 General

(1) The testing level shall be adjusted using the following reference reflectors:

a) end faces (front faces) or flat bottom holes vertical to the scanning surface of the test object or reference block

or

b) flat-bottom holes which, depending on the testing task, are oblique to the scanning surface of the test object.

The flat bottom holes shall be of the same size as the disk shaped reflectors to be recorded.

(2) During testing level adjustment the zone edge allowance and transfer correction shall be considered.

D 9.4.2 Adjustment on end faces vertical to the scanning surface of the test object (front faces)

(1) For this type of adjustment probe-specific LLT sensitivity diagrams shall be submitted in accordance with clause D 9.2.4.

(2) When setting the testing level the value ΔV_{LLT} shall be taken from the probe-specific LLT sensitivity diagram (see **Figure D-18**) for the centre of the scanning zone (Y_s) and be increased by 6 dB for the zone edge. The setting shall be checked by means of flat bottom holes.

D 9.4.3 Adjustment on flat-bottom holes

Where no sensitivity diagrams are available or reference reflectors oblique to the test object scanning surface are to be found, the testing level shall be adjusted on flat bottom holes in a reference block. For each scanning zone at least three flat bottom holes shall be provided.

D 9.5 Transfer correction

(1) In the case of ferritic steels the transfer correction may globally be assumed to be 2 dB.

(2) In the case of austenitic steels and nickel alloys the difference of the acoustic properties between the similar reference block and the test object shall be determined and be considered. This may also be done by assuming a global transfer measurement.

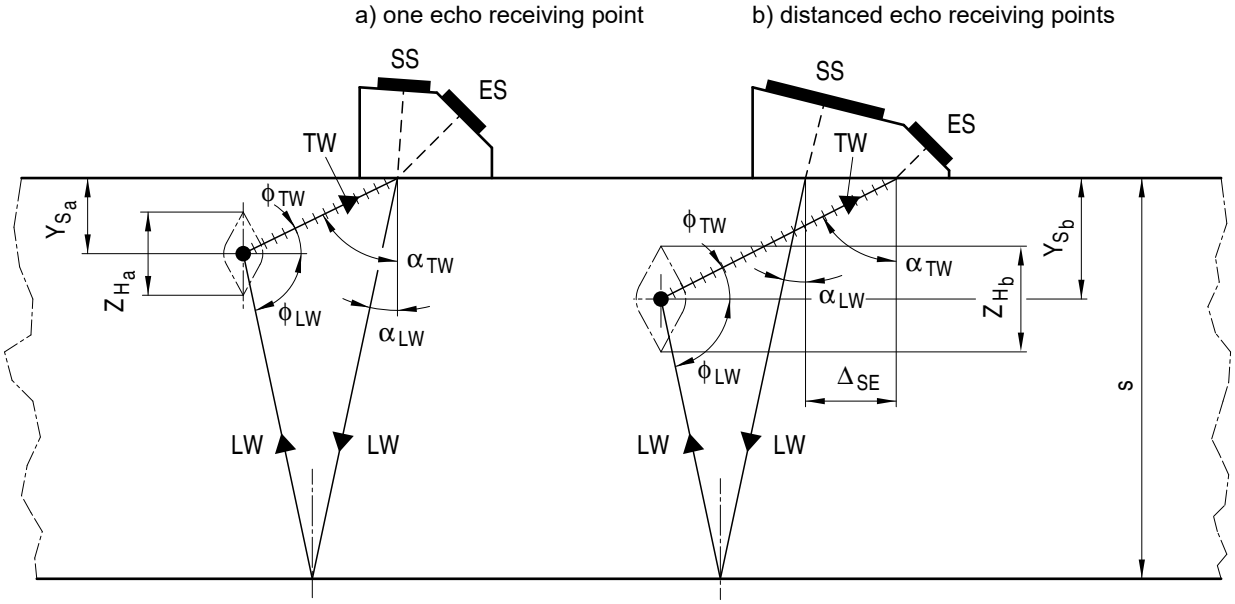
D 9.6 Performance of testing

(1) The testing using the LLT technique shall be performed separately for each scanning zone.

(2) The probe shall be coupled on the test object for each scanning zone at a distance a'_{LLT} (see **Figure D-18**) to the centre of the weld. The distances a'_{LLT} shall be determined on the reference block.

(3) The probes shall be moved over each scanning zone vertically to the direction of weld progress such that the volume to be tested is completely covered.

(4) The LLT probe coupling shall be monitored by observing the noise.



$$\alpha_{TW} = \arccos\left(\frac{c_{TW}}{c_{LW}} \cdot \cos\alpha_{LW}\right)$$

$$Y_{S_a}, Y_{S_b} = \frac{2\,s \cdot \tan\alpha_{LW} + \Delta_{SE}}{\tan\alpha_{TW} + \tan\alpha_{LW}}$$

Z_{H_a}, Z_{H_b} : depth zone

Figure D-17: Principle of LLT technique

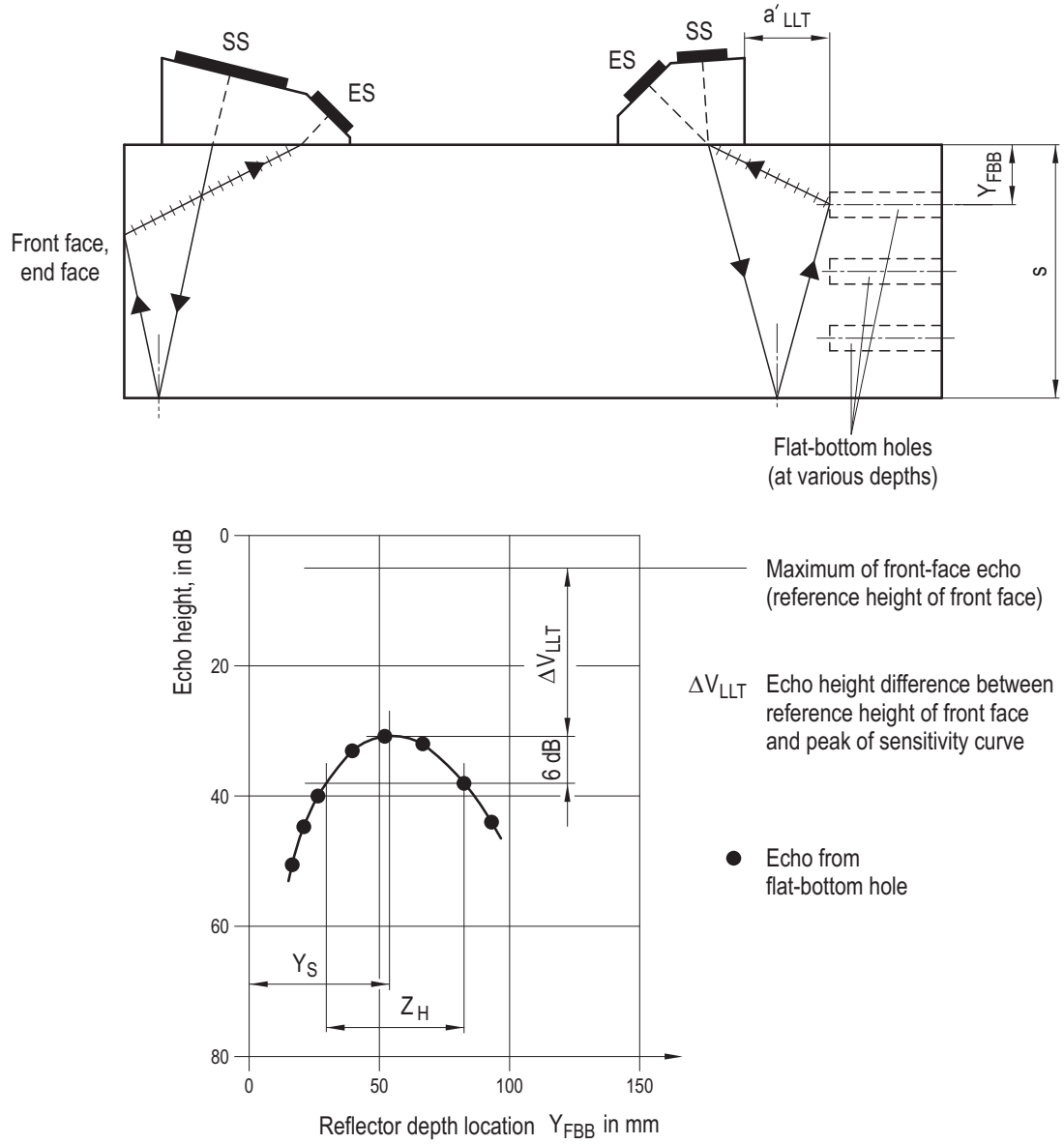


Figure D-18: Example for a LLT sensitivity diagram

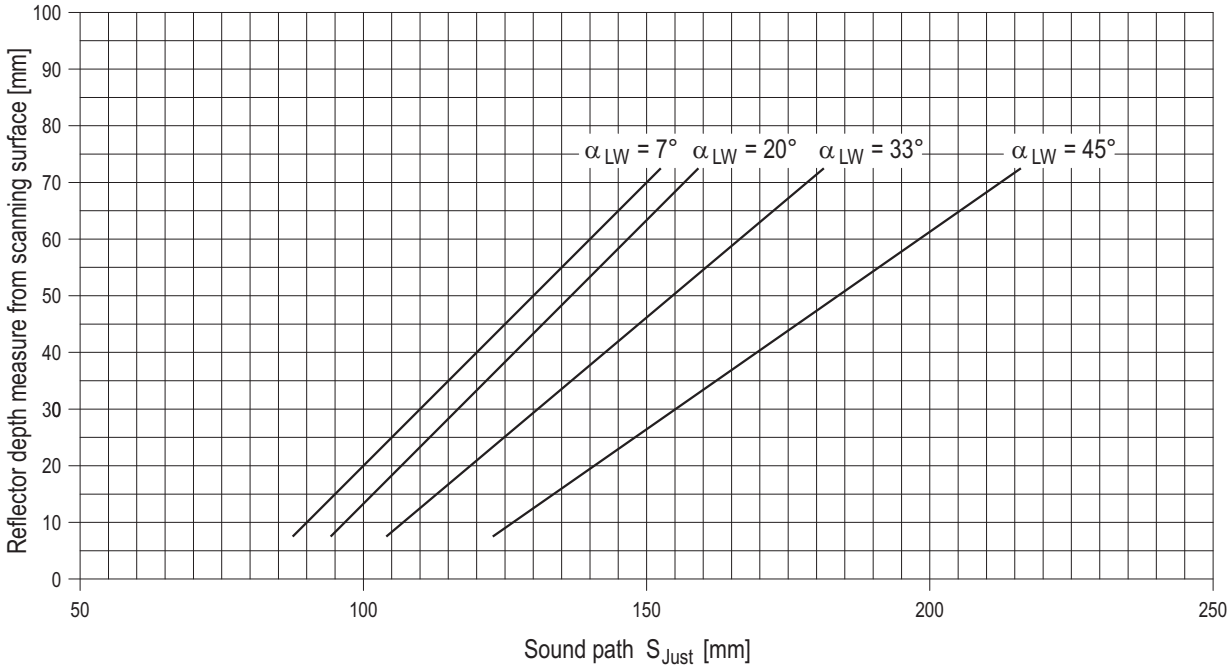


Figure D-19: Example for LLT reflector depth scales

D 10 Performance of testing

D 10.1 Overlap

To ensure complete coverage during testing the distance between two adjacent scanning tracks in the examination volume shall be smaller than the beam width $D_{B\text{-}6dB}$ transverse to the scanning direction.

D 10.2 Rate of probe movement

When selecting the rate of probe movement the pulse repetition frequency, the operator's ability of detecting signals and the test instrument's capability of recording signals shall be taken into account.

During manual scanning the rate of probe movement should not exceed 150 mm/s.

D 10.3 Adjustment and check of the test system

(1) Prior to testing, the testing level and range adjustments shall be made after the warm-up periods given by the instrument manufacturer. To this end, suitable calibration or reference blocks shall be used. The instrument setting shall be maintained during scanning and shall be controlled regularly during and at the end of testing.

(2) Where deviations from the checks made before are found, all tests performed after the last check without deviations shall be repeated with a corrected adjustment.

D 11 Description of indications

D 11.1 Echo amplitude

The maximum echo amplitude of an indication referred to the respective valid recording level is to be indicated in dB.

Note:
The reproduceability of the echo amplitude determination is generally ± 3 dB.

D 11.2 Extension of indications

D 11.2.1 General requirements

Lengths of indications equal to or greater than 10 mm shall be measured. Shorter indication lengths shall be recorded as „< 10“.

D 11.2.2 Determination of the recording length at fixed recording level

The extension of reflector (see **Figure D-20**) shall be given by the probe displacement range. This range is determined as the distance between locations where the echo amplitude is lower the recording level by either 0 dB, 6 dB or 12 dB. Where the noise level is reached, the recording length shall be indicated to cover the point where the echo reaches the noise level. Here, the distance of the recording level to the noise level shall be recorded.

D 11.2.3 Determination of half-amplitude length

When measuring the half-amplitude length of indications, the related probe displacements at echo amplitude decreases of 6 dB compared to the maximum echo amplitude shall be determined. Here, for dual-element probes the acoustic separating line and for line focussing probes the line focus shall be vertical to the extension direction of the indication.

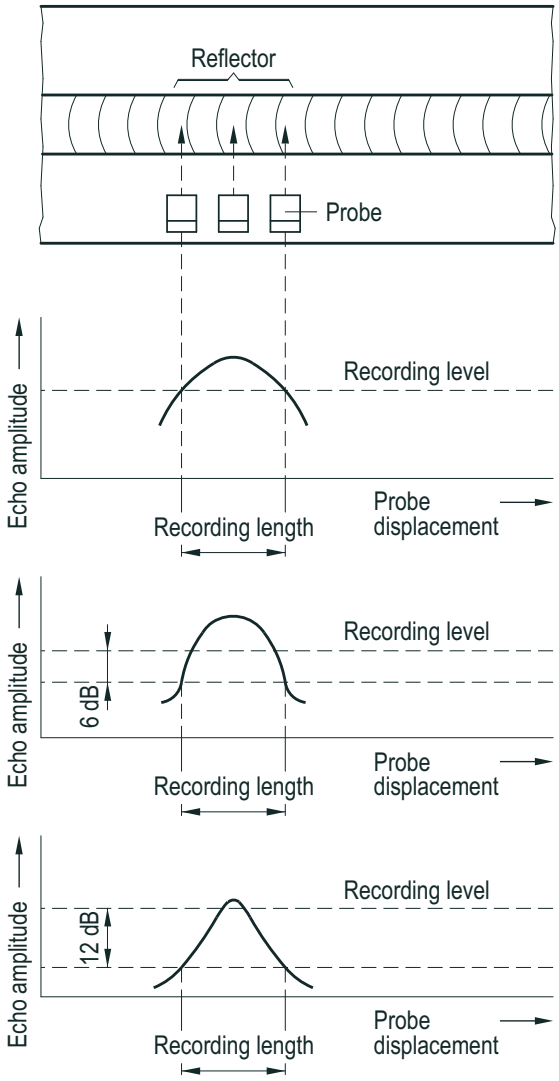


Figure D-20: Determination of recording length

D 11.2.4 Methods for the exact determination of indication extension

The determination of the indication extension may be optimized by one of the corrections described in clauses D 11.2.4.1 to D 11.2.4.4 or by examinations according to clause D 11.2.5.

D 11.2.4.1 Correction for curved surfaces

For curved surfaces the length shall be determined mathematically or graphically in the reflector depth determined.

D 11.2.4.2 Selection of probe

Scan positions and beam angle shall be selected such that the scan path length shows the slightest deviation from $1.0 \cdot N$ however is greater than $0.7 \cdot N$. In such a case, a higher nominal frequency than during the test may be used.

D 11.2.4.3 Consideration of sound beam width

(1) The sound beam width $D_{S\text{-}6dB}$ shall be determined at the reflector location. If the measured indication length exceeds this measured beam width the length of indication shall be the corrected recording length calculated as per equation D-6.

(2) The beam width shall be determined by calculation or experimental analysis.

(3) In the case of calculation equation D-4 shall be used if probes are used, the contact surface of which has not been adapted. In the case of angle beam scanning the horizontal included angle shall be inserted for γ_6. The included angle shall be taken from the data sheets on the probes used.

(4) Where the beam width has to be determined by experimental analysis, measurements shall be made on a reference block to Section D 3.3. A reference reflector shall be provided into this reference block at the same depth location like for the reflector to be gauged. As reference reflector a flat bottom hole of 3 mm diameter may be suited. The half-amplitude length shall be determined on the reference reflector on the same sound path travel distance as for the reflector to be gauged. The value determined such shall correspond to the beam width at the respective depth of reflector.

D 11.2.4.4 Use of dual-element probes and focussing probes

(1) By means of dual-element probes or focussing probes with suitable sound field the indication length shall be measured in the focal zone using the half-amplitude method.

(2) In this case several echo dynamics may be recorded from the reflector on a grid pattern to increase the measuring accuracy and to improve the reproduceability in the case of focussing probes. The grid-line distances shall be smaller than the diameter of the focussing beam of the probe.

D 11.2.5 Use of additional ultrasonic testing techniques for the determination of indication extension

Where additional ultrasonic testing techniques are to be used to determine the indication extension (length or depth), the procedural requirements shall be laid down in a test instruction.

Note:

Examples for ultrasonic testing techniques for a more exact determination of indication extension are:

a) Synthetic aperture focussing technique (SAFT),

b) Time-of-flight diffraction technique (TOFD),

c) Crack-tip signal detection technique,

d) Echo tomography.

D 11.3 Indications due to geometric discontinuities

(1) Where indications from the root area of a weld are to be classified as indications due to geometric discontinuities, control measurements shall be made to determine the cause of indication.

(2) If it is to be proved that the indications recorded from both weld sides arise on the two flanks of the excess penetration and are not caused by weld defects, the control measurement may be made by measuring the projected-surface distance on the test piece (see **Figure D-21 a**). The exact projected-surface distances shall be determined on notches having rectangular cross-section with a depth and width of 1 mm each on a reference block (see **Figure D-21 b**). Where it is found out that the projected-surface distances of the respective indications clearly overlaps [(2a - a') equal to or greater than 3 mm], the indications are considered to be caused by geometric discontinuities. Where a smaller distance than 3 mm is found, the indications shall no more be treated separately.

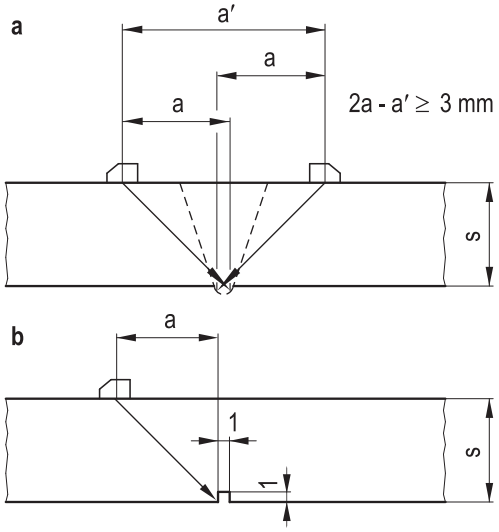


Figure D-21: Proof of indications caused by structural discontinuities from the root area of single-side welds

Annex E

Performance of surface inspections by magnetic particle and penetrant methods

E 1 General requirements

E 1.1 Surface condition

(1) The surfaces to be inspected shall show a condition suitable for testing.

(2) They shall be free from scale, weld spatter or other disturbing impurities.

(3) Grooves and notches affecting the test result shall be removed.

E 1.2 Viewing conditions

(1) The viewing conditions of DIN EN ISO 3059 shall be observed. In addition, the requirements as per (2) to (5) shall be met.

(2) The eyes of the operator shall have at least 5 minutes to adapt to the light conditions.

(3) For the purpose of better detectability of defects sufficient contrast shall be provided in magnetic particle testing by the use of suitable media (e.g. fluorescent detection media or application of a thin colour coat only slightly covering the underground). Ultraviolet radiation of type UVA may additionally be used to improve the contrast in penetrant testing using fluorescent penetrants.

(4) During the inspection the angle of viewing shall not deviate by more than 30 degrees from the surface normal. During viewing the distance to the examination surface shall normally be approximately 300 mm.

(5) For the inspection auxiliary means (e.g. magnifying glasses, contrast-improving spectacles, mirrors) are permitted.

E 1.3 Post-cleaning

Upon completion of inspection, the parts shall be properly cleaned to remove residues from the test fluid.

E 2 Magnetic particle testing

E 2.1 Methods and performance of testing

Magnetic particle testing shall be performed to DIN EN ISO 9934-1 to meet the following requirements.

E 2.1.1 Methods

(1) Where magnetisation is achieved in partial areas by current flow technique or yoke magnetisation, AC magnetisation shall normally be used.

(2) The DC magnetisation method shall only be used upon agreement by the authorized inspector.

(3) The residual magnetic field strength shall not exceed 800 A/m unless a lower value is required for the fabrication. Where the specified value is exceeded, the part shall be demagnetised and the value of the residual magnetic field strength be recorded.

(4) For the magnetic particle testing techniques the following identifying characters shall be used:

Magnetic particle testing technique		Characters
Yoke magnetization	with permanent magnet	JD
	with electromagnet	JE
Magnetization by current carrying-conductors	with coil	LS
	with other conductors (cable)	LK
Magnetization by current flow	self-induced current	SS
	induced current flow	SI

E 2.1.2 Contact areas in case of direct magnetisation

(1) Where the test is performed by current flow technique, consumable electrodes (e.g. lead fin alloys) shall be used, if possible. It shall be ensured that in the contact areas overheating of the material to be tested is avoided.

(2) Where overheating has occurred the overheated areas shall be marked, ground over after the test and be examined for surface cracks, preferably by magnetic particle testing using yoke magnetisation.

E 2.1.3 Direction of magnetisation

Each location on the surface shall be tested from two directions of magnetisation offset by approximately 90 degrees.

E 2.1.4 Magnetic field strength

(1) In the case of AC magnetisation the tangential field strength on the surface shall normally be at least 2 kA/m and shall not exceed 6.5 kA/m.

Note:

a) The required magnetic flux density in the test object surface of at least 1 Tesla will be obtained in low-alloy or low-carbon steels with high relative permeability as early as at a tangential field strength of 2 kA/m.

b) For other steels with lower permeability a higher field strength may be required.

c) Where magnetisation is too high, structural indications (spurious indications) may cover relevant indications.

(2) It shall be checked by measurements that these values are adhered to or test conditions shall be determined under which these values may be obtained.

E 2.1.5 Magnetisation times

The following guide values apply with respect to the application of the magnetic particles and magnetisation:

a) Magnetisation and application: at least 3 seconds

b) Subsequent magnetisation: at least 5 seconds

E 2.2 Inspection medium

According to DIN EN ISO 9943-2 sample-tested media shall be used. Verification of such sample testing shall be submitted to the authorized inspector.

E 2.2.1 Wet particle inspection method

(1) Magnetic particles with an average grain size smaller than or equal to 8 µm shall be used. Depending on application, black, fluorescent or coloured powders may be used.

Note:
The required average grain size ensures comparability with in-service inspections, cf. DIN 25435-2.

(2) Prior to bathing the surface care shall be taken to ensure that the magnetic powder is distributed uniformly in the vehicle fluid and is kept in suspension. Prior to and during testing the powder suspension shall be spot-checked by suitable pre-magnetised test units.

E 2.2.2 Dry particle method

(1) The dry particle method shall only be used for an intermediate test in warm condition.

(2) The device for applying the powder shall make possible such a fine spraying that no accumulations of powder occurs. It shall be ensured that the powders used do not agglomerate under the influence of the workpiece temperature.

E 2.3 Test instruments

The test instruments shall meet the requirements of DIN EN ISO 9934-3.

E 3 Penetrant testing

E 3.1 Testing system

(1) Colour contrast penetrants shall preferably be used. Fluorescent penetrants or fluorescent colour contrast penetrants may also be used.

(2) Solvents or water or both in combination may be used as penetrant remover.

(3) Only wet developers suspended in an aqueous solvent shall be used. Dry developers may only be applied on the testing surface by electrostatic charging.

(4) For the examination system at least sensitivity class „highly sensitive“ to DIN EN ISO 3452-2 shall be adhered to.

(5) The suitability of the testing system (penetrant, solvent remover and developer) shall be demonstrated by means of a sample examination as to DIN EN ISO 3452-2. The results of the demonstration by sample testing shall be submitted to the authorized inspector.

(6) Penetrants in test equipment and partly used open tanks (except for aerosol cans) shall be monitored by the user with flux indicator 2 to DIN EN ISO 3452-3. In this test the maximum penetration and development times shall not exceed the minimum times specified for the evaluation. The testing sensitivity obtained shall be recorded.

E 3.2 Performance

(1) Penetrant testing shall be performed to DIN EN ISO 3452-1 to meet the following requirements.

(2) The penetration time shall normally be at least half an hour.

(3) Immediately after drying of the developer a first inspection shall normally be made. A further inspection shall normally be made not earlier than half an hour after the first inspection has passed.

(4) Further inspection times are required if during the second inspection indications are detected which were not visible during the first inspection.

Note:
Further inspection times may also be suitable if during the second inspection significant changings or additional indications are detected.

(5) The evaluation shall be made in consideration of the results of all inspections.

Annex F

Regulations and literature referred to in this Safety Standard

(The references exclusively refer to the version given in this annex. Quotations of regulations referred to therein refer to the version available when the individual reference below was established or issued.)

AtG		Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards (Atomic Energy Act) of December 23, 1959 (BGbl. I, p. 814) as Amended and Promulgated on July 15, 1985 (BGBl. I, p. 1565), last amended by article 2 (2) of the law dated 20th July 2017 (BGBl. I 2017, no. 52, p. 2808)
StrlSchV		Ordinance on the Protection against Damage and Injuries Caused by Ionizing Radiation (Radiation Protection Ordinance) dated 20th July 2001 (BGBl. I p. 1714; 2002 I p. 1459), last amended in accordance with article 10 by article 6 of the law dated 27th January 2017 (BGBl. I p. 114, 1222)
SiAnf	(2015-03)	Safety Requirements for Nuclear Power Plants (SiAnf) as Promulgated on March 3rd 2015 (BAnz AT 30.03.2015 B2)
Interpretations	(2015-03)	Interpretations of the Safety Requirements for Nuclear Power Plants of November 22nd 2012, as Amended on March 3rd 2015 (BAnz. AT 30.03.2015 B3)
KTA 1401	(2017-11)	General Requirements Regarding Quality Assurance
KTA 1408.1	(2017-11)	Quality Assurance for Weld Filler Materials and Welding Consumables for Pressure and Activity Retaining Systems in Nuclear Power Plants; Part 1: Qualification Testing
KTA 1408.2	(2017-11)	Quality Assurance for Weld Filler Materials and Welding Consumables for Pressure and Activity Retaining Systems in Nuclear Power Plants; Part 2: Manufacture
KTA 1408.3	(2017-11)	Quality Assurance for Weld Filler Materials and Welding Consumables for Pressure and Activity Retaining Systems in Nuclear Power Plants; Part 3: Processing
KTA 3211.2	(2013-11)	Pressure and Activity Retaining Components of Systems Outside the Primary Circuit; Part 2: Design and Analysis
KTA 3211.3	(2017-11)	Pressure and Activity Retaining Components of Systems Outside the Primary Circuit; Part 3: Manufacture
DIN EN ISO 148-1	(2017-05)	Metallic materials - Charpy pendulum impact test - Part 1: Test method (ISO 148-1:2016); German version EN ISO 148-1:2016
DIN EN ISO 643	(2013-05)	Steels - Micrographic determination of the apparent grain size (ISO 643:2012); German version EN ISO 643:2012
DIN EN ISO 898-1	(2013-05)	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread (ISO 898-1:2013); German version EN ISO 898-1:2013
DIN EN ISO 898-2	(2012-08)	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread (ISO 898-2:2012); German version EN ISO 898-2:2012
DIN EN ISO 1127	(1997-03)	Stainless steel tubes - Dimensions, tolerances and conventional masses per unit length (ISO 1127:1992); German version EN ISO 1127:1996
DIN EN 1369	(2013-01)	Founding - Magnetic particle testing; German version EN 1369:2012
DIN EN 1370	(2012-03)	Founding - Examination of surface condition; German version EN 1370:2011
DIN EN 1371-1	(2012-02)	Founding - Liquid penetrant testing - Part 1: Sand, gravity die and low pressure die castings; German version EN 1371-1:2011
DIN EN 1559-2	(2014-12)	Founding - Technical conditions of delivery - Part 2: Additional requirements for steel castings; German version EN 1559-2:2014
DIN EN ISO 2400	(2013-01)	Non-destructive testing - Ultrasonic testing - Specification for calibration block No. 1 (ISO 2400:2012); German version EN ISO 2400:2012
DIN EN ISO 2560	(2010-03)	Welding consumables - Covered electrodes for manual metal arc welding of non-alloy and fine grain steels - Classification (ISO 2560:2009); German version EN ISO 2560:2009
DIN EN ISO 3059	(2013-03)	Non-destructive testing - Penetrant testing and magnetic particle testing - Viewing conditions (ISO 3059:2012); German version EN ISO 3059:2012
DIN EN ISO 3452-1	(2014-09)	Non-destructive testing - Penetrant testing - Part 1: General principles (ISO 3452-1:2013, Corrected version 2014-05-01); German version EN ISO 3452-1:2013

DIN EN ISO 3452-2	(2014-03)	Non-destructive testing - Penetrant testing - Part 2: Testing of penetrant materials (ISO 3452-2:2013); German version EN ISO 3452-2:2013
DIN EN ISO 3452-3	(2014-03)	Non-destructive testing - Penetrant testing - Part 3: Reference test blocks (ISO 3452-3:2013); German version EN ISO 3452-3:2013
DIN EN ISO 3506-1	(2010-04)	Mechanical properties of corrosion-resistant stainless steel fasteners - Part 1: Bolts, screws and studs (ISO 3506-1:2009); German version EN ISO 3506-1:2009
DIN EN ISO 3506-2	(2010-04)	Mechanical properties of corrosion-resistant stainless steel fasteners - Part 2: Nuts (ISO 3506-2:2009); German version EN ISO 3506-2:2009
DIN EN ISO 3651-2	(1998-08)	Determination of resistance to intergranular corrosion of stainless steels - Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels - Corrosion test in media containing sulfuric acid (ISO 3651-2:1998); German version EN ISO 3651-2:1998
DIN EN ISO 4136	(2013-02)	Destructive tests on welds in metallic materials - Transverse tensile test (ISO 4136:2012); German version EN ISO 4136:2012
DIN EN ISO 4287	(2010-07)	Geometrical Product Specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters (ISO 4287:1997 + Cor 1:1998 + Cor 2:2005 + Amd 1:2009); German version EN ISO 4287:1998 + AC:2008 + A1:2009
DIN EN ISO 5173	(2012-02)	Destructive tests on welds in metallic materials - Bend tests (ISO 5173:2009 + Amd 1:2011); German version EN ISO 5173:2010 + A1:2011
DIN EN ISO 5577	(2017-05)	Non-destructive testing - Ultrasonic testing - Vocabulary (ISO 5577:2017); German version EN ISO 5577:2017
DIN EN ISO 5579	(2014-04)	Non-destructive testing - Radiographic testing of metallic materials using film and X- or gamma rays - Basic rules (ISO 5579:2013); German version EN ISO 5579:2013
DIN EN ISO 6157-2	(2004-10)	Fasteners - Surface discontinuities - Part 2: Nuts (ISO 6157-2:1995); German version EN ISO 6157-2:2004
DIN EN ISO 6506-1	(2015-02)	Metallic materials - Brinell hardness test - Part 1: Test method (ISO 6506-1:2014); German version EN ISO 6506-1:2014
DIN EN ISO 6506-4	(2015-02)	Metallic materials - Brinell hardness test - Part 4: Table of hardness values (ISO 6506-4:2014); German version EN ISO 6506-4:2014
DIN EN ISO 6507-1	(2006-03)	Metallic materials - Vickers hardness test - Part 1: Test method (ISO 6507-1:2005); German version EN ISO 6507-1:2005
DIN EN ISO 6507-4	(2006-03)	Metallic materials - Vickers hardness test - Part 4: Tables of hardness values (ISO 6507-4:2005); German version EN ISO 6507-4:2005
DIN EN ISO 6892-1	(2017-02)	Metallic materials - Tensile testing - Part 1: Method of test at room temperature (ISO 6892-1:2016); German version EN ISO 6892-1:2016
DIN EN ISO 6892-2	(2011-05)	Metallic materials - Tensile testing - Part 2: Method of test at elevated temperature (ISO 6892-2:2011); German version EN ISO 6892-2:2011
DIN EN ISO 7963	(2010-12)	Non-destructive testing - Ultrasonic testing - Specification for calibration block No. 2 (ISO 7963:2006); German version EN ISO 7963:2010
DIN EN ISO 8249	(2000-10)	Welding - Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals (ISO 8249:2000); German version EN ISO 8249:2000
DIN EN ISO 8492	(2014-03)	Metallic materials - Tube - Flattening test (ISO 8492:2013); German version EN ISO 8492:2013
DIN EN ISO 8493	(2004-10)	Metallic materials - Tube - Drift-expanding test (ISO 8493:1998); German version EN ISO 8493:2004
DIN EN ISO 8495	(2014-03)	Metallic materials - Tube - Ring-expanding test (ISO 8495:2013); German version EN ISO 8495:2013
DIN EN ISO 8496	(2014-03)	Metallic materials - Tube - Ring tensile test (ISO 8496:2013); German version EN ISO 8496:2013
DIN EN ISO 9606-1	(2013-12)	Qualification testing of welders - Fusion welding - Part 1: Steels (ISO 9606-1:2012, including Cor. 1:2012); German version EN ISO 9606-1:2013
DIN EN ISO 9712	(2012-12)	Non-destructive testing - Qualification and certification of NDT personnel (ISO 9712:2012); German version EN ISO 9712:2012
DIN EN ISO 9934-1	(2017-03)	Non-destructive testing - Magnetic particle testing - Part 1: General principles (ISO 9934-1:2016); German version EN ISO 9934-1:2016
DIN EN ISO 9934-2	(2015-12)	Non-destructive testing - Magnetic particle testing - Part 2: Detection media (ISO 9934-2:2015); German version EN ISO 9934-2:2015

DIN EN ISO 9934-3	(2015-12)	Non-destructive testing - Magnetic particle testing - Part 3: Equipment (ISO 9934-3:2015); German version EN ISO 9934-3:2015
DIN EN 10028-2	(2009-09)	Flat products made of steels for pressure purposes - Part 2: Non-alloy and alloy steels with specified elevated temperature properties; German version EN 10028-2:2009
DIN EN 10028-3	(2009-09)	Flat products made of steels for pressure purposes - Part 3: Weldable fine grain steels, normalized; German version EN 10028-3:2009
DIN EN 10028-7	(2016-10)	Flat products made of steels for pressure purposes - Part 7: Stainless steels; German version EN 10028-7:2016
DIN EN 10160	(1999-09)	Ultrasonic testing of steel flat product of thickness equal to or greater than 6 mm (reflection method); German version EN 10160:1999
DIN EN 10163-2	(2005-03)	Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections - Part 2: Plate and wide flats; German version EN 10163-2:2004
DIN EN 10164	(2005-03)	Steel products with improved deformation properties perpendicular to the surface of the product - Technical delivery conditions; German version EN 10164:2004
DIN EN 10204	(2005-01)	Metallic products - Types of inspection documents; German version EN 10204:2004
DIN EN 10213	(2016-10)	Steel castings for pressure purposes; German version EN 10213:2007+A1:2016
DIN EN 10216-2	(2014-03)	Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties; German version EN 10216-2:2013
DIN EN 10216-3	(2014-03)	Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 3: Alloy fine grain steel tubes; German version EN 10216-3:2013
DIN EN 10216-5	(2014-03)	Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 5: Stainless steel tubes; German version EN 10216-5:2013 (Corrigendum 2015-01)
DIN EN 10217-7	(2015-01)	Welded steel tubes for pressure purposes - Technical delivery conditions - Part 7: Stainless steel tubes; German version EN 10217-7:2014
DIN EN 10222-2	(2017-06)	Steel forgings for pressure purposes - Part 2: Ferritic and martensitic steels with specified elevated temperatures properties; German version EN 10222-2:2017
DIN EN 10222-4	(2017-06)	Steel forgings for pressure purposes - Part 4: Weldable fine grain steels with high proof strength; German version EN 10222-4:2017
DIN EN 10222-5	(2017-06)	Steel forgings for pressure purposes - Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels; German version EN 10222-5:2017
DIN EN 10228-1	(2016-10)	Non-destructive testing of steel forgings - Part 1: Magnetic particle inspection; German version EN 10228-1:2016
DIN EN 10228-2	(2016-10)	Non-destructive testing of steel forgings - Part 2: Penetrant testing; German version EN 10228-2:2016
DIN EN 10228-3	(2016-10)	Non-destructive testing of steel forgings - Part 3: Ultrasonic testing of ferritic or martensitic steel forgings; German version EN 10228-3:2016
DIN EN 10228-4	(2016-10)	Non-destructive testing of steel forgings - Part 4: Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings; German version EN 10228-4:2016
DIN EN 10269	(2014-02)	Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties; German version EN 10269:2013
DIN EN 10272	(2016-10)	Stainless steel bars for pressure purposes; German version EN 10272:2016
DIN EN 10273	(2016-10)	Hot rolled weldable steel bars for pressure purposes with specified elevated temperature properties; German version EN 10273:2016
DIN EN 10307	(2002-03)	Non-destructive testing - Ultrasonic testing of austenitic and austenitic-ferritic stainless steels flat products of thickness equal to or greater than 6 mm (reflection method); German version EN 10307:2001
DIN EN 10308	(2002-03)	Non-destructive testing - Ultrasonic testing of steel bars; German version EN 10308:2001
DIN EN ISO 10484	(2004-10)	Widening test on nuts (ISO 10484:1997); German version EN ISO 10484:2004
DIN EN ISO 10893-2	(2011-07)	Non-destructive testing of steel tubes - Part 2: Automated eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections (ISO 10893-2:2011); German version EN ISO 10893-2:2011
DIN EN ISO 10893-3	(2011-07)	Non-destructive testing of steel tubes - Part 3: Automated full peripheral flux leakage testing of seamless and welded (except submerged arc-welded) ferromagnetic steel tubes for the detection of longitudinal and/or transverse imperfections (ISO 10893-3:2011); German version EN ISO 10893-3:2011

DIN EN ISO 10893-4	(2011-07)	Non-destructive testing of steel tubes - Part 4: Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections (ISO 10893-4:2011); German version EN ISO 10893-4:2011
DIN EN ISO 10893-5	(2011-07)	Non-destructive testing of steel tubes - Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections (ISO 10893-5:2011); German version EN ISO 10893-5:2011
DIN EN ISO 10893-8	(2011-07)	Non-destructive testing of steel tubes - Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections (ISO 10893-8:2011); German version EN ISO 10893-8:2011
DIN EN ISO 10893-10	(2011-07)	Non-destructive testing of steel tubes - Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections (ISO 10893-10:2011); German version EN ISO 10893-10:2011
DIN EN ISO 11699-1	(2012-01)	Non-destructive testing - Industrial radiographic films - Part 1: Classification of film systems for industrial radiography (ISO 11699-1:2008); German version EN ISO 11699-1:2011
DIN EN ISO 11970	(2007-09)	Specification and approval of welding procedures for production welding of steel castings (ISO 11970:2001); German version EN ISO 11970:2007
DIN EN 12668-1	(2010-05)	Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 1: Instruments; German version EN 12668-1:2010
DIN EN 12668-2	(2010-06)	Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 2: Probes; German version EN 12668-2:2010
DIN EN 12668-3	(2014-02)	Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 3: Combined equipment; German version EN 12668-3:2013
DIN EN 12680-2	(2003-06)	Founding - Ultrasonic examination - Part 2: Steel castings for highly stressed components; German version EN 12680-2:2003
DIN EN 12681	(2003-06)	Founding - Radiographic examination; German version EN 12681:2003
DIN EN 13018	(2016-06)	Non-destructive testing - Visual testing - General principles; German version EN 13018:2016
DIN EN ISO 13916	(1996-11)	Welding - Guidance on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature (ISO 13916:1996); German version EN ISO 13916:1996
DIN EN ISO 14174	(2012-05)	Welding consumables - Fluxes for submerged arc welding and electroslag welding - Classification (ISO 14174:2012); German version EN ISO 14174:2012
DIN EN ISO 14284	(2003-02)	Steel and iron - Sampling and preparation of samples for the determination of chemical composition (ISO 14284:1996); German version EN ISO 14284:2002
DIN EN ISO 19232-1	(2013-12)	Non-destructive testing - Image quality of radiographs - Part 1: Determination of the image quality value using wire-type image quality indicators (ISO 19232-1:2013); German version EN ISO 19232-1:2013
DIN EN ISO 19232-3	(2014-02)	Non-destructive testing - Image quality of radiographs - Part 3: Image quality classes (ISO 19232-3:2013); German version EN ISO 19232-3:2013
DIN EN 26157-3	(1991-12)	Fasteners; surface discontinuities; bolts, screws and studs subject to special requirements (ISO 6157-3:1988); german version EN 26157-3:1991
DIN 50104	(1983-11)	Testing of hollow bodies by internal pressure; leak detection up to a certain pressure value; general specifications
DIN 50125	(2016-12)	Testing of metallic materials - Tensile test pieces
DIN 51220	(2003-08)	Materials testing machines - Generals for requirements and for verification and calibration of materials testing machines
SEW 088	(1993-10)	Weldable fine-grained structural steels; guidelines for processing, in particular for fusion welding (incl. supplementary sheets 1 and 2)
AD 2000-Merkblatt HP 3	(2014-11)	Welding supervisors, welder
AD 2000-Merkblatt W 2	(2008-02)	Austenitic and austenitic-ferritic steels
AD 2000-Merkblatt W 5	(2009-03)	Cast steel
VdTÜV material sheet 113/2	(2001-06)	High-temperature austenic rolled and forged steel, X 8 CrNiMoBNb 16 16 + wk, material no. 1.4986 + wk

VdTÜV material sheet 352/1	(2017-04)	Weldable fine-grained steels with a minimum yield strength of 275 MPa; strips, plates, wide flats, steel sections, steel bars
VdTÜV material sheet 352/2	(2017-04)	Weldable fine-grained steels with a minimum yield strength of 275 MPa; seamless hollow parts, seamless pipes, seamless headers
VdTÜV material sheet 354/1	(2017-04)	Weldable fine grain steels with a minimum yield strength of 355 MPa; steel plate, metal strips, wide flats, steel sections, steel bars
VdTÜV material sheet 354/2	(2016-03)	Weldable fine grain steels with a minimum yield strength of 355 MPa; seamless hollow parts, seamless pipes, seamless headers
VdTÜV material sheet 354/3	(2013-12)	Weldable fine grain steels with a minimum yield strength of 355 MPa; flanges; rings, hollow parts, forgings, steel bars
VdTÜV material sheet 395/3	(2010-09)	Weldable martensitic rolled and forged steel, X3CrNiMo13-4; material no. 1.4313; steel sections and steel bars, forged products
VdTÜV material sheet 452	(2011-06)	Martensitic cast steel G-X4 CrNi 13 4 / G-X 3 CrNi 13 4, material no. 1.4317 / material 1.6982; hollow castings, solid castings, cast valve bodies, pump casings, impellers and diffusers, machine parts for hydraulic systems

Literature

[1]	Handbuch für das Eisenhüttenlaboratorium	Loseblattsammlung (Loose-leaf edition); Verlag Stahleisen, Düsseldorf
[2]	De Long, W. T.	Welding Research Supplement 53 (1974), p. 273/286
[3]	Richter, F.	Physikalische Eigenschaften von Stählen und ihre Temperaturabhängigkeit, (Physical Properties of Steels and Their Temperature Dependence) Stahleisen-Sonderberichte Heft 10, 1983, Verlag Stahleisen, Düsseldorf.
[4]	Petzow, G.	Metallographisches, keramographisches, plastographisches Ätzen, (Metallographic, ceramographic, plastographic etching) Verlag Borntraeger; Nachdruck der 6. vollständig überarbeiteten Auflage (19. Oktober 2006)
[5]		Reference-Atlas for a comparative evaluation of ferrite percentage in the fused zone of austenitic stainless steel welded joints; Internationales Institut für Schweißtechnik: Istituto Italiano della Saldatura, Genova, 1972