Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3201.1 (2017-11)

Components of the Reactor Coolant Pressure Boundary
of Light Water Reactors
Part 1: Materials and Product Forms
(Komponenten des Primärkreises von Leichtwasserreaktoren;
Teil 1: Werkstoffe und Erzeugnisformen)

Previous versions of this Safety Standard were
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Please note:
This translation includes the correction
published in BAnz of April 24th, 2019.

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

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KTA SAFETY STANDARD

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PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 35-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in the Federal Gazette (Bundesanzeiger) on February 5th, 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:

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Comments by the editor:

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

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

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. 2.1 of the Safety Requirements for Nuclear Power Plants, among other things, sets high requirements for the quality assurance and reliability of fabrication. no. 3.1 furthermore the use of qualified materials as well as the safeguarding and maintenance of quality features during fabrication. Safety requirement no. 3.4 (1) requires, among other things, that the reactor coolant pressure boundary is constructed such that the occurrence of rapidly extending cracks and of brittle fractures need not be assumed. Safety standard KTA 3201.1 is intended to specify detailed measures which shall be taken to meet these requirements within the scope of its application. For this purpose, a large number of standards from conventional engineering, in particular DIN standards, are also used; these are specified in each particular case. For the components of the reactor coolant pressure boundary the requirements of the aforementioned safety requirements are further concretised with the following safety standards

KTA 3201.2 Design and Analysis,

KTA 3201.3 Manufacture,

KTA 3201.4 Inservice Inspection and Operational Monitoring,

KTA 3203 Surveillance of the Irradiation Behaviour of Reactor Pressure Vessel Materials of LWR Facilities,

KTA 3206 Verification Analysis for Rupture Preclusion for Pressure Retaining Components in Nuclear Power Plants.

(3) The requirements specified under KTA 3201.1 address, in particular,

a) the organisations that are involved in manufacture,

b) the manufacture of materials as well as their chemical composition, mechanical properties, physical characteristics, heat treatment and subsequent fabrication,

c) the procedures for controlling and certification of the required material quality, e.g. destructive and non-destructive testing as well as in-process inspection and manufacturing supervision,

d) the preparation of documents for the documentation of test results.

(4) This safety standard does not specify any requirements that do not serve the primary purpose of a safe enclosure of the reactor coolant.

1 Scope

(1) This safety standard applies to the manufacture of the materials and product forms of pressure retaining components of the reactor coolant pressure boundary of light water reactors.

(2) This safety standard does not apply to pipes and valves with nominal diameters equal to or smaller than DN 50.

(3) In the case of pressurised water reactors, the reactor coolant pressure boundary comprises the following components without internals:

a) the reactor pressure vessel,

b) the primary side of the steam generators, the secondary shell of the steam generators including the feedwater inlet and main steam exit nozzles up to the pipe connecting welds, but not the minor nozzles and nipples, shall also be treated in accordance with this safety standard,

c) the pressurizer,

d) reactor cooling pump casing,

e) the connecting pipes between the above components and the valve casings of any type contained in the pipe system,

f) the pipes branching off from the above components and their connecting pipes including the valve bodies installed in the piping system up to and including the first shut-off valve,

g) the pressure retaining walls of the control rod drives and the in-core instrumentation,

h) the integral parts of the component support structures in accordance with Fig. 8.5-1 of KTA 3201.2 and the welded attachments.

(4) In the case of boiling water reactors, the reactor coolant pressure boundary comprises the following components without internals:

a) the reactor pressure vessel,

b) the pipework belonging to the same pressure space as the reactor pressure vessel including the installed valve bodies up to and including the first shut-off valve, pipework penetrating the containment shell and belonging to the same pressure space as the reactor pressure vessel up to and including the last shut-off valve located outside the containment shell,

c) the pressure retaining walls of the control rod drive and in-core instrumentation,

d) the integral parts of the component support structures in accordance with Fig. 8.5-1 of KTA 3201.2 and the attachments.

2 General principles and definitions

2.1 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) Room temperature

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

(5) Noise

Noise means randomly distributed signals in the screen image which are due to test conditions, reflections from the structure of the material, its surface condition or the electronics.

(6) 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.

(7) 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.

(8) 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.

(9) Ultrasonic testing, global

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

(10) 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.

(11) 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).

2.2 Selection and appraisal of materials

2.2.1 Selection of materials

(1) The materials shall be selected according to their intended application by taking into account the mechanical, thermal and chemical loadings and the damage possible due to neutron irradiation.

(2) The materials shall safely withstand the loadings from pressure tests, operation and all specified plant conditions.

Note:

The materials, in as far as they are certified with regard to the intended application, shall basically be chosen by the manufacturer, however if necessary, after consultation with the material manufacturer.

2.2.2 Material appraisal

(1) The material appraisal with regard to their characteristics with respect to the above mentioned loadings and to the workability of the materials shall be carried out by the authorized inspector. Any individual appraisal will be applicable to all products delivered hereinafter by the same manufacturer within the scope of the appraisal.

(2) If the material is to be welded then it shall be suited for welding. The weldability shall be attested in the material appraisal of the authorized inspector. Where special conditions have to be observed during welding, these shall be specified in the material appraisal.

(3) The use of materials with the material characteristics laid down in **Annex A** is permitted. Manufacturers listed in the supplementary sheets to the pertinent VdTÜV material sheets are deemed to have been qualified.

(4) An initial material appraisal for qualification by the authorized inspector is required for

a) other materials not listed in **Annex A**,

b) manufacturers that have not been approved.

In this material appraisal, the material characteristics shall be laid down in due consideration of this safety standard. Within the course of acceptance process, the authorized inspector shall check whether continuous material quality is guaranteed by the respective material manufacturer.

(5) The tests by the authorized inspector required for the material appraisal shall be specified with regard to type and extent such that they form, together with the supplied manufacturer`s documentation, a sufficient basis for the material appraisal. The proof that the required material characteristics are continuously attained should be supported by a mathematical and statistical evaluation of already available test results. If the material is manufactured in more than one plant, this shall be considered in the material appraisal. The material appraisal shall extend to the evaluation of the following points

a) steel-making process,

b) chemical composition (also with respect to neutron activation),

c) segregation behaviour,

d) product form,

e) limitations in dimensions,

f) as-delivered condition,

g) mechanical properties,

h) resistance to corrosion,

i) workability,

j) weldability,

k) scope of applicability,

l) type and extent of tests and inspections,

m) test certification,

n) identification marking.

(6) If a material is to be used beyond the scope of its certified applicability, a supplementary appraisal by the authorized inspector is required. This also applies to a special material that is to be used in an individual application. In special cases, an individual material appraisal regarding the extended scope of applicability shall be issued. This individual material appraisal for an individual material shall be limited to the certified material manufacturer and to similar scopes of application. This individual certification shall be specified in the inspection certificate.

(7) If new kinds of manufacturing processes (e.g. steel-making, casting and forming processes) are applied that were not considered in the initial material appraisal then their equivalency with those procedures considered in the initial material appraisal shall be demonstrated. This proof shall be contained in the supplementary material appraisal by the authorized inspector.

2.3 Welding consumables

KTA safety standards 1408.1 to 1408.3 apply to the welding consumables.

2.4 General requirements regarding quality assurance

General requirements regarding quality assurance are specified in KTA safety standard 1401.

2.5 Requirements to be met by the material manufacturer

(1) The manufacturers shall have manufacturing equipment at their disposal which allow a proper and state-of-the-art manufacturing of materials and product forms.

Note:

The term “materials” in the following refers to both the materials and their product forms.

(2) The manufacturers shall have testing equipment at their disposal which allow the testing of materials in accordance with the corresponding DIN Standards or with other standards that apply. 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 1 %. Upon request, the test reports to DIN 51 220 shall be submitted to the authorized inspector.

(3) Where testing equipment of other facilities is employed, these requirements apply accordingly.

(4) The manufacturer shall have equipment at his disposal, either at his works or at other facilities that allow carrying out the non-destructive tests required in accordance with this safety standard. Mechanical or automated equipment employed in the non-destructive examination in accordance with this safety standard shall be certified by the authorized inspector.

(5) A list shall be available of the required operating instructions for the manufacturing and testing equipment in accordance with para (1) through (4).

(6) The quality surveillance department of the manufacturer shall ensure, and document correspondingly, that the materials are properly manufactured and processed and that the corresponding technical standards have been met.

(7) The manufacturer shall have at his disposal expert personnel that is able to carry out the tests and examinations properly.

(8) Personnel performing visual inspections shall be informed on the applicable manufacturing process and have vision to comply with the requirements of DIN EN ISO 9712, which shall be checked every 12 months.

(9) 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.

(10) 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.

(11) 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.

(12) The manufacturer`s authorized inspection representative shall be a staff member of the manufacturer`s works. The name and stamp of the manufacturer`s authorized inspection representative shall be known to the authorized inspector.

(13) In as far as the manufacturing of the product forms requires welding, then the following requirements shall be met:

a) The manufacturer shall have own supervisory personnel and welders that are qualified in accordance with DIN EN ISO 9606-1 in connection with AD 2000-Merkblatt HP 3. Only qualified welders shall be employed for the welding activities. The revalidation of welder qualification must be acquired to clause 9.3 a) or clause 9.3 b) of DIN EN ISO 9606-1.

b) The welding supervisor shall be a member of the staff of the manufacturer`s works and be named to authorized inspector. With regard to the technical qualifications of the welding supervisor the requirements in accordance with KTA 3021.3 shall apply.

(14) Any deviation observed from quality requirements shall be reported to the appropriate division. The procedure shall be specified in writing.

(15) The manufacturer shall have a quality department that is organisationally independent from the fabrication department.

(16) The organisational independence and the individual tasks of the manufacturer`s authorized inspection representative, the supervisory personnel for the operators, the quality department and, if required, the welding supervision shall be specified in writing.

(17) Before initiating any fabrication steps, the authorized inspector shall verify and certify in writing that all requirements in sub-paras (1) through (16) have been met. This examination shall be repeated at time intervals of between about one and two years unless the authorized inspector can verify by other means that the requirements are being continually met.

2.6 Design review and quality documentation

2.6.1 General requirements

(1) The required values for the manufacture of the product forms and the required certifications of the tests and examinations to be performed in the course of manufacture shall basically be specified in the design review documents. By agreement with the authorized inspector, it may not be necessary to prepare design review documents in part or in total for particular product forms, provided the requirements in accordance with this safety standard are met and this safety standard contains sufficient acceptance requirements for the particular product form. Regarding the product forms in accordance with Secs. 22 through 24 and 27, a design review shall be carried out only with respect to the design review documents specified in the corresponding sections.

(2) The design review documents and the certifications of the tests and examinations performed in the course of manufacture shall be documented and be compiled to form the quality assurance documentation. The quality documentation shall be continuously established in parallel to manufacture.

2.6.2 Type and duration of document filing

(1) The filing of the quality assurance documentation, i.e. final filing (E) or interim filing (Z), is specified in **Table 2-1** in accordance with KTA 1404.

(2) General requirements regarding the type and extent of documentation as well as the filing duration and location are specified in KTA 1404.

2.6.3 Abbreviations

(1) Uniform abbreviations shall be used in the manufacturing documents.

(2) If possible, the abbreviations suggested in **Table 2-2** shall be used.

(3) Any other or additional abbreviations used shall be explained in the particular document.

2.6.4 Design review

2.6.4.1 Design review documents

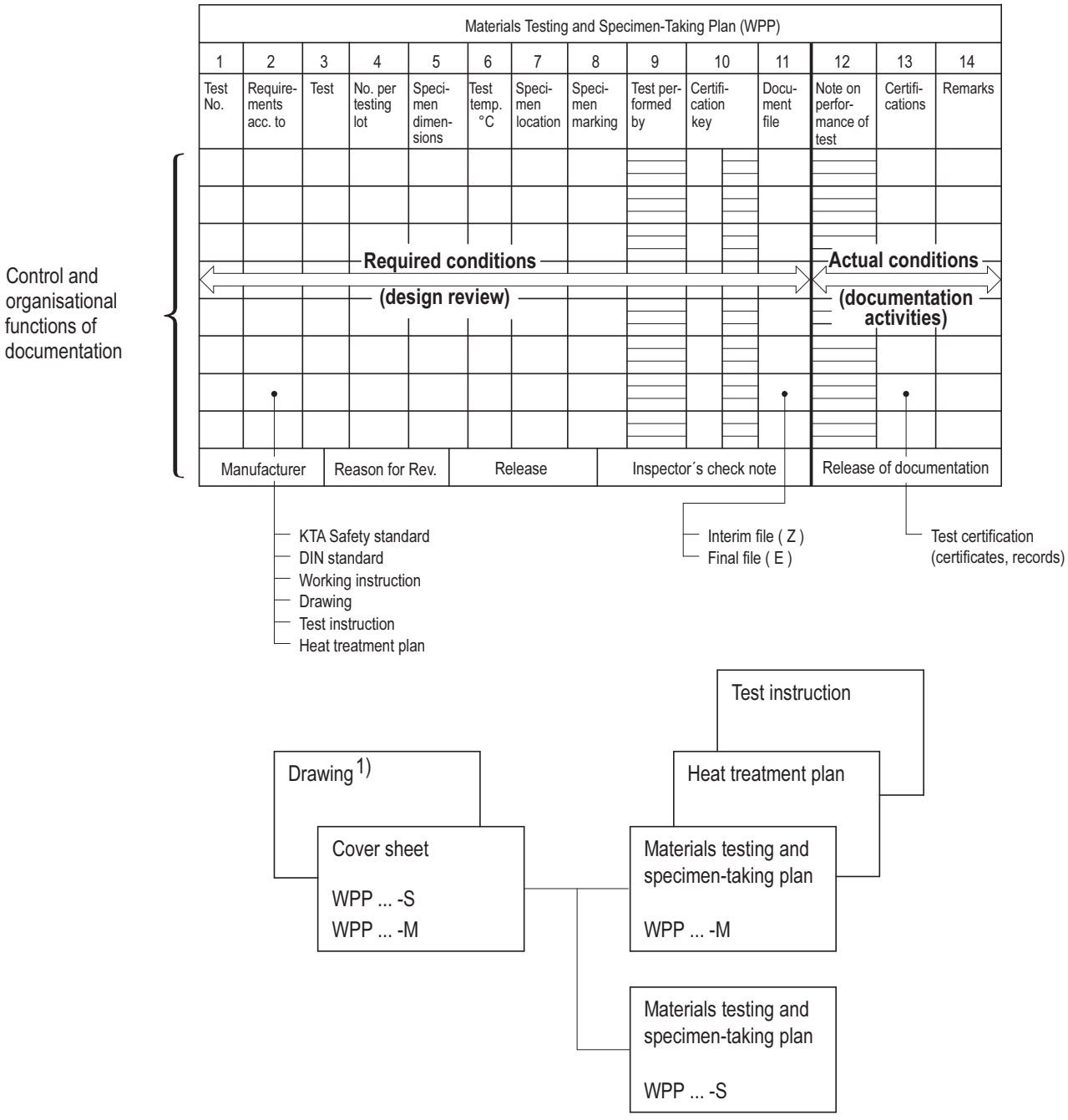
The design review documents shall be prepared in due time prior to the planned start of manufacture of the product form and shall be submitted to the authorized inspector. It is allowed to submit partially or completely standardised design review documents.

2.6.4.2 Type and content

2.6.4.2.1 General requirements

(1) Generally, the documents specified in Secs. 2.6.4.2.2 through 2.6.4.2.6 shall be prepared for design review. Additional documents, e.g. for fabrication welds on cast steel, shall be prepared in accordance with the requirements in the product-form related sections.

(2) The documents shall contain the required information in accordance with the **forms E-1** through **E-4**. It is suggested that these forms be also used as the basic format for the documents.



1) only if required due to product form geometry

Figure 2-1: Design review documents for product forms

Test/inspection certificates		Performance/ Attendance	Type of Documentation		
1 Tests/inspections at the product manufacturer's works					
1.1	Check of qualification or approval of manufacturer	S			ST
1.2	Check of material appraisal (base material, welding consumables)	S			ST
1.3	Chemical analysis (ladle analysis, product analysis)	H	E		
1.4	Check of validity of procedures for the				
	a) production welding of cast iron	H, S			ST
	b) pressure testing of steam generator heat exchanger tubes	H, S			ST
	c) special processes (e.g. sandblasting, bending)	H, S			ST
1.5	Mechanical testing prior to final heat treatment	H, S [3)]		Z	
1.6	Non-destructive testing prior to final heat treatment	H, S [1)]	E [1)]	Z	
1.7	Dimensional check prior to final heat treatment	H		Z	
1.8	Proof of heat treatment (furnace recordings, furnace allocation plans, temperature measuring points)	H, S		Z	
1.9	Heat treatment certificates	H, S	E		
1.10	Sulphur prints	H		Z	
1.11	Testing of mechanical properties in the heat treated condition or as-fabricated condition including simulated heat treatments, if any, to prove that the required material properties have been obtained, e.g. by means of				
	a) mechanical testing	H, S	E		
	b) toughness testing	H, S	E		
	c) hardness testing	H, S	E		
	d) metallographic testing (e.g. grain size, structure, delta-ferrite, disk pickling test)	H	E		
	e) corrosion testing (test for resistance to intergranular corrosion)	H			ST
1.12	Non-destructive testing in the as-delivered condition or upon final heat treatment prior to further processing	H, S	E		
1.13	Dimensional check in the as-delivered condition				
	a) with yes/no statement	H, S			ST
	b) with recording of actual dimensions	H, S	E		
1.14	Visual inspection	H, S			ST
1.15	Pressure test	H, S	E		
1.16	Check of identification marking	H, S	E [2)]		ST
1.17	Material identification check	H			ST
1.18	Cleanliness check	H			ST
1.19	Check of correct packing	H			ST
1.20	Review of documents	H, S			ST
1.21	Release of documentation	S	E		

[1)] Only if testing upon final heat treatment is limited due to geometry.
[2)] Replica of stamping, if possible.
[3)] If required for the specific product form.

E : Final file
Z : Interim file
ST : Stamping
S : Authorized inspector
H : Manufacturer

Table 2-1: Test/Inspections - Performance/Attendance /Documentation

(1) Tests and inspections		
AP	:	production control test
CHP	:	welding material test
DIP	:	leak test
DOP	:	review of documents
DRP	:	pressure testing
EK	:	receiving inspection
ET	:	eddy-current testing
MK	:	dimensional check
MT	:	magnetic particle testing
MTP	:	mechanical testing
PT	:	penetrant testing
RP	:	cleanliness check
RT	:	radiographic testing
SUE	:	welding supervision
UT	:	ultrasonic testing
VP	:	welding procedure qualification
VWP	:	materials identification check
WBK	:	heat treatment check
WP	:	materials testing
ZfP	:	non-destructive testing
(2) Documents		
AB	:	Non-conformance report
AW	:	work instruction
CHPP	:	plan for welding material tests
DBL	:	cover sheet
DRPP	:	pressure test plan
PA	:	test instruction
PFP	:	test and inspection sequence plan
RPL	:	cleaning plan
RTP	:	radiographic testing plan
SP	:	welding procedure sheet (welding procedure specification)
SPK	:	welding record
WBP	:	heat treatment plan
WBPK	:	heat treatment record
WPP	:	materials testing and specimen-taking plan
ZG	:	drawing
(3) Others		
AN	:	person responsible for establishment of certificates
E	:	final file
E/S	:	final file for overall certificate
QS	:	quality assurance
QST	:	quality department
SF	:	welding sequence
ST	:	stamping plus initials
Z	:	interim file
..-S	:	signifies simulated heat treatment condition
..-M	:	signifies accompanying heat treated conditions
..-R	:	signifies repair document
..-RM	:	signifies reserve material documents
..-L	:	signifies service lifetime
(4)		**Participants in tests and inspections**
H	:	manufacturer
S	:	authorized inspector

Table 2-2: Abbreviations to be used

2.6.4.2.2 Cover sheet

A cover sheet for the design review documents shall exactly specify the product form to be subjected for design review and shall list the individual design review documents with their abbreviation and the number of pages they contain. Additionally, a revision table and a list of all KTA safety standards applicable to the manufacture and, if applicable, any specifications, test and inspection as well as operating instructions shall be included in the design documents.

2.6.4.2.3 Technical drawings

(1) The product forms shall be represented in technical drawings if their geometry so requires.

(2) The technical drawings shall contain the major dimensions including their tolerances.

2.6.4.2.4 Materials testing and specimen-taking plans

(1) The materials testing and specimen-taking plans (WPP) shall be subdivided into a design review and documentation sequence plan and shall contain the following information:

a) any information regarding fabrication (e.g. heat treatment) that is important for specifying and correlating the tests and supervision measures,

b) the mechanical tests including number, orientation and position of the specimen in the test coupons and the position of the test coupons in the product form. If the geometry of the product form so requires, the position of the test specimen and test coupons shall be shown in a location plan as an appendix to the materials testing and specimen-taking plan. All test specimens shall be identified unambiguously in the specimen-taking plan.

c) the non-destructive tests and inspections,

d) the individual measures, work and inspection instructions required for the individual test steps,

e) the departments involved in the tests with an indication of their activities (e.g. performing the test, participating in the test),

f) specification of the documentation (type of certification and type of filing, cf. **Table 2-1**).

(2) The materials testing and specimen-taking plans shall contain all tests and examinations to be performed in accordance with this safety standard. In this connection and under consideration of **Table 2-1** they shall also specify

a) whether the test results shall be certified by individual test certificates or by attestation stamp and signature,

b) which form of filing (E or Z) is required for the documentation and

c) for which tests an overall certification (E/S) is applicable.

2.6.4.2.5 Heat treatment plans

Heat treatment plans shall be prepared for all heat treatments of product forms and accompanying test specimens as well as for the simulation heat treatment of base material coupons. These should contain at least the following information:

a) type of heat treatment (e.g. tempering, simulation stress relief heat treatment),

b) wall thickness and shapes of the pieces in the condition ready for heat treatment (if necessary with technical drawing in accordance with Sec. 2.6.4.2.3),

c) type of the heat treatment equipment (e.g. continuous furnace, hearth type furnace),

d) type and extent of temperature measurements, location of the thermocouples on the piece taking into consideration the intended location of the piece in the furnace,
e) time-temperature chart (e.g. heat-up rate, holding time, cooling rate; if the heat treatment is part of the hot forming process, this shall be indicated),
f) type of cooling, cooling agent.

2.6.4.2.6 Test instructions for non-destructive testing

(1) Test instructions shall be established by the manufacturers for non-destructive tests and inspections.

(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 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 regarding non-destructive tests and inspections is restricted,
f) system of coordinates (reference system and counting direction) for a description of indications or irregularities assigned to a test object,
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).

2.6.4.3 Performing the design review

(1) The authorized inspector shall check whether or not the submitted design review documents are complete and whether or not they meet the requirements under this safety standard regarding their technical content and prescribed measures.

(2) In the case of a positive result of his design review, the authorized inspector shall put his check note and signature on the documents, thereby certifying that the design review has been completed.

(3) Any change and additions that become necessary in the course of the design review shall be worked into the design review documents and shall be marked by a note of the authorized inspector.

2.6.4.4 Validity

The design review documents basically remain valid until the product form has been completed. However, a review of these documents is required
a) if manufacturing is not begun within 24 months after the date of the check note application,
b) if manufacturing is interrupted for more 24 months,
c) if essential aspects of the requirements and safety standards on which the design review was based have been changed.

2.6.4.5 Revision of the design review documents

(1) If, after completion of the design review certain revisions of the documents become necessary, the corresponding documents shall be re-subjected to a design review.

(2) The changed documents shall be subsequently numbered corresponding to their state of revision.

2.6.5 Quality documentation by the manufacturer

(1) The manufacturer shall designate the task of compiling the required documents to a central department which shall be named to the authorized inspector.

(2) The manufacturer shall ensure
a) that the documentation system specified in this safety standard is observed at his works,
b) that the prepared documents meet the requirements of this safety standard with regard to completeness of data and with the required check notes,
c) that, in the course of the manufacturing process, the quality documentation is continually checked for correct entries and completeness such that this documentation correctly represents the test condition of the product at all times during manufacturing.

(3) If in the course of manufacture deviations from the required values are noticed, the manufacturer shall prepare non-conformance reports and submit them for review by the authorized inspector. In addition to a description of the deviation, the non-conformance report shall contain a description of the further measures to be taken (e.g. repairing or tolerating the division) together with the statement of the corresponding reasons. The non-conformance report shall become part of the final file (E).

(4) The revised and design reviewed documents shall be documented such that the traceability to the original planning stage is ensured.

(5) Upon completion of the product form, the manufacturer shall submit the original documentation to the authorized inspector for final review.

2.7 In-process inspection

2.7.1 In process inspection by the manufacturer

(1) During manufacture of the products, from the steel-making process to the delivery, an in-process inspection on the basis of the manufacturing and design review documents shall be carried out by the manufacturer’s quality assurance department that is organisationally independent from manufacture.

(2) This accompanying in-process inspection shall extend to at least the following points:
a) checking of the fabrication prerequisites with regard to the fulfilment of technical and organisational requirements in accordance with this safety standard,
b) checking of the fabrication and hold points including countersigning in the records and certifications during the steel-making process including casting, treatment and in the case of repairs,
c) supervision and performance of the tests in accordance with the manufacturing and design review documents in the case of:
   ca) non-destructive tests and inspections,
   cb) mechanical tests,
   cc) dimensional checks,
   cd) identification stamping,
   ce) visual inspection,
   cf) material identification check,
   cg) leak tests (of steel castings).

(3) The manufacturer shall prepare a documentation of the in-process inspection in accordance with the manufacturing and

design review documents; this documentation shall be available at the time of final inspection.

2.7.2 Manufacturing supervision by the authorized inspector

(1) The authorized inspector shall randomly convince himself of the proper in-process inspection by the manufacturer. The authorized inspector has the right to attend any of the manufacturing processes. However, this may not impair the manufacturing process. All quality assurance documents regarding fabrication and testing shall be made available to the authorized inspector.

(2) The authorized inspector shall perform the tests and checks prescribed for him in the design reviewed documents. In individual cases, the authorized inspector has the right to require test coupons for a product analysis by an independent testing agency.

(3) The authorized inspector shall establish a report on his manufacturing supervision activities that should also address any deviations from required values, the evaluation of these deviations, corrective changes and repairs; this report shall be part of the acceptance certificate of the authorized inspector.

2.8 Test and certification of material quality

(1) The tests and certification regarding the material quality shall meet the requirements in accordance with the product-form related sections and with **Annex A**.

(2) The material quality shall be demonstrated by inspection certificates in accordance with DIN EN 10204. They shall contain the results of the tests, the test prerequisites, the test conditions and the name of the operator. In addition, they shall certify that the requirements under this safety standard have been met.

(3) The materials shall be tested at the manufacturer’s works. The materials shall be identified in accordance with the requirements under Sec. 3.5. The entire wording of the identification marking shall be contained in the inspection certificate in accordance with DIN EN 10204.

(4) An inspection certificate 3.2 in accordance with DIN EN 10204 shall be established for the product, which shall contain all results of the tests in accordance with the manufacturing documents and shall certify that the quality assurance system was applied to the accepted product.

(5) Inspection certificates 3.2 to DIN EN 10204 shall be confirmed or be established by the authorized inspector.

2.9 Repairs

(1) Prior to taking any measures with respect to repairing a flaw it shall be evaluated in how far repairing the flaw or leaving it as it is has any advantages or disadvantages regarding the safety of the component. This also applies to repair and temporary welds on finished parts.

(2) The cause for the repairs shall be determined, documented and reported to the authorized inspector.

(3) In the case of welds, the requirements under KTA 3201.3 shall be considered. The same applies to temporary welds on finished parts.

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

(5) Prior to performing any repair, corresponding design review documents shall be prepared and they shall be reviewed by the authorized inspector. The requirements in accordance with Secs. 2.6.1 and 2.6.2 also apply to repairs.

2.10 Material properties for strength calculations

(1) The decisive material parameters required for the strength calculation shall be taken from **Annex A**, provided a material appraisal exists for the material in question.

(2) In the case of other materials, these characteristics shall be taken from the authorized inspector's appraisal.

3 General requirements for and testing of materials

3.1 Allowable materials

Only such materials are allowed for application that meet the requirements under Sec. 2 and whose suitability in accordance with this safety standard has been verified in a material appraisal by the authorized inspector. This appraisal shall relate to the manufacturer and the specific product forms.

3.2 Requirements

3.2.1 General Requirements

(1) The materials chosen for the individual case of application shall be able to withstand any loadings, e.g. mechanical, thermal and chemical loadings on which the design was based, including any loadings from the manufacturing process. In addition to the general requirements usually applicable to pressure vessel manufacture, neutron irradiation shall be considered for those components in the core belt line region.

Note:
The core belt line region is the irradiated section of the reactor pressure vessel wall which directly encloses the radioactive part of the reactor (length of the fueled part of the fuel elements) as well as the adjacent sections which, on account of the predicted reference temperature increase are to be considered when selecting the materials to be monitored.

(2) The material property requirements apply to the final state of the component after final inspection and pressure test. When testing materials and product forms, the material characteristics shall be demonstrated on test coupons that are sufficiently large and are in heat treatment conditions that meet the requirements under Sec. 3.3.5.

3.2.2 Manufacturing

(1) The materials shall be produced to the steel-making process specified in **Annex A** or in the material appraisal of the authorized inspector such that the chemical composition is in the allowed range. A proof of equivalency is required in the case of deviations.

(2) During manufacture, the degree of segregation should be kept as low as possible.

3.2.3 Heat treatment

(1) The heat treatment of the materials shall be performed as specified in the product-form related sections or in **Annex A** or in the material appraisal of the authorized inspector. A proof of equivalency is required in the case of any deviation from the specified heat treatments.

(2) Each heat treatment shall be documented in a temperature-versus-time log. The uniformity of the heat treatment across the product form shall be demonstrated by suitable instruments and be documented with automatic recording equipment. All records shall be made available to the authorized inspector for reviewing.

(3) If, in the course of fabrication, product forms of quenched and tempered steels are subjected to further heat treatments after their final tempering, the temperature ranges specified in

the design review documents for tempering and stress relieving should not overlap. If this cannot be avoided, then the highest unit temperatures measured in these further heat treatments shall not exceed the lowest unit temperature measured during final tempering.

3.2.4 Material properties

3.2.4.1 General requirements

(1) The requirements regarding the mechanical properties and their uniformity within a product form depend on the material and the shape of the product. The requirements are specified in the product-form related sections and in **Annex A** or in the material appraisal of the authorized inspector. In the case of product forms subjected to internal pressure, the material characteristics, especially the ductile behaviour shall preferably be specified with regard to the fibrous structure.

(2) In the course of the material appraisal, it shall be specified if and to what extent further examinations are required beyond the tests specified in the product-form related sections and in **Annex A**.

3.2.4.2 Requirements for ferritic materials

(1) This section specifies requirements for ferritic materials for the product forms named in the scopes of Secs. 4 through 17 and 29.

(2) In the case of ferritic steels, special attention shall be paid to the safety against brittle fracture in due consideration of the operating and loading conditions.

Note:
For the sake of simplicity, the following sections refer only to "ferritic steels". However, this always includes quenched and tempered steels.

(3) The ferritic steels used shall have a fine-grained structure.

(4) In the case of product forms for core belt line components, the design and loading conditions with regard to neutron irradiation may require that the content of certain elements determined in the product analysis, in particular copper and phosphor, is reduced with respect to the usual values. In this case the corresponding requirements shall already be stated in the order.

(5) Rolled and forged product forms with the exception of those under Secs. 14 and 15 shall show a reduction of area on perpendicular test specimens of 45 % as the average value of three values obtained on individual test specimens with no single value below 35 % being allowed.

(6) The ferritic steels for components subject to internal pressure shall be such that the reference temperature RT_{NDT} of the base metal, welding material and heat affected zone (HAZ) is at least 33 K below both the lowest operational load temperature and the pressure test temperature. Here, the reference temperature RT_{NDT} is defined by the following steps:

a) Specification of a temperature that is equal to or higher than the nil ductility transition temperature T_{NDT} determined by means of drop weight tests.

b) At a temperature not higher than T_{NDT} + 33 K each test specimen from the notched bar impact test (transverse test specimens) shall show an absorbed impact energy of at least 68 J and a lateral expansion of at least 0.9 mm. If these requirements are met, the reference temperature RT_{NDT} is equal to T_{NDT}.

c) Where the above mentioned requirements are not met, additional notched bar impact tests (transverse test specimens) in sets of 3 test specimens shall be performed to determine the temperature T_{AV} at which the above mentioned requirements are met. In this case the reference temperature is

$$RT_{NDT} = T_{AV} - 33\ K.$$

Thus, the reference temperature RT_{NDT} is the higher of the two temperatures T_{NDT} and T_{AV} - 33 K.

The reference temperature T_0 to ASTM E 1921 for positioning the fracture toughness curve K_{Ic} (T) may additionally be determined to KTA 3201.2, section 7.9.

(7) The upper shelf absorbed impact energy on transverse test specimens shall be at least 100 J.

(8) The NDT temperature shall normally be equal to or less than 0 °C. In the case of product forms for core belt line components the loading conditions may require that the NDT temperature is not higher than -12 °C. If the required NDT temperature is exceeded, it is the customer who by agreement with the authorized inspector and in consideration of the safety analysis, shall decide on further steps to be taken.

(9) The absorbed impact energy on transverse test specimens shall be determined at a temperature that is 33 K above the required NDT temperature. The values of the absorbed impact energy and the lateral expansion shall not be below 68 J and 0.9 mm, respectively. If these values are not obtained that higher temperature shall be determined at which the stated requirements are met in a notched bar impact test. When using these product forms it shall then be considered that this higher temperature must be below the temperatures possibly obtained under critical conditions (e.g. pressure test or incident). For the notched bar impact tests, a repetition of the test at the original temperature is allowed under the following conditions:

a) The average values of absorbed impact energy and lateral expansion shall not fall below the specified individual values.

b) Only one test specimen may show values that fall below the specified single values.

c) The test specimen which failed by not obtaining the specified single values shall not show values of the absorbed impact energy and lateral expansion that are lower than the specified single value by 14 J and 0.13 mm, respectively.

(10) When repeating a test, the failed test specimen shall be replaced by two additional test specimens. These two test specimens shall be taken from a location as close as possible to the specimen-taking location of the failed test specimen. Both of these test specimens shall obtain the specified individual value. Where the individually specified values are not obtained in the re-examination, than that higher temperature shall be determined at which each value meets the specified requirements. This shall be done on the basis of the available impact energy versus temperature curves which, if required, shall be supplemented by further tests.

(11) Details of the test are given in the sections for the individual product forms below.

3.2.4.3 Requirements for austenitic materials

(1) This section specifies the requirements for austenitic materials for the product forms under the scopes of Secs. 22 through 24 and 30.

(2) The average grain size shall correspond to a characteristic index equal to or greater than 4 in accordance with DIN EN ISO 643. Deviations are allowed provided requirements regarding subsequent fabrication and material characteristics are met and, especially, ultrasonic testing are not obstructed in any way.

(3) 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. The surface shall be free of ferritic impurities which are relevant for the corrosions resistance of the product form.

(4) The parts which during subsequent fabrication are subjected to welding without consumables shall have a delta-ferrite content of between 2 and 10 % in the base metal of the weld fusion zone. The parts which during subsequent fabrication are subjected to welding with consumables shall have a delta-ferrite content of between 1 and 10 % in the base metal of the weld-fusion zone. In both cases, no ferritic lattice structure is allowed.

(5) The material shall be resistant to intergranular corrosion under the specified processing conditions, especially after welding or after heat treatment.

3.2.4.4 Requirements for quenched and tempered steels for bolts, nuts and washers

(1) This section specifies the requirements for ferritic materials for the products forms under the scopes of Secs. 20 and 21.

(2) For the notched-bar impact bend tests to clause 3.3.7.3 (3) at a temperature of +20 °C the following requirements apply:

Governing thickness in mm	Impact energy absorbed in J		Lateral expansion in mm
	Mean value of 3 specimens	Smallest individual value	Smallest individual value
$D \leq 25$	52	42	—
$25 < D \leq 100$	52	42	0.65
$D > 100$	—	61	0.65

3.2.4.5 Material for specific loading conditions

If specified loading conditions exist (e.g. erosion, corrosion, thermal loading, wear) only materials meeting the specific individual specific requirements shall be used. The corresponding requirements shall be specified for each individual case by agreement with the authorized inspector.

3.2.5 Volumetric and surface defects

The product forms shall be free of volumetric and surface defects to the extent specified in the following sections.

Note:
The following paragraphs also specify the acceptance criteria for indications detected by non-destructive testing that consider type and subsequent fabrication of the product form, their application and loading.

3.2.6 Surface condition

(1) The type of treatment and surface condition of the product forms shall be laid down in the order.

(2) The surface condition shall meet the requirements with regard to non-destructive tests and inspections including in-service inspections. Details are specified under Sec. 3.3.8.

3.2.7 Subsequent fabrication

For the subsequent fabrication of the materials and product forms including tests and inspections the requirements of KTA 3201.3 apply.

3.3 Tests and inspections of materials and product forms

3.3.1 Materials testing and specimen-taking plan

The tests specified in the product-form related sections shall be compiled in a materials testing and specimen-taking plan in accordance with Sec. 2.6.4.2.4. In the course of the design review it shall be specified within this plan at which point of time during fabrication the required tests are to be performed.

Note:
In the case of product forms for components for which proof of rupture preclusion is to be rendered, material retention specimens, where required, will be needed in dependence of the type of proof for the determination of further material property data within the fracture-mechanics analysis to KTA 3206.

3.3.2 Identification of the orientation and location of test specimens

(1) The orientation of the test specimens with regard to the product forms shall be identified as follows:

a) Identification with regard to the direction of fibres:

Longitudinal test specimen (L): Major axis of specimen is parallel to the principal forming direction (parallel to the direction of fibres); the notch of impact test specimens shall be perpendicular to the plane of length and width direction.

Transverse test specimen (Q): Major axis of specimen is perpendicular to the plane of length and width direction; the notch of impact test specimens shall be perpendicular to the plane of length and width direction.

Perpendicular test specimen (S): Major axis of specimen is perpendicular to the plane of length and width direction; the notch of impact test specimens shall be parallel to the principal forming direction.

b) Identification with regard to the major direction of the product form shape:

Axial test specimen (A): Major axis of specimen is parallel to the axis of rotational symmetry of the product form; the notch of impact test specimens be perpendicular to the cylindrical surface.

Tangential test specimen (T): Major direction of specimen is in the direction of the circumference; the notch of impact test specimens shall be perpendicular to the cylindrical surface.

Radial test specimen (R): Major axis of specimen is normal to the cylindrical surface, the notch of impact test specimens shall be parallel to the principal direction in which the material is formed.

(2) The location of the test specimen with regard to its depth beneath the surface depends on the orientation of the specimen’s major axis and, with regard to the edge distance on the location of the specimen’s cross-section. Details are specified in the product-form related sections.

3.3.3 Size of test coupons

(1) A sufficient amount of material shall be provided for obtaining test specimens such that, in addition to the demonstra-

tion of the mechanical properties, a sufficient amount of material remains for test specimens, for production control test, for re-examination specimens and, if required, for material irradiation tests. If further test specimens are required for additional tests, the purchasing order shall specify the number and dimensions of these additional specimens.

(2) In the case of castings, additional test coupons, if required, shall be provided from the same melt from which the product form was cast.

(3) In addition, reserve material from product forms intended for the pressure retaining wall of the reactor pressure vessel (ferritic steel forgings with an internal diameter equal to or greater than 250 mm and plates) shall be kept in reserve at the user's facilities. Heat treatment condition: ferritic steels, quenched and tempered; austenitic steels, solution annealed, in both cases corresponding to the condition of the product form.

(4) This reserve material shall be dimensioned such that in the case of forgings and plates enough material is available in the specified specimen-taking depth and major test direction for one tensile test each at room temperature and at design temperature for one set of test specimen for notch bar impact tests and, if required in the product-form related sections, for two Pellini-P2 test specimen.

3.3.4 Identification marking of test specimens, test coupons, remaining and reserve materials

(1) For the acceptance test, the test coupons shall be legibly and unambiguously marked with respect to the specimen-taking plan prior to taking them from the product form. The marking of the test specimens shall make it possible to exactly determine their original location in the product form (dimensional drawing). The authorized inspector charged with the acceptance test shall apply his stamp to the marking in the course of the acceptance test.

(2) The remaining and reserve material shall be marked similarly.

3.3.5 Heat treatment conditions of the test specimens

3.3.5.1 Ferritic steels

(1) All test coupons shall be heat treated on and together with the product form.

(2) The tests required in accordance with Sec. 3.3.7, with the exception of the chemical analysis and the hardness test, shall be performed on test specimens from these test coupons. Subsequent to quenching and tempering the product form, the test coupons shall be divided to provide those test coupons

a) which are to be subjected to a simulation heat treatment

and

b) which will go through all further temperature-versus-time sequences during the processing of the product form (accompanying test coupons).

Note:

The purpose of the simulating heat treatment is to predict the material properties in the final condition of the product form. The purpose of testing specimens from the accompanying test coupon which undergoes all heat treatment together with the product form and is subjected to tests only after the final heat treatment of the product form is to demonstrate the proper processing.

(3) To be able to specify the required heat treatment as exactly as possible in advance, the individual fabrication steps associated with a specific heat treatment must be known. Since this is usually not the case, e.g. with respect to repairs during fabrication, the simulation heat treatment shall be specified with the greatest possible safety with regard to the expected highest temperature, number and duration of the individual heat treatments.

(4) In general, the test coupons for the simulation heat treatment shall be detached from the product form after the last tempering. The simulated heat treatment then comprises all temperature-versus-time sequences above 500 °C, especially the stress relief heat treatment which the product form undergoes from the last tempering to the completion of the component. In addition, two intermediate stress relief heat treatments and one final stress heat relief treatment shall be carried out on the test coupon.

(5) In the simulation heat treatment, the holding times of the intermediate stress-relief heat treatments may be summed up. They shall be increased by a supplemental value equal to half of the sum of heat-up and cooling-down rates above 500 °C.

(6) Prior to the two simulations final stress heat relief treatments the test coupon shall be cooled down to at least 500 °C.

Note:

*Information regarding possible differences between simulation conditions is given in the product-form related sections or in **Annex A**.*

(7) If the time-at temperature sequence of the stress relief treatments is not yet known after the last quenching and tempering, then the simulated heat treatment shall be specified by agreement with the authorized inspector.

(8) In general, the following simulated heat treatments shall be applied:

Component	Simulation heat treatment
Parts for the pressure vessel, steam generators and pressurizer (product form under Secs. 4, 5, 6, 7, 8, 13 and 14)	30 h 550 °C + 12 h 600 °C + 6 h 600 °C
Primary coolant pump (product forms under Secs. 10 and 25)	9 h 600 °C + 3 h 600 °C
Primary coolant pipes and valves (product forms under Secs. 9, 11, 12, 16, 17, and 26)	6 h 600 °C

(9) If the products are delivered for subsequent fabrication in a non-tempered condition and are tempered only in the course of final processing, the simulation heat treatment shall also include the tempering process.

(10) Sec. 3.2.3 applies to the monitoring of temperatures during the simulation heat treatment. The test coupons subjected to simulation heat treatment shall be tested prior to completion of the component.

(11) The accompanying test specimens shall be tested by the subsequent manufacturer; to this end, the material manufacturer shall supply the test coupon.

3.3.5.2 Austenitic steels

Test specimens of products from austenitic steels shall be taken and tested in the heat treatment condition typical for these steels (in general solution annealed), in accordance with the applicable sections of **Annex A**.

3.3.6 Taking of trepanned plugs

If during the fabrication of thick-walled components cut-outs form penetrations are obtained that are sufficiently large for the taking of trepanned plugs, these cut-outs shall be stored until a decision is made on the taking of trepanned plugs and their use. The results of the material appraisal shall be considered.

3.3.7 Tests and applicable test procedures

3.3.7.1 Chemical analysis

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

(2) 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 [1]).

(3) Unless different requirements are specified in the product-form related sections, the chemical elements specified in **Annex A** or in the corresponding material appraisal of the authorized inspector shall be determined during each chemical analysis.

(4) In the case of products fabricated from several melts, the ladle analysis documented shall be the average chemical composition calculated from the chemical compositions of the individual melts.

(5) In the case of electroslag or vacuum molten steels the melt analysis shall be that of the remolten ingot.

3.3.7.2 Hardness test

(1) Where required in the product-form related sections, products from tempered steels shall be subjected to hardness tests upon tempering and prior to subsequent fabrication to demonstrate the uniformity of the heat treatment. The lowest and the highest individual hardness value determined on the same piece shall be documented in the quality certificate. The difference between these two values, after carrying out a recalculation in accordance with DIN EN ISO 18265, shall lie within the specified allowed range of tensile strength values for single units.

(2) The hardness tests shall be performed in accordance with DIN EN ISO 6507-1 and DIN EN ISO 6507-4 or DIN EN ISO 6506-1 and DIN EN ISO 6506-4. Other hardness test procedures may be applied if specified in the course of the design review.

3.3.7.3 Mechanical-technological tests

(1) Tensile test

Where required in the product-form related sections or **Annex A,** the yield strength or 0.2%-proof stress, the tensile strength, the elongation at fracture and the reduction of area shall be determined. In the case of austenitic steels, the 1 %-proof stress shall additionally be determined.

The tensile test shall be performed in accordance with DIN EN ISO 6892-1 und DIN EN ISO 6892-2. Where method A is used, the strain rates recommended by the standard shall normally be used. Tensile test specimens in accordance with DIN 50125 may also be used. The tensile tests at room temperature and at elevated temperatures shall, if possible, be performed on test specimens with a diameter equal to or greater than 10 mm.

(2) Tensile test in thickness direction

As regards the proof of reduction of area in thickness direction, tensile tests shall be carried out to DIN EN 10164 at room temperature.

(3) 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. For determining the impact energy absorbed, specimens with V-notch shall be tested at test temperatures that are specified in the product-form related sections or in **Annex A**. In the case of ferritic steels the lateral expansion and the portion of dull fracture surface (ductile fracture portion) to DIN EN ISO 148-1 shall be determined additionally.

(4) Impact energy versus temperature curves

Where required in the product-form related sections or **Annex A**, the impact energy versus temperature curves shall be determined. The test shall be performed on specimens with V-notch for at least six temperature values. Three of these temperature values shall always be 33 °C, 0 °C and -12 °C.

For products that are intended for core belt line components and must therefore reach an NDT temperature of -12 °C, the upper temperature of 33 °C shall be substituted by 21 °C. The other temperatures shall be chosen such that both the upper shelf energy, characterised by a dull fracture surface portion of 100 %, and the lower shelf energy, characterised by a dull fracture surface portion of 10 %, are determined and that the course of the nil-ductility transition temperature curve is reliably demonstrated.

At each test temperature a set of three notched bar impact test specimens shall be tested. In the case of notched bar impact test specimens to determine the impact energy versus temperature curves for ferritic steels, the lateral expansion and the portion of dull fracture surface to DIN EN ISO 148-1 shall be determined additionally.

The tests in accordance with para (3) may be performed.

(5) Nil-ductility transition temperature (NDT Temperature)

If the product-form related sections or **Annex A** require a Pellini drop-weight test to be performed to demonstrate that the requirements regarding the NDT temperature are met, then this test shall be performed on two test specimens (yes/no test). If an exact determination of the NDT temperature is required, this test shall be performed on at least three test specimens. Eight test specimens shall be made available.

The Pellini drop-weight test shall be performed in accordance with SEP 1325.

(6) Technological tests

The technological tests shall be performed in accordance with

a) DIN EN ISO 8493 - Drift test or
b) DIN EN ISO 8492 - Flattening test or
c) DIN EN ISO 8495 - Ring expanding test or
d) DIN EN ISO 8496 - Ring tensile test.

3.3.7.4 Metallographic examinations

(1) At all locations where the grain size is to be determined, the metallographic structure shall be assessed at an adequate enlargement and documented by micrographs (generally 200:1 enlargement).

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

(3) In the case of products from quenched and tempered steels the grain size need only be determined if portions of polygonal ferrite occur. In this case, it is only required to determine the characteristic grain size of the ferrite.

3.3.7.5 Determining the delta-ferrite content

(1) If so required by the product-form related sections or **Annex A,** the delta-ferrite content of products from austenitic steel or austenitic steel castings as well as austenitic claddings of extruded composite tubes shall be in accordance with one of the following methods:

a) metallographic analysis of the as-delivered condition,
b) metallographic analysis of the specimen in which case the bead-on-plate weld test shall be performed on that component section for which the chemical composition has been determined by product analysis,

c) mathematical estimation in accordance with the De Long [2] procedure from the chemical composition.

(2) The product-form related sections indicate which of the three models under para (1) a) through c) shall be applied.

(3) If the mathematical estimation results in ferrite numbers below 3 or larger than 7, then the delta ferrite content shall additionally be determined by a metallographic analysis of the bead-on-plate test specimen.

(4) Details for performing the methods under para (1) a) through c) are given in **Annex D**.

(5) In the case of bead-on-plate weld test a penetrant testing of the melt run shall be performed to detect hot cracks. Indications shall be documented in the quality certificate and shall be assessed by means of a metallographic examination.

(6) The particular method to be employed shall be documented in the quality certificate.

3.3.7.6 Test for corrosion resistance

(1) In the case of austenitic stainless steels the resistance against intergranular corrosion shall be demonstrated in the sensitization annealed condition (650 °C; 30 min) in accordance with DIN EN ISO 3651-2 method A.

(2) In the case of nickel alloys the corrosion resistance shall be demonstrated in accordance with ASTM A262 method B.

3.3.7.7 Influence of neutron irradiation

(1) If, in the case of components made of ferritic steels, the flux of fast neutrons integrated over the component's lifetime exceeds a certain limit (cf. KTA 3203), test specimens for irradiation tests shall basically be provided unless these tests can be dispensed with on the basis of the operational and loading conditions and the current experience.

(2) The test specimens for these tests shall be taken from the individual components under examination.

3.3.7.8 Check for dimensional accuracy

(1) After completion of the products, the actual dimensions shall be documented in an actual-dimension drawing or in an as-built-report. This document shall be available for the acceptance test at the material manufacturer (final pre-delivery test).

(2) Dimensional deviations are acceptable only within the limits specified in the design-review documents.

3.3.7.9 Materials identification check

In the case of batch by batch examination each alloy steel part shall be subjected to a materials identification check using a spectrometric method (e.g. optical emission spectroscopy, x-ray fluorescence spectrometry) except for parts which were subjected to a product analysis.

3.3.7.10 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.

3.3.8 Non-destructive tests and inspections

3.3.8.1 General requirements

(1) The requirements under Sec. 3.3.8 apply unless deviating requirements are specified in the product-form related sections.

(2) The entire volume of the product form shall be subjected to an ultrasonic testing at the material manufacturer's works after the last forming and heat treatment in the most simple geometric condition, where possible.

(3) If, for reasons of material technology (e.g. reduction of the tempering cross-section), a geometry exists after the last heat treatment that does not permit the examination of the entire volume with the required incidence angles then, by agreement with the authorized inspector, additional examinations of these areas of limited testability shall be performed at an earlier point of time during manufacturing when a favourable geometric condition exists. This shall be indicated in the test report.

(4) Where weld edges and nozzles are dressed, these dressed areas shall be subjected to an ultrasonic testing if the surface is in its final condition and prior to dressing the fusion faces. In this case, the requirements for the testing after welding laid down in KTA 3201.3, Section 12, shall apply. 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) The entire surface in its finished condition shall be subjected to a surface inspection. Surfaces to be clad shall be examined prior to cladding. The surfaces of tapped holes shall be tested prior to tapping. Fusion faces shall be tested in accordance with section 12 of KTA 3201.3.

3.3.8.2 Requirements for surfaces

3.3.8.2.1 Radiographic testing

For radiographic testing, the surfaces shall be such that the evaluation is in no way impaired.

3.3.8.2.2 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.

3.3.8.2.3 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.

3.3.8.2.4 Surface quality of steel castings

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 normally have a surface quality equal to or better than that of BNIF visual tactile comparators 3 S1 or 4 S2. Castings to be tested by the ultrasonic method shall normally have a surface quality equal to or better than that of BNIF visual tactile 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 visual tactile comparators 2 S1 or 3 S2.

3.3.8.2.5 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.

3.3.8.3 Procedural requirements

3.3.8.3.1 Manual ultrasonic testing

(1) The general specifications laid down in **Annex D** shall apply.

(2) Evaluation of indications

Where the boundary conditions of the distance gain (DGS) method as per section B 6.2 cannot be satisfied or the DGS method cannot be applied due to the sound attenuation of the material, the reference block method or DAC method to section B 6.3 shall be applied.

(3) Adjustment of the test system

For reference reflectors the following applies:

a) Flat bottom and round bottom holes for testing level adjustment shall have a diameter of 4 mm.

b) Side-drilled holes for testing level adjustment shall have a diameter of 3 mm and a length of 30 mm unless specified otherwise in the product-form related section.

Where a lateral wall effect occurs, the reference block method with a flat bottom hole as reference reflector shall preferably be used. This reference reflector may be on the test object or on a reference block. The reference block diameter and length (for bars) or the wall thickness (for hollow parts) shall not deviate by more than 10 % from the respective test object dimensions.

During the testing level adjustment the highest sound attenuation values determined in accordance with section B 6.4 shall be considered for all search units and sound entry directions.

The evaluation of the reflector indication shall be made in due consideration of the actual sound attenuation values measured adjacent to the indicated echoes.

(4) Sound beam directions

The total volume shall basically be examined in three directions vertical to one another by means of straight-beam scanning unless specified otherwise in the product-form related sections.

Where straight-beam scanning is not possible for geometric reasons each impracticable straight-beam scanning direction shall be substituted by two opposite angle-beam scanning directions on the respective surface.

Note:

The beam angles specified in this safety standard refer to the respective probe nominal angles.

(5) Recording levels

a) When applying the DGS method the limit values apply which depend on the nominal wall thickness or bar diameter, width or side length and have been specified in the product-form related sections.

b) When applying the reference block method or DAC method with the reference reflectors to **Figure B-1** all indications shall be recorded the echo amplitude of which is equal to or exceeds 50 % of the echo amplitude of the reference reflector.

c) The following shall be recorded additionally:

ca) all locations where 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,

cb) clusters of indications up to 6 dB below recording level occur and

cc) locations where the distance of the recording level to the noise level attains or is less than 6 dB.

(6) Acceptance criteria

The acceptance criteria are laid down in the product-form related sections. In addition, the following applies:

a) Indications from regions which will definitely not be removed during finish-machining shall not be considered, but recorded only. All echo indications from the structure shall not be part of the evaluation but shall be recorded in the test record.

b) Where during straight-beam scanning using the DGS method liable-to-record echo indications of reflections are found in the area of lateral wall effect influence, these indications shall be verified by means of straight-beam scanning using the reference block method or by means of purposive angle beam scanning.

Where the area of lateral wall effect is omitted due to the cutting-to size of the test object, this condition shall preferably be re-examined. The results of the re-examination shall be considered in the evaluation.

c) In regions with signal-to-noise ratios smaller than or equal to 6 dB, or if the back-wall echo falls down to the recording level for which no explanation is found, examinations (e.g. sound attenuation measurements) shall be made by agreement with the authorized inspector which make a decision on the usability of the component possible.

d) Where indications below the recording level accumulate which cannot be resolved into single echo indications for one search unit position or in the case of search unit displacement, or which cannot be clearly correlated to the sound beam angles used, supplementary examinations (e.g. by scanning in different directions) shall be performed. Where these examinations (e.g. by loss of intensity of a signal compared to product areas free from indications) show planar discontinuities or systematic defects, these locations shall not be accepted.

e) In the case of test objects with a wall thickness exceeding 15 mm, the reference block method with a rectangular notch of 1 mm depth as reference reflector may be used for testing level adjustment for near-surface areas.

f) If a more exact determination of the reflector extension is required, the method of section B 11.2.4 shall apply.

(7) Checking of coupling

Where the coupling cannot be checked by other means during manual examinations (e.g. by observation of a back wall echo), the gain shall be increased such that the noise level becomes visible.

(8) Size of reflectors

Where laminar or planar indications are permitted at the location of indication and no other requirements apply, the reflector size is determined from that probe movement where, depending on the wall thickness,

a) for wall thicknesses smaller than or equal to 10 mm the echo amplitudes correspond to the registration level

or

b) for wall thicknesses exceeding 10 mm up to and including 40 mm the echo amplitudes have dropped 6 dB below the recording level

or

c) for wall thicknesses exceeding 40 mm the echo amplitudes have dropped up to 12 dB below the recording level.

Where the noise level is reached, the reflector size is determined by the locations where the echo disappears in the background. If the reflector size is the determining factor for its acceptability, additional examinations shall be performed (cf. Sec. B 11.2.4) to increase the accuracy of the reflector size measurement. Reflectors with dimensions smaller than 10 mm shall be considered to be point-type indications.

3.3.8.3.2 Surface inspections

(1) The general specifications laid down in **Annex C** shall apply.

(2) Surface inspections of sufficiently magnetizable materials shall basically be performed by the magnetic particle method, unless specified otherwise in the product-form related sections.

(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.

3.3.8.3.3 Radiographic testing

(1) The requirements for performing radiographic testing on pipe elbows to replace the ultrasonic testing for transverse defects are contained in section 17.4.3.

(2) Requirements for performing radiographic testing of castings are specified in DIN EN 12681 as well as in Secs. 25.6 and 27.6.

3.3.8.3.4 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 shall apply.

3.3.8.4 Testing by the authorized inspector

(1) The following shall apply to the performance of non-destructive tests by the authorized inspector:

a) Ultrasonic, eddy-current and magnetic flux leakage testing

aa) In the case of manual testing, the authorized inspector shall perform the tests and evaluate the test results independently of the tests performed by the material manufacturer.

ab) In the case of mechanized or automated testing the authorized inspector shall attend the sensitivity calibration 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)

The authorized inspector shall attend the test to be performed by the manufacturer and evaluate the result obtained.

(2) After completion of each test step, the authorized inspector shall check the test reports produced by the manufacturer for consistency with his own tests. If the test results are the same considering the scattering subject to test method variations, this shall be certified by the authorized inspector.

(3) 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 and be assessed by the authorized inspector and the manufacturer.

3.3.8.5 Test reports

3.3.8.5.1 General requirements

(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) All test reports on non-destructive tests and inspections shall become part of the inspection certificate 3.2 in accordance with DIN EN 10204. The test reports shall contain all data required for any possible reference testing.

(3) Test results of similar test objects which are correlated to similar test instructions may be documented in a joint test report.

(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).

3.3.8.5.2 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).

3.3.8.5.3 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.

3.3.8.5.4 Surface inspection (magnetic particle and penetrant testing)

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.

3.3.8.5.5 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.

3.4 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 test shall be repeated.

(2) Should the results of a properly performed test fail to meet the requirements, the further procedure is as follows:

a) Lot-wise 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, each individual piece of the lot may be subjected to a renewed test regarding the specific property found to be inadequate.
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) If the cause for the inadequacy of an examination can be removed by a corresponding heat treatment, the heat treatment may be carried out with the test unit to be subsequently submitted for re-examination.

(4) The cause for the inadequacy of the first examination shall be examined.

3.5 Identification marking of the product forms

(1) All product forms shall be marked clearly, durably, as notch-free as possible and such that an unambiguous correlation to the test certificates is possible at all times.

(2) The identification marking shall contain the following information:

a) identification of the material manufacturer,
b) material identification,
c) melt number,
d) test specimen number,
e) head and tail location,
f) location of the neutral axis,
g) certification stamp of the authorized inspector,
h) major direction of forming.

Note:
Further details on identification marking are contained in Sec. 10.2 of KTA 3201.3.

3.6 Documentation

(1) Details regarding the required test certification are specified in the product-form related sections.

(2) All test documents including acceptance test documents and the heat treatment records shall be compiled and checked for completeness by the material manufacturer and shall be presented to the authorized inspector for his preparation of the inspection certificate.

4 Seamless hollow parts, forged or rolled

4.1 Scope

(1) This section applies to the following forged or rolled product forms from quenched and tempered steel:

a) seamless cylindrical rings without discontinuities for shell sections as well as seamless, non-cylindrical hollow parts and
b) seamless cylindrical rings for flanges and end (head) reinforcements.

(2) For seamless hollow parts for forged, rolled or pressed nozzles Section 5 applies.

(3) The requirements for the materials for these product forms are specified in Sec. A 1.

4.2 Requirements

The requirements under Sec. 3.2.4.2 shall apply.

4.3 Tests and inspections

4.3.1 Specimen-taking locations

4.3.1.1 General requirements

(1) Product forms with a tempering length exceeding 3000 mm shall be tested at the head and tail ends. One of these two ends shall be subjected to the major examination in accordance with clause 4.3.2.2.1.

(2) Tests performed on the other end serve to demonstrate post-tempering uniformity of the material characteristics (cf. Clause 4.3.2.2.2). The extent of tests on this end is reduced with respect to the tests on the other end.

(3) The end at which the extent of tests may be reduced shall be specified in the initial material appraisal.

(4) Products with a tempering length between 1500 mm and 3000 mm may be tested on only one end provided, the authorized inspector agrees and the material manufacturer has demonstrated the post-tempering uniformity of the material characteristics unless specified otherwise in the initial material appraisal.

(5) Products with a tempering length equal to or less than 1500 mm need to be tested on only one end unless specified otherwise in the initial material appraisal. This also applies if two or more components are to be fabricated from the quenched and tempered product.

(6) If tests on transverse test specimens are specified in the following sections, however, the fibre direction on the product cannot be unambiguously identified, it is permitted to use tangential test specimens in the tests instead of the transverse test specimens.

4.3.1.2 Special requirements for seamless hollow, cylindrical rings without discontinuities for shell sections

(1) In the case of product forms with a clear tempering diameter exceeding 2000 mm, the test coupons shall be taken from the end faces at three locations offset by 120 degrees to each other.

(2) In the case of product forms with a clear tempering diameter equal to or less than 2000 mm, the test coupon shall be taken from the end faces at two locations offset by 180 degrees to each other. Where the test coupons are taken at the head and tail ends, they shall be taken from locations that are offset by 90 degrees with respect to the specimen-taking locations at the opposite end.

(3) The test specimen shall be taken from locations at a depth of at least one quarter of the quenched and tempered wall thickness but not deeper than 80 mm beneath the cylindrical surface, and at least one half of the quenched and tempered wall thickness but not deeper than 160 mm beneath the end face surface leveled for heat treatment. Thermal buffering may be applied.

4.3.1.3 Special requirements for seamless cylindrical rings for flanges and head (end) plate reinforcements

(1) This section applies to product forms with a tempering diameter exceeding 2000 mm and a quenched and tempered wall thickness exceeding 320 mm.

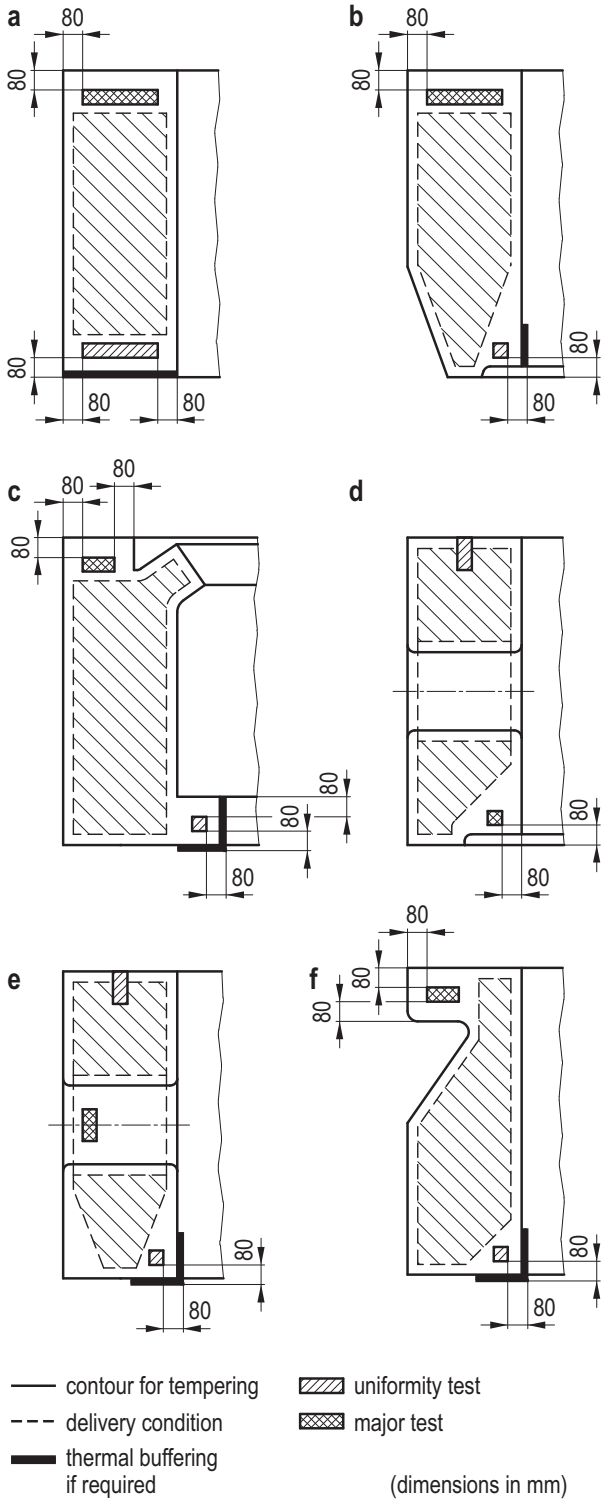


Figure 4-1: Examples of specimen-taking locations in case of products in accordance with clause 4.3.1.3

(2) Depending on the form of the product or the method of producing it from the initial material block, the test specimens shall be taken in accordance with **Figure 4-1**

- from the end faces of the ring (head or tail end),
- from the punched-out metal discs taken after the tempering process

or

- from beneath the inner or outer circumferential surface near the head or tail end.

(3) The test specimens for the major test in accordance with clause 4.3.2.2.1 and for the tests to demonstrate uniformity of material characteristics over the height of the product in accordance with clause 4.3.2.2.2 shall be taken such that the top and bottom end of the initial material block are included.

(4) The specimen-taking locations shall be at least 80 mm under the individual tempering surface. Thermal buffering may be employed.

(5) If the test for verifying the NDT temperature in accordance with clause 3.2.4.2 does not show the required values at the above mentioned depths of the specimen-taking locations, then the verification of these values shall be carried out for a depth t under the cylindrical tempering surface and a depth of 2t under a tempering surface perpendicular to the former. The value t is equal to the tempering allowance for the product, however, at least 20 mm.

4.3.2 Extent of testing

4.3.2.1 Chemical analysis

4.3.2.1.1 Ladle analysis

(1) In the case of products manufactured from a single heat, the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined. Heats of materials for core belt line components shall additionally be analysed for cobalt and tantalum.

(2) In the case of products manufactured from more than one heat, the calculated average chemical composition shall be specified.

4.3.2.1.2 Product analysis

(1) On each product (piece) the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined for one specimen-taking location each at both the head and the tail end. If the product form is required to be tested on only one end, then the product analysis is required, likewise, for only one end.

(2) Additional product analyses, e.g. on the shell surface of the product, may be specified during the initial material appraisal.

(3) The content of carbon, manganese, phosphorus and sulphur shall be determined for all remaining specimen-taking locations in accordance with Sec. 4.3.1.

4.3.2.2 Tests on specimens subjected to simulation heat treatment

4.3.2.2.1 Major test

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with clause 3.3.7.3 (1), one at room temperature and one at design temperature. In addition, one perpendicular test specimen from one specimen-taking location shall be tested at room temperature, if a standard tensile specimen can be taken.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C, 33 °C and 80 °C. In the case of product forms intended for core belt line components, the test at 33 °C shall be replaced by a test at 21 °C.

One set each of longitudinal and of perpendicular test specimens from one specimen-taking location shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C.

(4) Impact-energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with clause 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location.

(5) Nil-ductility transition temperature

The NDT temperature shall be determined in accordance with clause 3.3.7.3 (5) on longitudinal or transverse test specimens from one specimen-taking location. At least eight test specimen shall be kept ready for these tests.

It shall be shown on two longitudinal or transverse test specimens from each of the other specimen-taking locations that they meet the requirements regarding the NDT temperature.

If this cannot be shown then the NDT temperature shall be determined for each specimen-taking location.

(6) Metallographic examinations

The grain size shall be determined from longitudinal cross sections on one impact test specimen from each specimen-taking location, in each case, the microstructure shall be evaluated and documented in accordance with clause 3.3.7.4.

4.3.2.2.2 Test to demonstrate uniformity of material characteristics

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with clause 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C.

(4) Nil-ductility transition temperature

In the case of product forms intended for core belt line components, it shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens from one specimen-taking location that they meet the requirements for the NDT temperature.

(5) Metallographic examinations

The grain size shall be determined from longitudinal cross sections on one impact test specimen from each specimen-taking location, and the microstructure shall be evaluated and documented in accordance with clause 3.3.7.4.

4.3.2.3 Tests on production control test coupons

(1) General requirements

From each specimen-taking location, test coupons shall be taken for tests on production control test coupons. The tests shall be performed for each product, however, for only one specimen-taking location. The remaining test coupons shall be stored in the as-removed condition.

No tests on production control test coupons are required, if the impact test on simulation heat treated transverse test specimens demonstrates that the smallest value of the impact energy absorbed at 0 °C is equal to or greater than 68 J. However, tests on productions control test coupons are always required for products intended for the reactor pressure vessel.

(2) Tensile test

Two transverse test specimen shall be subjected to a tensile test in accordance with clause 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Impact test

One set of transverse test specimens shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with clause 3.3.7.3 (4) shall be plotted using transverse test specimens.

In the case of products not intended for core belt line components, it will suffice to perform the test at 33 °C and 80 °C.

(5) Nil-ductility transition temperature

It shall be demonstrated in accordance with clause 3.3.7.3 (5) by two longitudinal or transverse test specimens that the requirements for the NDT temperature are met. In the case of products intended for core belt line components, the exact NDT temperature shall be determined. At least eight test specimens shall be prepared for this test.

4.3.2.4 Hardness test

(1) To prove the uniformity of quenching and tempering a sufficient number of hardness tests shall be performed in accordance with clause 3.3.7.2.

(2) In the case of products with a length equal to or greater than 3000 mm or a clear diameter equal to or greater than 2000 mm, hardness tests shall be performed on both end faces and on the circumferential surface in a grid with a maximum grid size of 1000 mm by 1000 mm.

4.4 Non-destructive tests and inspections

The requirements under clause 3.3.8 and 5.4 shall apply to the non-destructive tests and inspections.

4.5 Visual inspection

The requirements under clause 3.3.7.10 shall apply to the visual inspection.

4.6 Check for dimensional accuracy

The requirements under clause 3.3.7.8 apply to the dimensional accuracy check.

4.7 Verification of quality characteristics

The results of the tests and examinations in accordance with clauses 4.3.2.1, 4.3.2.2.1 (6), 4.3.2.2.2 (5) and 4.3.2.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

5 Seamless hollow parts for nozzles, forged, rolled or pressed

Note:

This section does not apply to set-on nozzles on the secondary shell of the steam generator. Requirements for this case are specified in KTA 3211.1.

5.1 Scope

The requirements regarding materials for these product forms are specified in Section A1.

5.2 Requirements

The requirements under clause 3.2.4.2 apply.

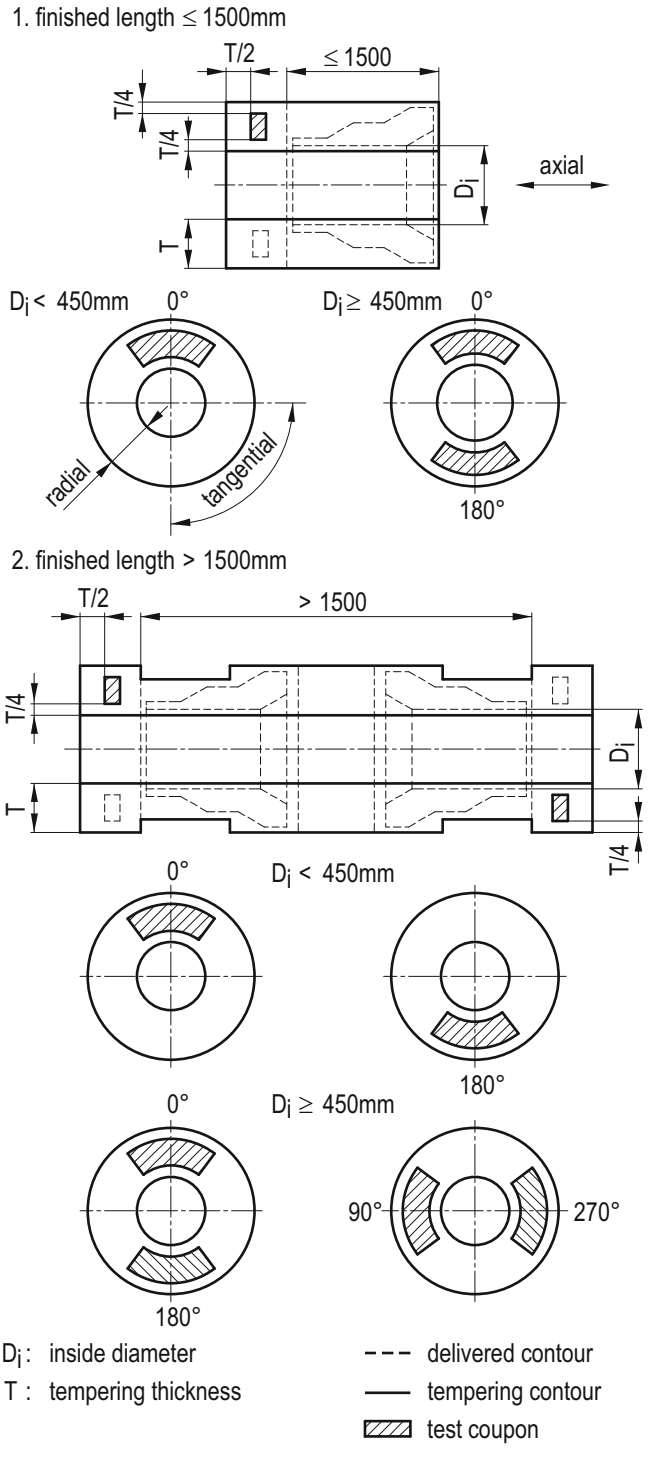


Figure 5-1: Examples for specimen-taking locations

5.3 Tests and examinations

5.3.1 Specimen-taking locations

(1) A quenched and tempered product with a finished length equal to or smaller than 1500 mm shall be tested from one end face, and with a finished length exceeding 1500 mm from both end faces. The number of nozzles fabricated from this product is not considered.

Note:
Finished length means fabrication length minus length of the test coupon. The fabrication length is the length of the product during quenching and tempering.

(2) Examples for specimen-taking locations are shown in **Figure 5-1**.

(3) If the quenched and tempered product is used for the fabrication of nozzles with an inside diameter less than 450 mm in the finished condition, only one test coupon needs to be taken from each end face to be tested. In the case that both end faces are to be tested, the specimen-taking locations at opposite ends should be offset by 180 degrees to each other.

(4) If the quenched and tempered product is used for the fabrication of nozzles with an inside diameter equal to or greater than 450 mm in the finished condition, two test coupons shall be taken from each end face to be tested. The specimen-taking locations on the same end face shall be offset by 180 degrees to each other. In the case that both end faces are to be tested, the specimen-taking locations at opposite ends should be offset by 90 degrees to each other.

(5) In the case of combination of forged set-in nozzles, the test specimens shall be taken at that cross section that is relevant to the tempering process. With regard to test specimen location, the requirements under this section apply.

(6) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness but not deeper than 80 mm beneath the cylindrical surface, and at least one half of the quenched and tempered wall thickness but not deeper than 160 mm beneath the end face surface levelled for heat treatment. Thermal buffering may be applied.

(7) If the taking of transverse test specimens is impossible or in the case of products for the fabrication of nozzles with a clear diameter of less than 450 mm, longitudinal test specimens may be used instead of the transverse test specimens specified in the following sections.

5.3.2 Extent of testing

5.3.2.1 Chemical analysis

5.3.2.1.1 Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

5.3.2.1.2 Product analysis

(1) On each product (piece) the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined for one specimen-taking location at one end face.

(2) Where a product analysis is required for both ends, the content of carbon, manganese, phosphorus, and sulphur shall be determined for one specimen-taking location at the opposite end face.

5.3.2.2 Tests on test specimens subjected to simulation heat treatment

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with

clause 3.3.7.3 (1), one at room temperature and one at design temperature.

In the case of tempered products for the fabrication of nozzles with an inside diameter equal to or greater than 450 mm in the finished condition, one perpendicular test specimen from one specimen-taking location shall additionally be tested at room temperature, if a standard tensile specimen can be taken.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C.

Additionally, one set of transverse test specimens from one specimen-taking location at each end face shall be subjected to an impact test at 33 °C and at 80 °C.

In the case of tempered products for the fabrication of nozzles with an inside diameter equal to or greater than 450 mm in the finished condition, one set of longitudinal and of perpendicular test specimens from one specimen-taking location shall be subjected to an impact test at 0 °C.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with clause 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location. The tests described in para (3) may be performed.

(5) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens from one specimen-taking location that they meet the requirements regarding the NDT temperature.

(6) Metallographic examinations

The grain size shall be determined from longitudinal cross sections on one impact test specimen from each specimen-taking location and the microstructure shall be evaluated and documented in accordance with clause 3.3.7.4.

5.3.2.3 Hardness test

In the case of quenched and tempered products with a length equal to or greater than 3000 mm, hardness measurements shall be performed on both end faces in the middle of the wall thickness and on the circumferential surface along a surface line beginning at the edge and at distances not exceeding 1000 mm.

5.3.2.4 Tests on production control coupons

(1) General requirements

From each specimen-taking location test specimens shall be taken for tests on production control test coupons. The tests shall be performed for each product, however, for only one specimen-taking location. The remaining test coupons shall be stored in the as-removed condition.

If the product is used for the fabrication of several nozzles that are used in different component groups and are separately subjected to stress relief heat treatment, one set of production control test coupons shall be prepared from the product for each component group.

No tests on accompanying test coupons are required, if the impact test on simulation heat treated transverse test specimens demonstrates that the smallest value of the impact energy absorbed at 0 °C is not less than 68 J. However, tests on production control test coupons are always required for products intended for the reactor pressure vessel.

(2) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with clause 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Impact test

One set of transverse test specimens shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C.

(4) Impact energy-versus-temperature curve

In the case of products for the fabrication of nozzles with an inside diameter equal to or greater than 450 mm in the finished condition, an impact-energy-versus-temperature curve in accordance with clause 3.3.7.3 (4) shall be plotted using transverse test specimens. It is sufficient to perform the test at 33 °C and 80 °C.

(5) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens that they meet the requirements regarding the NDT temperature.

5.4 Non-destructive tests and inspections

5.4.1 General requirements

The following requirements shall apply in addition to the requirements under clause 3.3.8.

5.4.2 Ultrasonic testing

5.4.2.1 Sound attenuation measurements

For wall thicknesses equal to or greater than 200 mm sound attenuation measurements shall be made in accordance with clause B 6.4.2 on three surface lines offset by 120 degrees at least at three measuring points with a distance of not more than one metre. Where during straight-beam scanning no essential local deviations (deviations equal to or less than 6 dB), the number of measurements may be halved for angle-beam scanning.

5.4.2.2 Sound-beam angles

(1) All products shall be tested by the straight-beam method from one shell surface and from both end faces, and by the angle-beam method from one cylindrical surface in both circumferential directions. Those regions which are not reached by the end-face straight-beam testing (e.g. cones) or where recordable indications from the straight-beam testing with side-wall effects have to be evaluated shall be tested by the angle-beam method from one cylindrical surface in both axial directions.

(2) If necessary to achieve the required measuring accuracy or to cover the total area to be tested, the test shall be performed from both cylindrical surfaces.

5.4.2.3 Recording levels

(1) All indications shall be recorded the echo amplitudes of which are equal to or exceed the echo amplitude values of the disc shaped reflectors specified in **Table 5-1**.

(2) In the case of the sound attenuation measurements, any sound attenuation shall be recorded that exceeds 4 dB/m when testing at 2 MHz or that exceeds 10 dB/m when testing at 4 MHz.

5.4.2.4 Acceptance criteria

5.4.2.4.1 General requirements

(1) The distance between the finished surface and the reflectors that lead to a recordable indication shall not be less than the values specified in **Table 5-2**.

(2) All recordable indications from the angle-beam scanning that do not exceed the recording levels in the straight-beam scanning shall be subjected to a detailed examination regarding their orientation. Recordable indications which extend in the direction of depth are unacceptable.

Nominal wall thickness s in mm	Diameter of the disc shaped reflector in mm	
	Straight-beam scanning	Angle-beam scanning
$s \leq 15$	1.5	1
$15 < s \leq 30$	1.5	1.5
$30 < s \leq 60$	2	2
$60 < s \leq 120$	3	3
$120 < s \leq 250$	4 [1) 2)]	3
$s > 250$	6 [1) 2)]	3

1) These values only apply if observation of the back wall echo is possible; otherwise the same value as for angle-beam scanning applies.

2) Where welding edge zones are tested, the same value as for angle-beam scanning applies.

Table 5-1: Recording levels for the ultrasonic testing of forgings

Nominal wall thickness s in mm	Minimum distance in mm
$s \leq 40$	5
$40 < s \leq 80$	10
$s > 80$	20

Table 5-2: Minimum distance of recordable locations from the finished surface

5.4.2.4.2 Additional requirements

(1) Regions of weld edges and nozzles

Unacceptable indications are:

a) indications having a linear extension,

b) straight-beam scanning echoes with an amplitude that exceed the recording limit by more than 12 dB.

Indications that are recordable both in the straight-beam and the angle-beam scanning are acceptable only up to an echo amplitude of 6 dB above the recording level for the angle-beam scanning.

Depending on the nominal wall thickness, the maximum acceptable frequency of all recordable echoes shall not exceed the values specified in **Table 5-3**.

The smallest distance between reflections shall not be less than 100 mm.

Nominal wall thickness s in mm	Frequency per meter
$s \leq 10$	0
$10 < s \leq 120$	2
$120 < s \leq 250$	4
$s > 250$	6

Table 5-3: Allowable frequency of recordable indications in welding edge and nozzle regions

(2) Other volumetric areas

Point-type indications found in the straight-beam scanning in radial direction are acceptable if their echo amplitudes are up to 18 dB above the recording level in accordance with **Table 5-1**. Depending on the maximum echo amplitude, indications with lengths in accordance with curve 1 of **Figure 5-2** are acceptable provided the amplitudes of the corresponding angle-beam echoes for these locations are less than 6 dB above the recording level. However, the maximum acceptable reflector length is 120 mm.

Point-type indications found in the straight-beam scanning in axial direction are acceptable if their echo amplitudes are up to 12 dB above the recording level. Depending on the maximum echo amplitude, indications with lengths in circumferential direction are acceptable according to curve 2 of **Figure 5-2** provided the amplitudes of the corresponding angle-beam echoes for these locations are less than 6 dB above the recording level. However, the maximum acceptable reflector length in circumferential direction is 60 mm. Indications which extend more than 10 mm in the direction of depth are unacceptable.

The frequency of indications shall locally not be higher than 10 per square metre with respect to the outer surface area and not higher than 5 per square metre with respect to the total surface area.

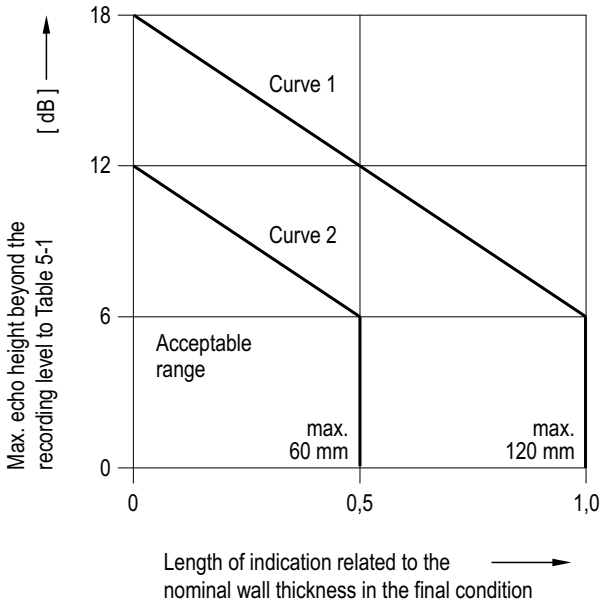


Figure 5-2: Allowable lengths of indications and echo heights for ultrasonic testing

5.4.3 Surface inspection

The requirements under **Tables 5-4** and **5-5** apply.

5.5 Visual inspection

The requirements under clause 3.3.7.10 apply to the visual inspection.

5.6 Check for dimensional accuracy

The requirements under clause 3.3.7.8 apply to the check for dimensional accuracy.

5.7 Verification of quality characteristics

The results of the tests in accordance with clauses 5.3.2.1, 5.3.2.2 (6), and 5.3.2.3 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

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 5 per dm^2, but maximum 10 per m^2 with respect to the total surface area.		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 area where indications were found.

[3] In the case of indications appearing systematically, the usability of the parts shall be decided jointly with the authorized inspector.

Table 5-4: 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 5 per dm^2, but maximum 10 per m^2 with respect to the total surface area.	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 area where indications were found.

[2] In the case of indications appearing systematically, the usability of the parts shall be decided jointly with the authorized inspector.

Table 5-5: Acceptance criteria for magnetic-particle testing

6 Forged plates for tubesheets

6.1 Scope

The requirements for the materials for this product form are specified in Sec. A 1.

Note:

During fabrication, when forging these product forms in the finished condition, adequate measures shall be taken to avoid, as far as technically feasible, any positive segregation on surfaces intended for welding or cladding. Measures to be considered are, e.g., upset forging, forging from the head surface and avoiding any machining in the segregated zones.

6.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

6.3 Tests and examinations

6.3.1 Specimen-taking locations

(1) The specimen-taking locations shall be specified in the course of the initial material certification in due consideration of the forging procedure (direction of major deformation either parallel or normal to the ingot axis).

(2) The plates for tubesheets shall be tested from one end face or on the circumference unless specified otherwise by the initial material appraisal.

(3) The test coupons shall be taken from three locations set apart by 120 degrees to each other. The specimen-taking locations shall be at least 80 mm away from any tempering surface. The specimen-taking locations are shown in **Figure 6-1**.

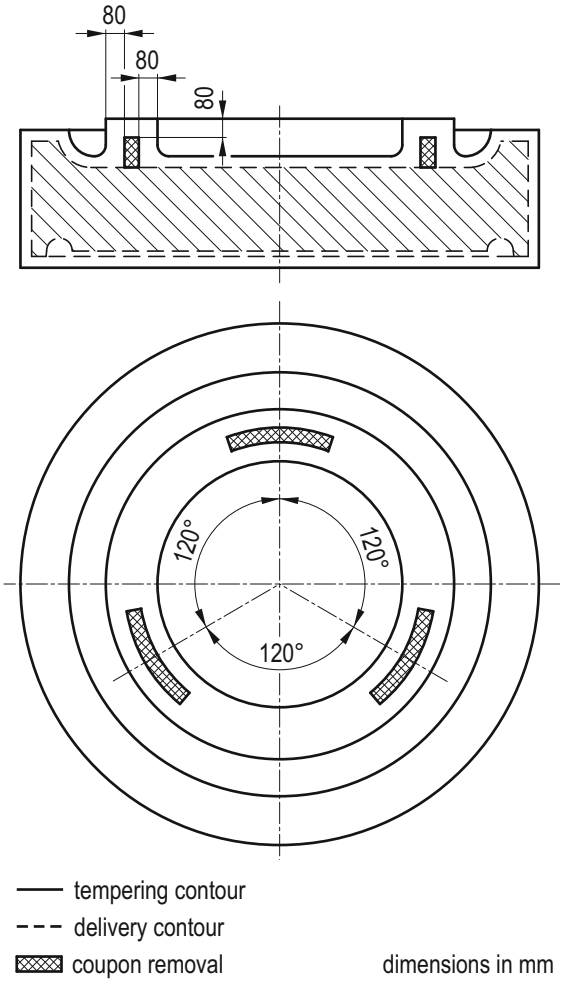


Figure 6-1: Example for specimen-taking locations

6.3.2 Extent of testing

6.3.2.1 Chemical analysis

6.3.2.1.1 Ladle analysis

For each tubesheet fabricated from a single melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined. In the case of tubesheets fabricated from more than one melt, the calculated average chemical composition shall be specified.

6.3.2.1.2 Product analysis

(1) For each specimen-taking location the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined. Where tests are required for only one end face, the product analysis shall additionally be performed on the other end face for a location that lies opposite to one specimen-taking location on the initial end face.

(2) If the head and tail end of the ingot are not covered by this analysis, the chemical composition of these areas shall additionally be determined.

6.3.2.2 Tests on test coupons subjected to simulation heat treatment

(1) Tensile test

Two transfer or one tangential test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with clause 3.3.7.3 (1), one at room temperature and one at design temperature.

In addition, one perpendicular test specimen (axial test specimen) from one specimen-taking location shall be tested at room temperature.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on specimens from one specimen-taking location.

(3) Impact test

One set of transverse or tangential test specimens from each specimen-taking location shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C, 33 °C and 80 °C. Additionally, one set each of longitudinal and perpendicular test specimens from one specimen-taking location shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C.

(4) Impact energy-versus temperature curve

An impact-energy-versus-temperature curve in accordance with clause 3.3.7.3 (4) shall be plotted using transverse or tangential test specimens from one specimen-taking location. The tests described in para (3) may be performed.

(5) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens that they meet the requirements regarding the NDT temperature.

(6) Metallographic examinations

The grain size shall be determined from longitudinal cross sections on one impact test specimen from each specimen-taking location; in each case, the microstructure shall be evaluated and documented in accordance with clause 3.3.7.4.

6.3.2.3 Tests on production control test coupons

(1) General requirements

From each specimen-taking location, test specimens shall be taken for tests on accompanying test coupons. The tests shall be performed for each product, however, only for one specimen-taking location. The remaining test coupons shall be stored in the as-removed condition.

(2) Tensile test

Two transverse or tangential test specimens shall be subjected to a tensile test in accordance with clause 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Impact test

One set of transverse or tangential test specimens shall be subjected to an impact test in accordance with clause 3.3.7.3 (3) at 0 °C.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with clause 3.3.7.3 (4) shall be plotted using transverse or tangential test specimens. It is sufficient to perform the test at 33 °C and 80 °C.

(5) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens that they meet the requirements regarding the NDT temperature.

6.3.2.4 Hardness test

(1) The requirements of clause 3.3.7.2 apply to the hardness tests.

(2) In the case of quenched and tempered products, the uniformity of tempering shall be demonstrated by hardness tests on both end faces in a grid with a maximum grid size of 1000 mm by 1000 mm and on the circumferential surface along one surface line beginning near the edge and continuing at distances of not more than 1000 mm.

6.4 Non-destructive tests and inspections

6.4.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8.

6.4.2 Ultrasonic testing

6.4.2.1 Sound attenuation measurements

At about 10 positions equally distributed over one end face, sound attenuation measurements shall be performed in accordance with clause B 6.4.2 using the straight-beam method.

6.4.2.2 Sonic probes

In order to achieve the required testing sensitivity in the near-surface region, special probes may have to be employed.

6.4.2.3 Sound beam angles

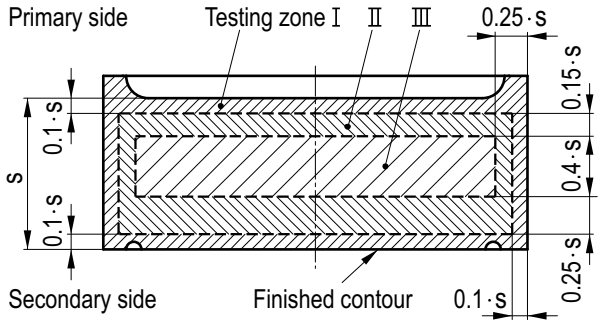
Ultrasonic testing shall be performed from the large surface and from the side face by means of the straight and angle beam techniques.

The incidence angles 1 to 15 shown in **Figure 6-2** shall be used where the angles 8 to 11 shall also be used from the ring surface.

In the case of angle-beam scanning a beam angle of 70 degrees and in the case of angle beam scanning from the side face in circumferential direction however, an angle of 35 degrees shall be used.

6.4.2.4 Recording levels

All indications shall be recorded the echo amplitudes of which are equal to or exceed the echo amplitude values of the disc shaped reflectors specified in **Table 6-1**.



Sound entry direction	Diameter of the disc shaped reflector in mm	
	Testing zone I and welded seam region	Testing zones II and III
Straight-beam scanning	3	6
Angle-beam scanning	3	—

Table 6-1: Division into testing zones and recording levels for the ultrasonic testing of forged plates for tubesheets

6.4.2.5 Acceptance criteria

6.4.2.5.1 General requirements

The distance between the finished surface and the location leading to a recordable condition shall not be less than 30 mm.

6.4.2.5.2 Additional requirements

(1) Weld edges and fusion faces

The requirements under Sec. 5.4.2.4.1 (2) and 5.4.2.4.2 (1) shall apply.

(2) Other volumetric regions

a) Straight-beam scanning in axial direction

In the straight-beam scanning in axial direction (beam angles 1 and 2 of **Figure 6-2**) the following indications are acceptable with the following restrictions:

aa) non-laminar indications with echo amplitudes up to 24 dB above the recording level,

ab) laminar indications with echo amplitudes below the curves in **Figure 6-3**.

The acceptance of these indications is based on the condition that in the case of angle-beam scanning from the large surfaces (sound entry directions 8 to 15 in **Figure 6-2**) no echo amplitudes higher than 6 dB above the recording level are obtained at the respective locations and in the case of straight-beam scanning from the side face (sound entry direction 3 in **Figure 6-2**) no recordable indications are found.

b) Straight-beam scanning from the side face

In the case of straight-beam scanning from the side face (sound entry direction 3 in **Figure 6-2**) indications up to 12 dB above the respective recording level are acceptable. If the indications show a longitudinal extension, additional non-destructive examinations shall be performed.

c) Angle-beam scanning

All recordable indications obtained by angle-beam scanning which in the case of straight-beam scanning are not found with a recording level corresponding to the respective angle-beam scanning method, shall be thoroughly examined for their orientation. Indications having an extension in excess of 10 mm in thickness direction are not permitted.

d) Acceptable frequencies

The frequencies of recordable indications shall, when projected onto one end face of the tubesheet, not exceed the values specified in **Table 6-2**.

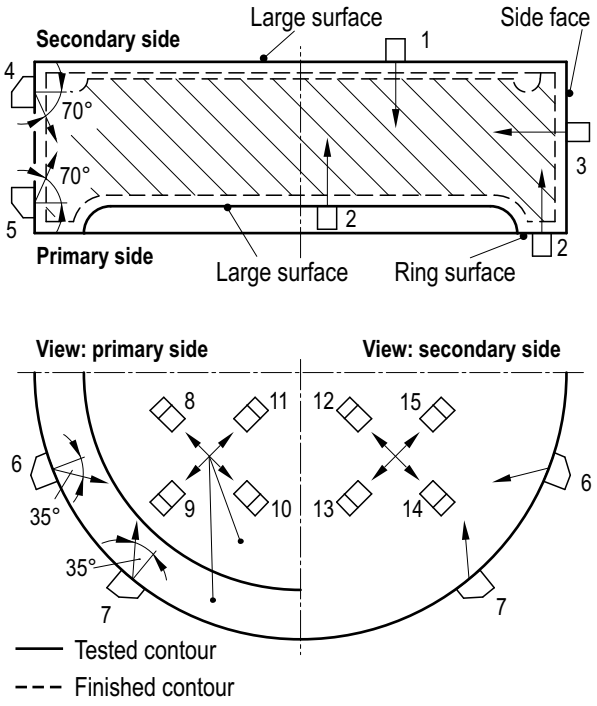


Figure 6-2: Sound entry directions 1 to 15 for the ultrasonic testing of forged plates for tubesheets

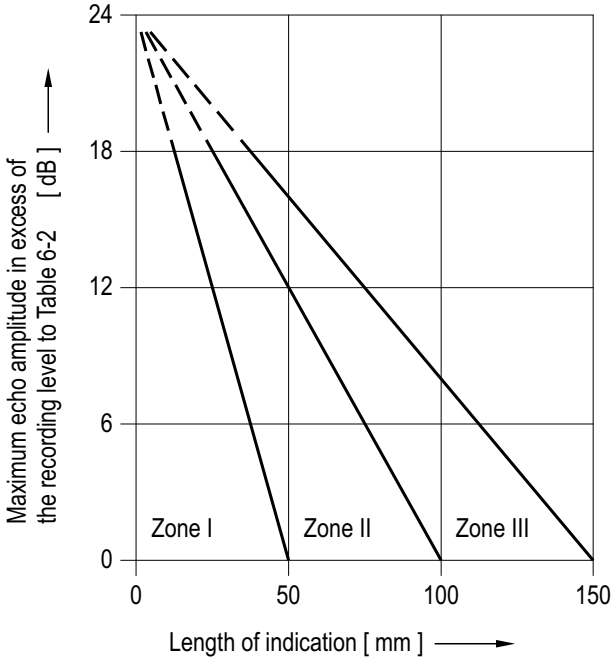


Figure 6-3: Allowable indication lengths and echo amplitudes for straight-beam scanning in axial direction (Sound entry direction 1 and 2 in Figure 6-2) in the case of forged plates for tubesheets

Testing zone to Table 6-1	Number of recordable indications per m^2
I	10
II	25
III	40

Table 6-2: Acceptable frequency of recordable indications

6.4.3 Surface inspection

The requirements under Sec. 5.4.3 shall be applied to the surface inspection.

6.5 Visual inspection

The requirements under Sec. 3.3.7.10 apply to the visual inspection.

6.6 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 apply to the check for dimensional accuracy.

6.7 Verification of quality characteristics

The results of the tests in accordance with Secs. 6.3.2.1, 6.3.2.2 (6) and 6.3.2.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

7 Sheets and plates

7.1 Scope

The requirements for the materials for this product form are specified in Sec. A 1.

7.2 Requirements

(1) The requirements under Sec. 3.2.4.2 shall apply.

(2) The tensile strengths determined for different specimen-taking locations of the same plate on similarly positioned and oriented test specimens shall not differ from each other by more than 80 N/mm^2.

7.3 Tests and examinations

7.3.1 Specimen-taking locations

(1) The test coupons shall be taken from the middle of the head and tail end of each plate or of each tempering unit. Plates with a length of less than 5 m shall be tested only at the head end. It is assumed that the direction of main deformation lies in the head-to-tail direction of the ingot and that it is possible to identify the head and tail ends of the plate.

(2) The specimen-taking location shall be at a depth of at least one quarter of the quenched and tempered wall thickness beneath the rolled surface and at least one half of the quenched and tempered wall thickness beneath the end face surfaces levelled for heat treatment.

(3) The specimen-taking locations are shown in **Figure 7-1**.

7.3.2 Extent of testing

7.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

For each plate the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

7.3.2.2 Mechanical-technological tests and microstructure

7.3.2.2.1 General requirements

If, during the fabrication of the plates, the direction of main forming does not clearly lie in the head-to-tail direction of the ingot, then in addition to the transverse test specimens called for in the following sections, the same number of longitudinal test specimens from the same specimen-taking location shall be tested.

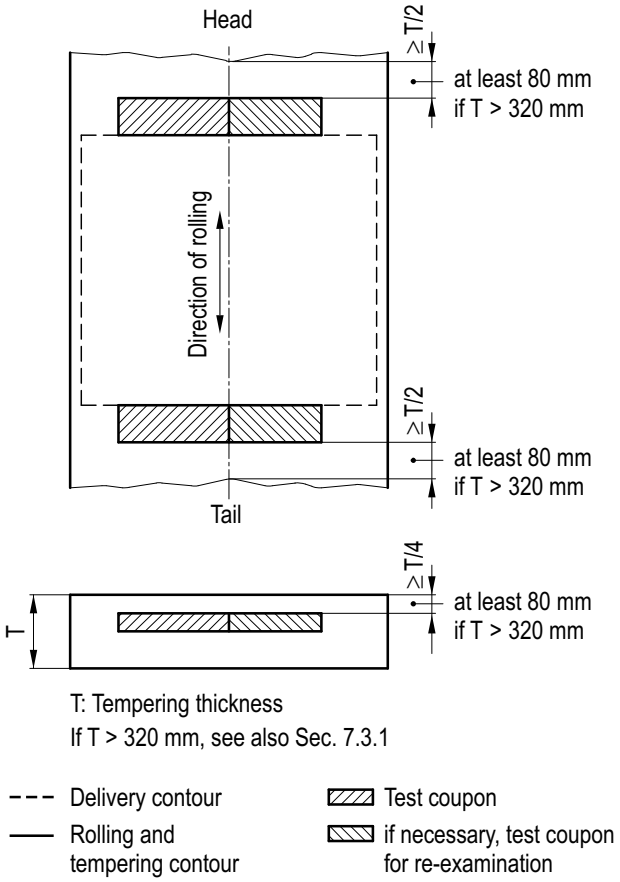


Figure 7-1: Example for specimen-taking location on plates

7.3.2.2.2 Tests of plates prior to quenching and tempering

(1) In the following cases, the plates shall be tested prior to quenching and tempering:

Case A: If the material manufacturer delivers them to a manufacturer for subsequent fabrication in a condition prior to quenching and tempering, or

Case B: If, in the course of subsequent fabrication, they are cut prior to quenching and tempering and the head and tail end can no longer be correlated to the pieces.

(2) In case A (delivery of plates prior to quenching and tempering) the following tests shall be performed on test coupons that are both simulation quenched and tempered and simulation heat treated.

a) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

b) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) for each specimen-taking location.

c) Impact test

The impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) on one set of transverse test specimens from each specimen-taking location at 0 °C.

d) Metallographic examinations

For each specimen-taking location, one impact test specimen from the impact test shall be examined on a longitudinal polished section with respect to grain size; the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

(3) In case A (cutting of plates prior to quenching and tempering) the following tests shall be performed on test specimens that are both simulation quenched and tempered and simulation heat treated.

a) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

b) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) for each specimen-taking location.

c) Impact test

The impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at one specimen-taking location (tail end) on one set of transverse test specimens each at 0 °C, 33 °C and 80 °C.

d) Impact energy-versus-temperature curve

On transverse test specimens from one specimen-taking location (head end) the impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4).

e) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens from one specimen-taking location (head end) that they meet the requirements regarding the NDT temperature.

f) Metallographic examinations

For each specimen-taking location, the longitudinal cross-section of one impact-test shall be examined on a longitudinal polished section with respect to grain size, the microstructure shall be evaluated and documented in accordance with 3.3.7.4.

7.3.2.2.3 Testing of plates after quenching and tempering

(1) Tests of simulation heat treated test coupons

a) The following tests shall be performed on the plates:

aa) in case A of clause 7.3.2.2.2: tests according to para. b) to g),

ab) in case B of clause 7.3.2.2.2: tests according to para. b) to g), however at only one specimen-taking location without correlation to head or tail end.

b) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3(1), one at room temperature and one at design temperature.

c) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) for each specimen-taking location.

d) Impact test

On transverse test specimens from one specimen-taking location (tail end) the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C, 33 °C and 80 °C.

e) Impact energy-versus-temperature curve

On transverse test specimens from one specimen-taking location (head end) the impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4).

f) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens from one specimen-taking location (head end) that they meet the requirements regarding the NDT temperature.

g) Metallographic examinations

For each specimen-taking location, the longitudinal cross-section of one impact test specimen shall be examined on a longitudinal polished section with respect to grain size; the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

(2) Tests on accompanying test coupons

From each specimen-taking location, test specimens shall be taken for tests on accompanying test coupons. The tests shall be performed for each product, however, for only one specimen-taking location. The remaining test coupons shall be stored in the as-removed condition.

If the product is used for the fabrication of multiple products that are used in different component groups and are separately subjected to stress relief heat treatment, one set of accompanying test coupons shall be prepared from the product for each component group.

No tests on accompanying test coupons are required, if the impact test on simulation heat transverse test specimens demonstrates that the smallest value of the impact energy absorbed at 0 °C is not less than 68 J. However, tests on accompanying test coupons are always required for products intended for the reactor pressure vessel.

a) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

Where both transverse and longitudinal test specimens have to be tested, the test specimens from that orientation shall be tested for which poorer results were obtained on simulation heat treated test specimens (cf. Sec. 7.3.2.2.1).

b) Impact test

On one set of transverse test specimens the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C (cf. clause a) above, second paragraph).

c) Impact energy-versus-temperature curve

Unless specified otherwise by the initial material appraisal, the impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4) on transverse test specimens from the head end of the plate (cf. clause a) above, second paragraph). In the case of products not in close vicinity to the core, it is sufficient to perform the test at 33 °C and 80 °C.

d) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens that they meet the requirements regarding the NDT temperature.

7.3.2.3 Hardness test

(1) The requirements under Sec. 3.3.7.2 apply to hardness tests.

(2) The hardness of quenched and tempered plates with a length equal to or greater than 3000 mm shall be tested on the plate surface along two lines offset by 90 degrees from each other, starting close to the plate edge and continuing in length intervals of not more than 1000 mm.

7.4 Non-destructive tests and inspections

7.4.1 General requirements

(1) The following requirements apply in addition to the requirements under clause 3.3.8.

(2) Deviating herefrom, the size of the reflector in the straight-beam scanning shall be determined by means of the half-value method in accordance with Sec. B 11.2.3.

7.4.2 Ultrasonic testing

7.4.2.1 Extent and point of time of testing

The entire volume of the plane plates shall be tested by means of straight-beam scanning upon the final forming and heat treatment processes and prior to subsequent fabrication.

7.4.2.2 Sound attenuation measurements

(1) Sound attenuation measurements shall be performed in accordance with Section B 6.4.2 by means of the straight-beam method on a grid of 2 m · 2 m, however, at least on 4 locations of each plate.

(2) In the case of differing surface qualities the number of measuring points shall be increased such that all surface conditions are covered.

(3) Where the range of the minimum values obtained under the same beam entry condition exceeds 6 dB (referred to the sound path length to be evaluated) the number of measuring points shall be doubled at least.

7.4.2.2 Recording levels

(1) All indications shall be recorded the echo amplitudes of which are equal to or exceed the echo amplitude values of the disc shaped reflectors specified in **Table 7-1**.

(2) In the sound attenuation measurements any sound attenuation shall be recorded that is larger than 4 dB/m in testing with 2 MHz or larger than 10 dB/m in testing with 4 MHz.

Region	Plate thickness s in mm	Diameter of the disc shaped reflector in mm
Entire volume including weld edges, fusion faces and nozzle regions	$s \leq 40$	2
	$s > 40$	3

Table 7-1: Recording levels for straight-beam scanning

7.4.2.4 Acceptance criteria

(1) Referring to the size and frequency of indications quality class S_3 as per DIN EN 10160, Tables 3 and 4, shall be adhered to.

(2) Recordable indications in regions of weld edges, nozzles and fusion faces shall be examined with respect to a subsequent testing of the weld and be evaluated.

Planar indications up to 100 mm^2 and with maximum lengths and frequencies in accordance with **Table 7-2** are allowed. The smallest distance between indications shall not be less than 100 mm.

Plate thickness s (nominal thickness) in mm	Allowable length in mm	Maximum allowable frequency per metre
$s \leq 10$	—	0
$10 < s \leq 20$	20	2
$20 < s \leq 40$	25	2
$40 < s \leq 60$	30	2
$60 < s \leq 120$	40	2
$120 < s \leq 200$	40	4

Table 7-2: Allowable frequency and length of recordable indications in weld edge and nozzle regions

7.4.3 Surface inspection

The requirements under Sec. 5.4.3 shall apply to the surface inspection.

7.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

7.6 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) The thickness shall be checked in a grid of 500 mm by 500 mm.

7.7 Verification of quality characteristics

The results of the tests in accordance with Secs. 7.3.2.1, 7.3.2.2.2 (2) d), 7.3.2.2.2 (3) f), 7.3.2.2.3 (1) g) and 7.3.2.3 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

8 Products dished, pressed, bent or rolled from sheets and plates

8.1 Scope

(1) This section applies to hot or cold dished, pressed, bent or rolled products from quenched and tempered alloy steel in the following product forms:

a) pressed parts, dished parts,

b) bent or rolled half shells,

c) bent or rolled sections.

(2) The requirements for the materials for these product forms are specified in Sec. A 1.

8.2 Requirements

(1) The requirements under Sec. 3.2.4.2 shall be applied.

(2) The tensile strengths determined for different specimen-taking locations of the same plate on similarly positioned and oriented test coupons shall not differ from each other by more than 80 N/mm^2.

8.3 Tests and examinations

8.3.1 Specimen-taking locations and treatment of test coupons

8.3.1.1 Specimen-taking locations

(1) The test coupons shall be taken from the middle of the head and tail end of each product and, unless specified otherwise by the initial material appraisal or in the following sections. It is assumed that the direction of main forming lies in the head-to-tail direction of the ingot and that the head and tail ends of the product can be identified.

(2) In the case of the product with a length of less than 5 m and a quenched and tempered wall thickness equal to or less than 200 mm, test specimens need to be removed only from the head end.

(3) The areas from which test coupons will be removed shall have been subjected to similar loading conditions in the forming process as the corresponding areas of the product to be tested. If, for reasons of fabrication, the taking of larger test coupons becomes necessary prior to the forming process, this is permitted provided it is carried out by agreement with the authorized inspector.

(4) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness beneath the rolled surface and at least one half of the quenched and tempered wall thickness beneath the end face surfaces of the edges levelled for heat treatment.

(5) If, in the course of fabrication, penetrations are to be made additional test coupons shall be taken from the cut-outs and trepanned plugs. By agreement with the parties involved, these may be used for supplementary tests.

(6) If the test coupons are removed prior to the hot forming and cannot receive a hot forming similar to that of the product, then the respective cut-outs and trepanned plugs shall be used for additional tests to an extent which shall be specified jointly with the authorized inspector.

(7) Examples for specimen-taking locations are shown in **Figure 8-1.**

8.3.1.2 Treatment of test coupons

The test coupons for tests subsequent to the forming process shall normally be removed only after having completed the forming and tempering process of the product. If test coupons are removed before forming, then prior to the final tempering process of the product, these test specimens shall be welded onto the product. These test coupons shall be subjected to all heat treatments under consideration of heating-up and cooling-down conditions, and as far as possible, to all forming processes which the product was subjected to in the intermediate fabrication stage.

8.3.2 Extent of testing

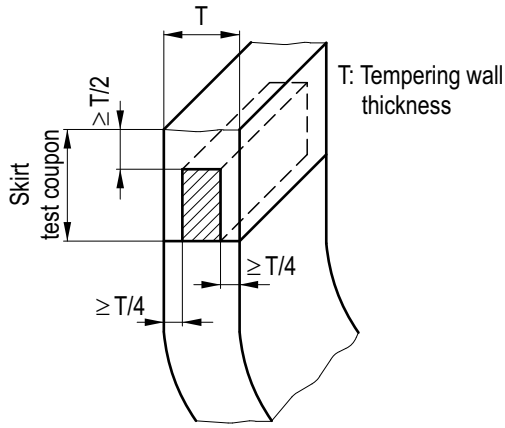
8.3.2.1 Chemical analysis

(1) Ladle analysis

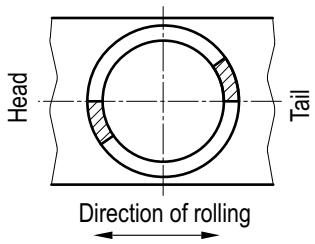
For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

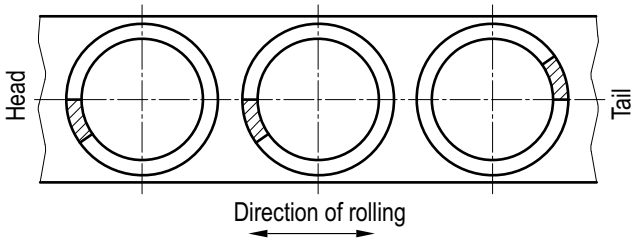
For each specimen-taking location the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.



The skirt test coupon shall be created from an additional skirt length or by welding the test coupon onto the skirt of the base plate.



Specimen taking location in the case of fabrication of only one base plate from only one rolled plate



Specimen taking location in the case of fabrication of a number of base plates from one rolled plate

Test coupon

Figure 8-1: Example for specimen-taking locations

8.3.2.2 Mechanical-technological tests and microstructure

8.3.2.2.1 General requirements

Note:

The extent of tests for demonstrating the mechanical-technological properties and assessing the microstructure depends on whether or not the product has to be quenched and tempered after the forming process. A post-forming tempering and quenching my only be omitted if

a) the original plate was quenched and tempered,

b) the temperature during forming does not exceed the maximum allowed temperature for stress relief treatment, and

c) the degree of forming does not exceed a certain limit value.

(1) The exact conditions under which post-forming, tempering and quenching may be omitted are specified in Sec. A 1.

(2) If, during fabrication of the plates, the direction of main forming is not clearly in the head-to-tail direction of the ingot, then the same number of longitudinal test specimens from the same specimen-taking location shall be tested additionally to the transverse test specimens required in the following sections.

8.3.2.2.2 Tests on products quenched and tempered after forming

(1) Test prior to forming on original plates

The original plate shall be tested in accordance with Sec. 7.3.2.2.2.

If the original plate is cut apart and the head and tail end cannot anymore be clearly correlated to the products, then the original plate shall be tested in accordance with Sec. 7.3.2.2.2 (3).

(2) Tests prior to forming on simulation quenched and tempered and stress relief heat treated test coupons

This section applies provided no tests in accordance with para (1) are performed.

a) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

b) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) for each specimen-taking location.

c) Impact test

The impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) on one set of transverse test specimens from each specimen-taking location at 0 °C.

d) Metallographic examinations

For each specimen-taking location, one impact test specimen shall be examined on a longitudinal polished section with respect to grain size; the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

(3) Test upon forming and quenching and tempering on simulation stress relieved test coupons

a) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature. In the case of components with a wall thickness exceeding 120 mm, one perpendicular test specimen from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1) at room temperature.

b) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) for each specimen-taking location.

c) Impact test

On sets of transverse test specimens taken from one specimen-taking location (tail end) the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C, 33 °C and 80 °C. The notch shall normally be perpendicular to the surface of the plate.

d) Impact energy-versus-temperature curve

On transverse test specimens from one specimen-taking location (head end) the impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4).

e) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens from one specimen-taking location (head end) that they meet the requirements regarding the NDT temperature.

f) Metallographic examinations

For each specimen-taking location, the longitudinal cross-section of one impact test specimen shall be examined with respect to grain size and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

(4) Tests on accompanying test coupons

From each test specimen-taking location, test coupons shall be taken for tests on accompanying test specimens. However, these tests need to be performed only for one specimen-taking location for each product. The remaining test coupons shall be stored in the as-removed condition.

No tests on accompanying test coupons are required, if the impact test on simulation heat treated transverse test coupons demonstrates that the smallest value of the impact energy absorbed at 0 °C is not less than 68 J. However, tests on accompanying test coupons are always required for products intended for the reactor pressure vessel.

a) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

Where both transverse and longitudinal test specimens have to be tested, the test specimens from the orientation shall be tested for which poorer results were obtained on simulation heat treated test specimens.

b) Impact test

On one set of transverse test specimens the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C (para a), second paragraph, above shall apply).

c) Impact energy-versus-temperature curve

Unless specified otherwise by the initial material appraisal, the impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4) on transverse test specimen (para a), second paragraph, above shall apply). It is sufficient to perform the test at 33 °C and 80 °C.

d) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens that they meet the requirements regarding the NDT temperature.

8.3.2.2.3 Tests of products not quenched and tempered after forming

(1) Test of the original plates

The original plate shall be tested in accordance with Sec. 7.3.2.2.3.

(2) Tests on accompanying test coupons

From each specimen-taking location, test coupons shall be taken for tests on accompanying test specimens. However, these tests need to be performed only for one specimen-taking location for each product. No tests on accompanying test coupons are required, if the impact test on simulation heat treated transverse test coupons demonstrates that the smallest value of the impact energy absorbed at 0 °C is not less than 68 J. However, tests on accompanying test coupons are always required for products intended for the reactor pressure vessel.

a) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature. In the case of components with a wall thickness exceeding 120 mm, one perpendicular test specimen from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1) at room temperature.

b) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) for each specimen-taking location.

c) Impact test

On one set of transverse test specimens the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C (para 8.3.2.2.2 (4) a), second paragraph, shall also apply).

d) Impact energy-versus-temperature curve

Unless specified otherwise by the initial material appraisal, the impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4) on transverse test specimens (para 8.3.2.2.2 (4) a), second paragraph, shall also apply). It is sufficient to perform the test at 33 °C and 80 °C.

e) Nil-ductility transition temperature

It shall be shown in accordance with clause 3.3.7.3 (5) on two longitudinal or transverse test specimens that they meet the requirements regarding the NDT temperature.

8.3.2.3 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to hardness tests.

(2) The hardness of each piece shall be tested on one outer surface along two surface lines offset by 90 degrees to each other, starting close to the edge and continuing in length intervals of not more than 1000 mm.

8.4 Non-destructive tests and inspections

(1) The following requirements apply in addition to the requirements under clause 3.3.8.

(2) The original plate shall be subjected to an ultrasonic testing in accordance with section 7.4.

(3) Each dished or pressed product form made from sheets and plates shall be subjected to a surface inspection in the finish-machined condition after the last heat treatment. The acceptance criteria are defined in **Tables 5-4** and **5-5**.

8.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

8.6 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 (2) shall apply to the check for dimensional accuracy.

(2) The wall thickness shall be checked in a grid of 500 mm by 500 mm.

8.7 Verification of quality characteristics

The results of the tests in accordance with Sec. 8.3.2.1, 8.3.2.2.2 (2) d), 8.3.2.2.2 (3) f) and 8.3.2.3 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

9 Straight pipe fittings

9.1 Scope

(1) This section applies to forged, seamless, pressure retaining straight pipe fittings with an internal diameter equal to or greater than DN 300 and a quenched and tempered wall thickness between 15 and 200 mm with forged-on nozzles.

(2) The requirements regarding the materials for these product forms are specified in Sec. A 1.

9.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

9.3 Tests and examinations

9.3.1 Specimen-taking locations

9.3.1.1 General requirements

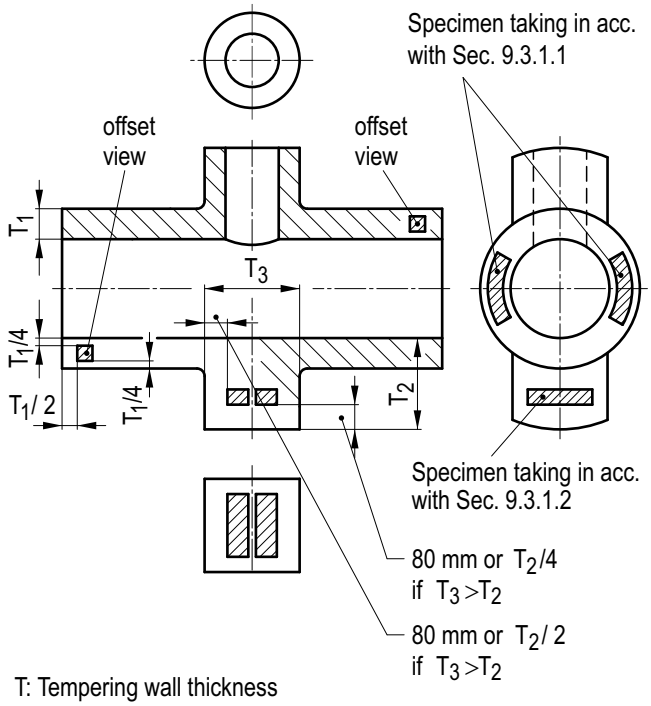
(1) All of the following requirements apply under the assumption that the direction of main forming of the pipe fittings is in the head-to-tail direction of the ingot.

(2) In the case of deviations from para (1), the requirements regarding specimen-taking shall be specified within the initial material appraisal.

(3) Fittings with a quenched and tempered length exceeding 3000 mm shall be tested on both ends. The specimen-taking locations should be offset by 180 degrees to each other.

(4) Fittings with a quenched and tempered length less than 3000 mm shall be tested on only one end, unless specified otherwise by the initial material appraisal.

(5) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness but not more than 80 mm beneath the outer surface of the fitting and at least one half of the quenched and tempered wall thickness but not more than 160 mm beneath the end face edges levelled for heat treatment (cf. **Figure 9-1**).



T: Tempering wall thickness

If $T_3 > T_2$: Specifications shall be established jointly with the authorized inspector.

Dimensions refer to the quenched and tempered condition.

Figure 9-1: Specimen-taking locations on a forged pipe fitting

9.3.1.2 Additional requirements for nozzle regions (cf. **Figure 9-1**)

Note:

This specimen-taking location is not required if the material manufacturer has demonstrated that the material characteristics determined for the pipe region are also valid in the nozzle region.

From each pipe fitting one set of test coupons shall be taken - in addition to the specimen-taking locations under Sec. 9.3.1.1 - from the nozzle with the largest nominal diameter. In the case of a quenched and tempered wall thickness in the nozzle region equal to or less than 320 mm, the specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness beneath the nozzle surface region levelled for heat treatment. In the case of a quenched and tempered wall thickness exceeding 320 mm, the specimen-taking locations shall be at a depth of at least 80 mm beneath any quenched and tempered surface. It should always be the aim to choose the depth of the specimen-taking location such that it is as close as possible to the remaining wall of the straight pipe fitting (cf. **Figure 9-1**). The specimen-taking location of the perpendicular test specimens should be as close as possible to the future weld seam bevel.

9.3.2 Extent of testing

9.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

For each pipe fitting the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

9.3.2.2 Tests on test coupons subjected to simulation heat treatment

Note:

Pipe fittings may show differing directions of main forming in the pipe region and in the nozzle region. This must be taken into account in correlating the fiber-related orientation of the test specimens with regard to the product form geometry. This correlation may change in the case of deviations in the fabrication procedure.

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at a design temperature. In addition, one perpendicular test specimen from the nozzle region shall be tested at room temperature.

Longitudinal test specimens are permitted if transverse test specimens cannot be taken from un-straightened test coupons of the pipe region.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) for one specimen-taking location in each the pipe region and the nozzle region.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C. The notch shall normally be perpendicular to the pipe surface.

Additionally, one set of transverse test specimens in the nozzle region shall be tested at 33 °C and at 80 °C.

(4) Impact energy-versus-temperature curve

For each fitting, an impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens from one specimen-taking location at the pipe end of each fitting it shall be demonstrated in accordance with Sec. 3.3.7.3 (5) that the requirements regarding NDT temperature are met.

(6) Metallographic examinations

The grain size shall be determined from longitudinal cross sections on one impact test specimen from one specimen-taking location for each fitting and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4. In addition, the grain size shall be determined from longitudinal cross sections on one impact test specimen of the nozzle region; a micrograph shall be taken for an evaluation of the microstructure in accordance with Sec. 3.3.7.4.

9.3.2.3 Tests on accompanying test coupons

(1) General requirements

From each specimen-taking location, test coupons shall be taken for tests on accompanying test coupons. The tests shall be performed for each pipe fitting, however, only for one specimen-taking location. The remaining test coupons shall be stored in the as-removed condition.

No tests on accompanying test coupons are required, if the impact test on simulation heat treated transverse test specimens demonstrates that the smallest value of the impact energy absorbed at 0 °C is equal to or greater than 68 J.

(2) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Impact test

One set of transverse test specimens shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C. The notch shall normally be perpendicular to the pipe surface.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens it shall be demonstrated in accordance with Sec. 3.3.7.3 (5), that the requirements regarding NDT temperature are met. These tests are not required for a quenched and tempered wall thickness of less than 25 mm.

9.3.2.4 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) In the case of quenched and tempered products with a length equal to or greater than 3000 mm, hardness measurements shall be performed on both end faces at mid-wall and on the circumferential surface along one surface line starting near the edge and continuing in length intervals of not more than 1000 mm.

9.4 Non-destructive tests and inspections

9.4.1 General requirements

(1) The pipe fittings for ultrasonic testing shall be separated into two test sections in accordance with **Figure 9-3.** Testing section 1 (pipe region) shall be tested in accordance with Sec. 5.4 covering also the transition region between pipe and nozzle. Test section 2 shall be tested in accordance with the following paragraphs.

(2) The following requirements apply in addition to the requirements under clause 3.3.8.

9.4.2 Ultrasonic testing

9.4.2.1 Extent and point of time of testing

(1) Test section 2 according to **Figure 9-3** shall be tested in two steps. In the first step, the forged-on collar is tested before the final heat treatment (**Figure 9-2**). In the second step, the nozzle (**Figure 9-3**) shall be tested after the final heat treatment. The second step is omitted, if the nozzle diameter is less than DN 100.

(2) For collar dimensions equal to or greater than 200 mm, sound attenuation measurements shall be performed in accordance with Section B 6.4.2 in radial direction for at least four locations distributed over the circumference.

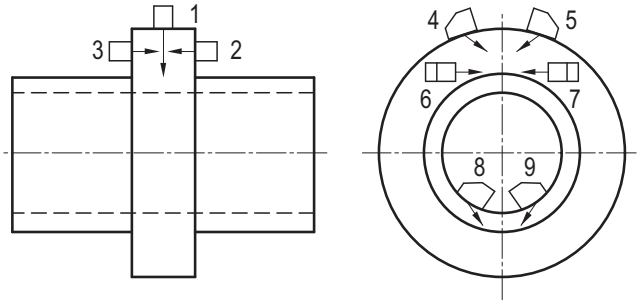
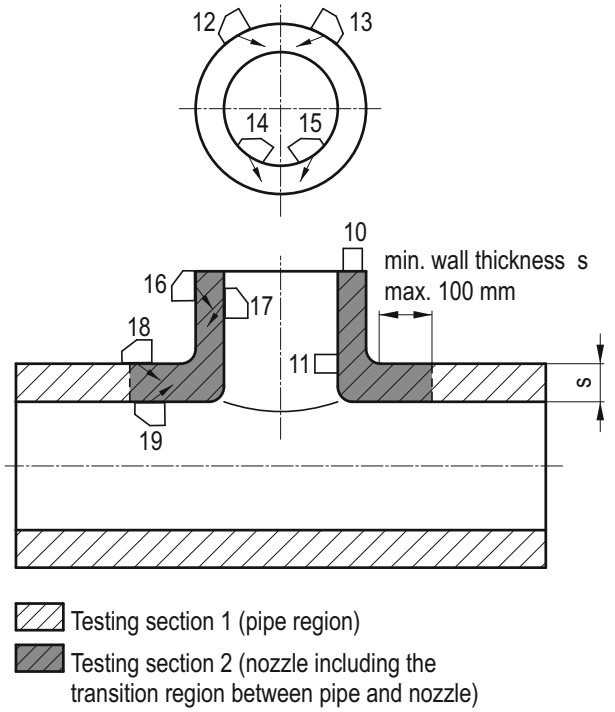


Figure 9-2: Sound entry position for the collar region in the as-forged condition



Note:
Test section 2 is comprised of the nozzle and transition region including the radius transition (to test section 1) with a width of at least the wall thickness (s), however, not to exceed 100 mm.

Figure 9-3: Test sections for ultrasonic testing and scanning positions for the nozzle region in the quenched and tempered condition

9.4.2.2 Sound beam angles

Test section according to **Figure 9-3** shall be tested using the following scanning position:

(1) As-forged condition (**Figure 9-2**)

a) straight-beam scanning
positions 1 to 3

b) angle-beam scanning
positions 4 to 7

In the case of scanning positions 4 and 5 it shall be ensured that the test covers the entire volume in the finished condition down to the inner surface of the pipe. If necessary, a supplementary test shall be performed from the inside surface of the pipe (scanning positions 8 and 9 of **Figure 9-2**). The scanning position 6 and 7 from the two end faces shall normally be used to cover the penetration region between nozzle and pipe.

(2) Quenched and tempered condition (**Figure 9-3**)

a) straight-beam scanning
positions 10 and 11
These positions may be replaced by an angle-beam scanning, e.g. by positions 16 to 19, provided it has sufficient informative value.

b) angle-beam scanning
positions 12 and 13

In the case of scanning positions 12 and 13 it shall be ensured that the test covers the entire volume in the finished condition down to the inner surface of the nozzle. If necessary, a supplementary test shall be performed from the inside surface of the nozzle (scanning positions 14 and 15 of **Figure 9-3**).

If the required scanning positions cannot be used or if their informative value is restricted, adequate replacement measures to be taken shall be specified jointly with the authorized inspector.

9.4.2.3 Recording levels

(1) The requirements under Sec. 5.4.2.3 apply.

(2) In the case of testing in accordance with Sec. 9.4.2.2 (2), the nominal wall thickness of the nozzle governs the recording level.

9.4.2.4 Acceptance criteria

The requirements under Sec. 5.4.2.4 apply.

9.4.3 Surface inspection

The requirements under Sec. 5.4.3 apply.

9.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

9.6 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) In case of wall thickness measurement by ultrasonics, Sec. 16.3.3.3 shall be taken into account.

9.7 Verification of quality characteristics

The results of the tests in accordance with Secs. 9.3.2.1, 9.3.2.2 (6) and 9.3.2.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

10 Seamless, forged hollow bodies for primary coolant pump casings

10.1 Scope

The requirements for the materials of these product forms are specified in Sec. A 1.

10.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

10.3 Tests and examinations

The following requirements apply to

a) casings with strongly varying contour and wall thickness on both ends of the individual casing (suction nozzles and discharge flange) and

b) forging procedures where the axis of the forging coincides with the axis of the ingot. If these axes do not coincide, the specimen-taking locations shall be specified in the initial material appraisal and such that, as far as feasible, both the head and tail end of the ingot are covered.

10.3.1 Specimen-taking locations

10.3.1.1 General requirements

(1) Each quenched and tempered forging shall be tested on both ends.

(2) The major test shall be performed on the end of the discharge flange. The suction nozzle end shall additionally be tested on two specimen-taking locations offset by 180 degrees to each other, this test serving both to demonstrate the material characteristics with regard to the pipe connection forces and to demonstrate the material uniformity. In addition, Sec. 3.3.6 shall be taken into account.

10.3.1.2 Number of specimen-taking locations

(1) In the case of products with an internal quenched and tempered diameter exceeding 2000 mm or an outer quenched and tempered diameter exceeding 3000 mm, the test specimens shall be taken from the end faces at three locations offset by 120 degrees from each other.

(2) In the case of products with an inner quenched and tempered diameter equal to or less than 2000 mm or an outer quenched and tempered diameter equal to or less than 3000 mm, the test specimens shall be taken from the end faces at two locations offset by 180 degrees to each other.

(3) The specimen-taking locations on the suction nozzle end shall be offset with regard to the specimen-taking location on the discharge flange end.

10.3.1.3 Specimen-taking depth

(1) On the discharge flange end, the specimen-taking locations shall be at least 80 mm beneath each quenched and tempered surface.

(2) On the suction nozzle end, the specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness but not more than 80 mm beneath the outer pipe surface and at least one half of the quenched and tempered wall thickness but not more than 160 mm beneath the end face edges levelled for heat treatment.

(3) Thermal buffering may be applied.

10.3.2 Extent of testing

10.3.2.1 Chemical analysis

10.3.2.1.1 Ladle analysis

For each product fabricated from one melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined. In the case of products fabricated from more than one melt, the calculated average chemical composition shall be indicated.

10.3.2.1.2 Product analysis

(1) For each product (piece) the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined for one specimen-taking location each at the head and the tail end.

(2) Additional product analysis, e.g. of the shell surface of the products may be specified in the initial material appraisal.

(3) For each of the other specimen-taking locations in accordance with Sec. 10.3.1 the content of carbon, manganese, phosphorus, and sulphur shall be determined.

10.3.2.2 Tests on test coupons subjected to simulation heat treatment

10.3.2.2.1 Major test on the discharge flange end

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

In addition, one perpendicular test specimen from one specimen-taking location shall be tested at room temperature.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C, 33 °C and 80 °C. In addition, one set each of longitudinal and perpendicular test specimens from one specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location. Results from tests in accordance with para (3) may be used.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens from one specimen-taking location it shall be demonstrated in accordance with Sec. 3.3.7.3 (5), that the requirements regarding the NDT temperature are met.

(6) Metallographic examinations

The grain size shall be determined from longitudinal cross sections on one impact test specimen from each specimen-taking location; in each case, the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

10.3.2.2.2 Tests on the suction nozzle end

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with

Sec. 3.3.7.3 (1), one at room temperature and one at design temperature. In addition, one perpendicular test specimen from one specimen-taking location shall be tested at room temperature.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 33 °C.

(4) Metallographic examinations

The grain size shall be determined from longitudinal cross sections on one impact test specimen from each specimen-taking location; in each case, the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

10.3.2.3 Tests on accompanying test coupons

From each specimen-taking location, test coupons shall be taken for tests on accompanying test coupons. The tests shall be performed for each product, however, only for one specimen-taking location. The remaining test coupons shall be stored in the as-removed condition.

(1) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

One set of transverse test specimens shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C.

(3) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens. It will suffice to perform the test at 33 °C and 80 °C.

(4) Nil-ductility transition temperature

On two longitudinal or transverse test specimens it shall be demonstrated in accordance with Sec. 3.3.7.3 (5), that the requirements regarding the NDT temperature are met.

10.3.2.4 Sulphur prints on the product

Sulphur prints that serve as information for the weld cladding manufacturer shall be taken at those locations specified by agreement with the authorized inspector.

10.3.2.5 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) The hardness tests shall include the discharge flanges and both inlet nozzles and shall be performed on the outer surface along one surface line beginning near the edge and continuing in length intervals of not more than 1000 mm.

10.4 Non-destructive tests and inspections

(1) The requirements under Sec. 3.3.8 and 5.4 shall apply.

(2) On account of the geometrical deviations with respect to the product forms under Sec. 5, the additional requirements under para (3) apply.

(3) When preparing the test instructions, the following points shall be taken into account:

a) A true-to-scale sketch shall be prepared of the test object in its test conditions, i.e. with scanning its sketch contour created by machining procedures. This sketch shall contain the positions for the straight-beam and angle-beam scanning and shall identify the test surfaces.
b) In the non-cylindrical sections angle-beam scanning from four directions offset by 90 degrees to each other and one straight-beam scanning shall be performed. As far as geometrically possible, the orientation of the scanning directions for the angle-beam scanning shall be specified with respect to the axes of the cylindrical regions.
c) The measuring points for the required sound attenuation measurements shall be specified. Deviating from Sec. 5.4.2.1, the sound attenuation measurements shall be performed for one scanning position per square meter of the outer surface, however, for at least three locations of the test object.

10.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

10.6 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

10.7 Verification of quality characteristics

The results of the tests in accordance with Sec. 10.3.2.1, 10.3.2.2.1 (6), 10.3.2.2.2 (4), 10.3.2.4, and 10.3.2.5 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

11 Forged valve bodies

11.1 Scope

(1) This section applies to open-die forged or drop-forged valve bodies made from quenched and tempered steel.

(2) The requirements for the materials of these product forms are specified in Sec. A 1.

11.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

11.3 Tests and examinations

11.3.1 Specimen-taking locations

11.3.1.1 Location of the test coupons

(1) Valve bodies equal to or less than DN 450

The test coupons shall be taken from one location on one end face of each quenched and tempered product form which, if practicable, shall include the head or tail end of the ingot.

In the case of product forms with a finished length exceeding 1500 mm, test coupons shall additionally be removed from the opposite end face at a location offset by 180 degrees to demonstrate the material uniformity.

Note:
Finished length means fabrication length minus length of the test coupon. The fabrication length is the length of the product as it is quenched and tempered.

(2) Valve bodies exceeding DN 450

The test coupons shall be taken from two locations offset by 180 degrees to each other on one end face of each quenched

and tempered product form which, if practicable, shall include the head or tail end of the ingot.

In the case of product forms with a finished length exceeding 1500 mm, test coupons shall additionally be removed from the opposite end face to demonstrate material uniformity.

(3) If the test specimens for the required tests can neither be removed at all nor in the required number due to the dimensions of the product form, e.g. in the case of drop-forged pieces, the extent of testing shall be specified in due consideration of the authorized inspectors appraisal. These cases may lead to a lot-wise testing where the test coupons are removed from one completely sectioned forging.

11.3.1.2 Specimen-taking depth

The specimen-taking location shall be at a depth of at least one quarter of the quenched and tempered wall thickness but not more than 80 mm beneath the cylindrical surface and at least one half of the quenched and tempered wall thickness but not more than 160 mm beneath the end face edges levelled for heat treatment. Thermal buffering may be applied.

11.3.2 Extent of testing

11.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

For each product (piece) the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined for one specimen-taking location at one end face. For the other end face, the content of carbon, manganese, phosphorus, and sulphur shall be determined.

11.3.2.2 Tests on test coupons subjected to simulation heat treatment

11.3.2.2.1 Major test

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature. In addition, one perpendicular test specimen from one specimen-taking location shall be tested in accordance with Sec. 3.3.7.3 (1) at room temperature, if a standard tensile specimen can be taken.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location of one end face shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C and 33 °C.

In the case of valve bodies exceeding DN 450, additionally one set of longitudinal and perpendicular test specimen from one specimen-taking location shall be subjected to an impact test at 0 °C.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens from one specimen-taking location it shall be demonstrated in accordance with Sec. 3.3.7.3 (5), that the requirements regarding the NDT temperature are met.

(6) Metallographic examinations

The grain size shall be determined from a longitudinal cross section of one impact test specimen from one specimen-taking location and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

11.3.2.2.2 Uniformity test on pieces with a finished length exceeding 1500 mm

(1) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

One set of transverse test specimens shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C and 33 °C.

(3) Metallographic examinations

The grain size shall be determined from a longitudinal cross section of one impact test specimen and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

11.3.2.3 Hardness test

(1) The requirements in accordance with Sec. 3.3.7.2 apply to hardness tests.

(2) In the case of product forms with a length equal to or greater than 2000 mm the hardness tests shall be performed at mid-wall on the head and tail end faces and on the outer surface, covering all nozzles, along one surface line beginning near the edge and continuing in length intervals of not more than 1000 mm.

11.4 Non-destructive tests and inspections

11.4.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8.

11.4.2 Ultrasonic testing

11.4.2.1 Extent and point of time of testing

11.4.2.1.1 Open-die forgings

(1) Ultrasonic testing generally comprises the testing prior to tempering in accordance with Sec. 11.4.2.2.1 and an additional post-tempering testing in accordance with Sec. 11.4.2.2.3. The tests shall normally be performed at an as simple as possible geometry.

(2) A pre-tempering ultrasonic testing may be omitted in those cases where a post-tempering ultrasonic testing is performed with the scanning positions in accordance with Sec. 11.4.2.2.1.

Note:

With regard to the acceptance test at the product form manufacturer`s works when the product form is still in its raw or unfinished condition, it is necessary that the drawings or the data regarding the nominal thickness are available to the manufacturer of the product forms so that the test criteria relating to the final dimensions can be satisfied.

11.4.2.1.2 Drop forgings

In the case of drop forgings, the ultrasonic testing shall be performed on the initial material prior to drop forging and in accordance with Sec. 11.4.2.2.2. In the case of drop forgings exceeding DN 100 and if the geometry allows, an additional post-tempering ultrasonic testing in accordance with Sec. 11.4.2.2.3 shall be performed with the product in a condition having an as simple as possible geometry.

11.4.2.1.3 Sound attenuation measurements

In the case of a wall thickness equal to or greater than 200 mm, sound attenuation measurements shall be performed in accordance with Section B 6.4.2 at one location per square meter of their outside surface, however, at not less than three locations per product form.

11.4.2.2 Sound beam angles

11.4.2.2.1 Open-die forgings

If geometrically possible, the entire volume shall be examined with the straight-beam scanning from three scanning directions perpendicular to each other. If this is impossible on account of the geometric shape of the product form, then for each missing straight-beam scanning two angle beam scannings from opposite directions shall be performed. In this case, the beam angle of the angle-beam scanning shall be parallel to the main beam of the missing straight-beam scanning.

11.4.2.2.2 Initial material for drop forging

The entire volume shall be tested from the shell surface by straight-beam scanning.

11.4.2.2.3 Additional post-tempering testing

(1) The additional post-tempering testing in accordance with Sec. 11.4.2.1.1 or 11.4.2.1.2 shall consist of a straight-beam scanning from all outer surfaces where the radius of curvature is larger than 30 mm.

(2) The cylindrical regions of open-die forgings shall be subjected to an angle-beam scanning in both circumferential directions instead of the straight-beam scanning.

11.4.2.3 Recording levels for forgings

(1) The requirements under Sec. 5.4.2.3 apply.

(2) The decisive factor for the recording level is the nominal wall thickness.

(3) In the case of initial material for drop forging, the recording level shall correspond to the acceptance criterion under Sec. 11.4.2.4.2.

11.4.2.4 Acceptance criteria

11.4.2.4.1 Forgings

(1) The distance between the final surface and locations from which recordable echoes are obtained shall not be less than the values shown in **Table 5-2**.

(2) In the case of straight-beam scanning, point-type indications with echo heights equal to or less than 12 dB above the recording level are permitted in all volumetric regions. Longitudinally extended indications with lengths below the values shown in curve 2 of **Figure 5-2** are permitted if during angle-beam scanning at these locations no echo heights equal to or greater than 6 dB above the recording level are obtained. Here, the greatest permissible reflector length in circumferential direction is limited to 60 mm. Indications with a length exceeding 10 mm in thickness direction are not permitted.

(3) In the weld edge and fusion face areas the requirements of Sec. 5.4.2.4.1 (2) respectively 5.4.2.4.2 (1) apply.

(4) For the other volumetric regions the frequency of indications referred to the outer surface of the test object shall not exceed 10 per square meter and with respect to the entire surface area 5 per square meter.

11.4.2.4.2 Initial material for drop forging

All indications are acceptable that, in the case of diameters, widths across flats or side lengths equal to or less than 60 mm, do not exceed the values from a disc shaped reflector of 2 mm and, in the case of larger dimensions, from a disc shaped reflector of 3 mm.

11.4.3 Surface inspection

The requirements under Sec. 5.4.3 apply.

11.5 Materials identification check

If the forgings are tested in lots (cf. Sec. 11.3.1.1 (3)), each piece shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

11.6 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

11.7 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 apply to the visual inspection.

11.8 Verification of quality characteristics

The results of the tests in accordance with Sec. 11.3.2.1, 11.3.2.2.1 (6), 11.3.2.2.2 (3) and 11.3.2.3 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

12 Forged plates

12.1 Scope

(1) This section applies to forged plates for closures, blind flanges and similar parts.

Note:
Regarding forged plates for tubesheets, cf. Sec. 6.

(2) The requirements for the materials of these product forms are specified in Sec. A 1.

12.2 Requirements

The requirements under Sec. 3.2.4.2 shall apply.

12.3 Tests and examinations

12.3.1 Specimen-taking locations

(1) In the case of a quenched and tempered weight equal to or greater than 500 kg, each quenched and tempered piece shall be tested at one specimen-taking location from the head

end. In the case of lengths exceeding 3000 mm one test each shall be performed on the head and the tail end.

(2) In the case of a quenched and tempered weight less than 500 kg, lot-wise testing shall be performed. The pieces shall be sorted into lots with a lot size of not more than 5 tons. For each dimension, melt and heat treatment lot, the hardest and the softest piece shall be tested.

(3) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness but not more than 80 mm beneath the plate surface and at least one half of the quenched and tempered wall thickness but not more than 160 mm beneath the end face edges levelled for heat treatment.

(4) Thermal buffering may be applied.

12.3.2 Extent of testing

12.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

For each specimen-taking location the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined

12.3.2.2 Tests on test coupons subjected to simulation heat treatment

(1) General

Where no welding or cladding work is performed on the product, the tests may be performed without prior simulation heat treatment.

(2) Tensile test

Two transverse test specimen from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(4) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C.

(5) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location for each piece to be tested.

(6) Nil-ductility transition temperature

On two longitudinal or transverse test specimens from one specimen-taking location it shall be demonstrated in accordance with Sec. 3.3.7.3 (5), that the requirements regarding the NDT temperature are met.

(7) Metallographic examinations

The grain size shall be determined from a longitudinal cross section of one impact test specimen from each specimen-taking location and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

12.3.2.3 Tests on accompanying test coupons

(1) General requirements

From each specimen-taking location, test coupons shall be taken for tests on accompanying test coupons. However, these tests need to be performed only for one specimen-taking location for each product. The remaining test coupons shall be stored in the as-removed condition.

The tests on accompanying test coupons may be dispensed with if no connection welds will be performed on the piece.

No tests on accompanying test specimens are required, if the impact test on simulation heat treated transverse test specimens demonstrates that the smallest value of the impact energy absorbed at 0 °C is not less than 68 J.

(2) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Impact test

The impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) on one set of transverse test specimens at 0 °C.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens. It will suffice to perform the test at 33 °C and 80 °C.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens it shall be demonstrated in accordance with Sec. 3.3.7.3 (5) that the requirements regarding the NDT temperature are met.

12.3.2.4 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) In the case of quenched and tempered pieces with a length exceeding 3000 mm the hardness tests shall be performed at mid-wall on the head and tail end faces and on the outer surface along one surface line beginning near the edge and continuing in length intervals of not more than 1000 mm.

12.4 Non-destructive tests and inspections

12.4.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8.

12.4.2 Ultrasonic testing

12.4.2.1 Sound attenuation measurements

In the case of wall thicknesses equal to or greater than 200 mm, sound attenuation measurements shall be performed in accordance with Section B 6.4.2 on a grid of 2 m x 2 m, however, at least at 4 locations of each test object. If, during straight-beam scanning, no significant local deviations (range equal to or smaller than 6 dB) are found, the number of measuring points for angle-beam scanning may be halved.

12.4.2.2 Sound beam angles

(1) The plates shall be tested from one major surface by means of straight and angle-beam scanning (scanning directions 1 to 5 in accordance with **Figure 12-1**). A test from the opposite surface shall also be performed, if necessary to obtain the required testing level.

(2) In the case of machined covers and blind flanges straight beam scanning shall be additionally performed from the lateral surface (scanning direction 6 in accordance with **Figure 12-2**) in the case of nominal wall thickness equal to or greater than 100 mm.

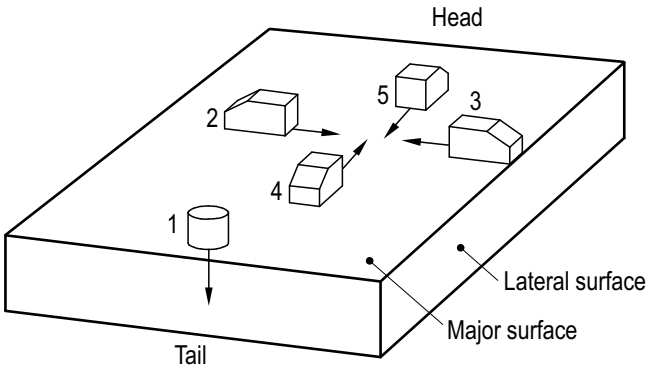


Figure 12-1: Sound entry directions 1 to 5 for the ultrasonic testing of forged plates

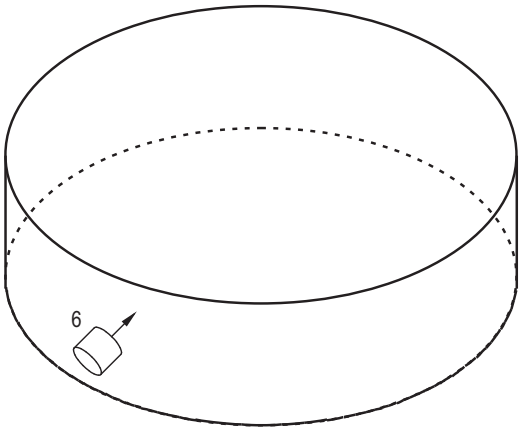


Figure 12-2: Sound entry direction 6 for the ultrasonic testing

12.4.2.3 Recording levels

The requirements under Sec. 5.4.2.3 apply.

12.4.2.4 Acceptance criteria

12.4.2.4.1 General requirements

The requirements under Sec. 5.4.2.4.1 apply.

12.4.2.4.2 Additional requirements

(1) In the straight-beam scanning from the major surface any point-type indications with an echo amplitude up to 18 dB above the recording level specified in **Table 5-1** are acceptable. Depending on the maximum echo amplitude, laminar longitudinal indications with a length dimension below the values of curve 1 in **Figure 5-2** are acceptable provided the angle-beam scanning of these locations does not lead to an echo amplitude of 6 dB above the recording level. The largest acceptable reflector length is limited to 120 mm.

Reflections with a longitudinal extension over 10 mm in thickness direction are not permitted.

(2) The frequency of indications relative to a major surface area shall locally not be larger than one per square meter.

(3) In the case of straight-beam scanning from the lateral surface point-type indications which are up to 12 dB above the recording limit are permitted. Extended indications shall be thoroughly examined for their orientation. Indications with a longitudinal extension above 10 mm in thickness direction are not permitted.

12.4.3 Surface inspection

The requirements under Sec. 5.4.3 apply.

12.5 Materials identification check

In the case of lot-wise testing each piece made of alloyed steels shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

12.6 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

12.7 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

12.8 Verification of quality characteristics

The results of the tests in accordance with Sec. 12.3.2.1, 12.3.2.2 (7) and 12.3.2.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

13 Hot dished or pressed products from forged plates

13.1 Scope

This section applies to hot dished or pressed products from forged plates, e.g. the spherical section of the reactor pressure vessel, steam generator, pressurizer.

The requirements for the materials of these product forms are specified in Sec. A 1.

13.2 Requirements

The requirements under Sec. 3.2.4.2 shall be applied.

13.3 Tests and examinations

13.3.1 General requirements

(1) The following requirements apply under the assumption that the direction of main forming of the initial plate lies in the head-to-tail direction of the ingot and that it is possible to identify the head and tail ends of the plate.

(2) If this assumption does not apply in part or as a whole, possibly deviating requirements regarding specimen-taking locations and orientations of the test specimens shall be specified in the initial material appraisal.

13.3.2 Specimen-taking locations

(1) The test coupons shall be taken from each product in the middle of the head and the tail end unless specified otherwise by the initial material appraisal (cf. Sec. 13.3.1).

(2) The areas from which test coupons shall be taken should have been subjected to similar loading conditions in the forming process as the corresponding areas of the product to be tested. If, for reasons of fabrication, the taking of larger test coupons

becomes necessary prior to dishing the plate, this is allowed provided this procedure is carried out by agreement with the authorized inspector. These test coupons shall be subjected to the same forming procedures as the dished product and shall be welded onto the latter prior to quenching and tempering.

(3) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness but not more than 80 mm beneath the plate surface and at least one half of the quenched and tempered wall thickness but not more than 160 mm beneath the end face edges levelled for heat treatment.

(4) Thermal buffering may be applied.

13.3.3 Extent of testing

13.3.3.1 Chemical analysis

(1) Ladle analysis

In the case of products from a single melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined. In the case of products from more than one melt the calculated average chemical composition shall be indicated.

(2) Product analysis

For each specimen-taking location the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

13.3.3.2 Tests on test coupons subjected to simulation heat treatment

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

One perpendicular test specimen from one specimen-taking location shall be subjected to a tensile test at room temperature in accordance with Sec. 3.3.7.3 (1).

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C, 33 °C and 80 °C. The notch shall normally be perpendicular to the spherical surface.

(4) Impact energy-versus-temperature curve

An impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens from one specimen-taking location it shall be demonstrated in accordance with Sec. 3.3.7.3 (5) that the requirements regarding the NDT temperature are met.

(6) Metallographic examinations

The grain size shall be determined from a longitudinal cross section of one impact test specimen from each specimen-taking location and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

13.3.3.3 Tests on accompanying test coupons

(1) General requirements

From each specimen-taking location, test coupons shall be taken for tests on accompanying test coupons. However, these tests need to be performed only for one specimen-taking location for each product. The remaining test coupons shall be stored in the as-removed condition.

No tests on accompanying test coupons are required, if the impact test on simulation heat treated transverse test specimens demonstrates that the smallest value of the impact energy absorbed at 0 °C is not less than 68 J. In the case of products for the reactor pressure vessel the tests on accompanying test coupons shall not be waived.

(2) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Impact test

On one set of transverse test specimens the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C.

(4) Impact energy-versus-temperature curve

The impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4) on transverse test specimens. It will suffice to perform the test at 33 °C and 80 °C.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens it shall be demonstrated in accordance with Sec. 3.3.7.3 (5) that the requirements regarding the NDT temperature are met.

13.3.3.4 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) The hardness test shall be performed on each piece on one outer surface along two surface lines offset by 90 degrees to each other, beginning near the edge and continuing in length intervals of not more than 1000 mm.

13.4 Non-destructive tests and inspections

13.4.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8.

13.4.2 Ultrasonic testing

13.4.2.1 Sound attenuation measurements

In the case of a wall thickness equal to or greater than 200 mm sound attenuation measurements shall be performed in accordance with Section B 6.4.2 in a grid of 2 m x 2 m, however, from not less than four locations per test object. If, during straight-beam scanning, no significant local deviations (range equal to or smaller than 6 dB) are found, the number of measuring points for angle-beam scanning may be halved.

13.4.2.2 Sound beam angles

(1) From one major surface, one straight-beam scanning and four angle-beam scanning with scanning directions offset by 90 degrees to each other shall be performed.

(2) In the case of cylindrical product forms, the angle-beam scanning shall be performed in the axial and circumferential directions and, in the case of spherical product forms, in the meridional and longitudinal directions.

(3) A test from the opposite surface shall also be performed, if necessary to obtain the required testing level.

13.4.2.3 Recording levels

The requirements under Sec. 5.4.2.3 apply.

13.4.2.4 Acceptance criteria

13.4.2.4.1 General requirements

The requirements under Sec. 5.4.2.4.1 apply.

13.4.2.4.2 Additional requirements

(1) Regions of weld edges and nozzles

The requirements under Sec. 5.4.2.4.2 (1) apply.

(2) Other volumetric regions

Point-type indications found in the straight-beam scanning in the thickness direction are allowable if their echo amplitudes are up to 18 dB above the recording level in accordance with **Table 5-1**. Depending on the maximum echo amplitude, indications with a longitudinal dimension in accordance with curve 1 of **Figure 5-2** are acceptable provided the amplitudes of the corresponding angle-beam echoes for these locations are less than 6 dB above the registration level. However, the maximum acceptable reflector length is 120 mm. Reflections with a longitudinal extension over 10 mm in thickness direction are not permitted.

With respect to the external surface area, the frequency of indications shall locally be not higher than 10 per square meter and, with respect to the entire surface area, not higher than 5 per square meter.

13.4.3 Surface inspection

The requirements under Sec. 5.4.3 apply.

13.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

13.6 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

13.7 Verification of quality characteristics

The results of the tests in accordance with Sec. 13.3.3.1, 13.3.3.2 (6) and 13.3.3.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

14 Forged or rolled bars

14.1 Scope

(1) This section applies to forged or rolled bars from quenched and tempered alloy steel with a maximum outer finished diameter of about 220 mm or a comparable cross-section that are used as starting material for pressure-retaining components, e.g. for the fabrication of nozzles and pipes.

(2) The requirements for the materials of these product forms are specified in Sec. A 1.

14.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

14.3 Tests and examinations

14.3.1 Specimen-taking locations

(1) A quenched and tempered product with a finished length equal to or less than 1500 mm shall be tested from one end face, and with a finished length exceeding 1500 mm from both end faces. The number of pieces fabricated from this product is not taken into account.

Note:
Finished length means fabrication length minus length of the test coupon. The fabrication length is the length of the product as it is quenched and tempered.

(2) In the case of step-forged bars, the test coupons shall be taken at that cross-section that governs the heat treatment.

(3) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered diameter, or as close as possible to this depth, and at least one half of the quenched and tempered diameter beneath the end face edges levelled for heat treatment. Thermal buffering may be applied.

(4) If transverse test specimens cannot be taken from unstraightened test coupons as required below, longitudinal test specimens may be tested.

14.3.2 Extent of testing

14.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

On each product form (piece) the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined for one specimen-taking location at one end face, specifically the head end. The contents of carbon, manganese, phosphorus, and sulphur shall be determined at the opposite end face.

14.3.2.2 Tests on test coupons subjected to simulation heat treatment

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C and 33 °C.

(3) Impact energy-versus-temperature curve

In the case of bars in the finished condition with a diameter equal to or greater than 160 mm, an impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location. Results from tests in accordance with para (2) may be used.

(4) Nil-ductility transition temperature

In the case of bars with a diameter equal to or greater than 120 mm, it shall be demonstrated on two longitudinal or transverse test specimens from one specimen-taking location in accordance with Sec. 3.3.7.3 (5) that the requirements regarding the NDT temperature are met.

(5) Metallographic examinations

The grain size shall be determined from a longitudinal cross section of one impact test specimen from each specimen-taking

location and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

14.3.2.3 Tests on accompanying test coupons

(1) General requirements

From each specimen-taking location, test coupons shall be taken for tests on accompanying test coupons. However, these tests need to be performed only for one specimen-taking location for each product. The remaining test coupons shall be stored in the as-removed condition.

If more than one piece are fabricated from one bar which are intended for different components and are subjected to separate stress relief heat treatments then one set of accompanying test coupons shall be provided for each of these components.

No tests on accompanying test coupons are required, if the impact toughness test on simulation heat treated transverse test specimens demonstrates that the smallest value of the impact energy absorbed at 0 °C is not less than 68 J. In the case of products for the reactor pressure vessel the tests on accompanying test coupons may not be dispensed with.

(2) Tensile test

Two transverse test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(3) Impact test

On one set of transverse test specimens the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3), one at 0 °C and 33 °C.

(4) Nil-ductility transition temperature

On two longitudinal or transverse test specimens it shall be demonstrated in accordance with Sec. 3.3.7.3 (5) that the requirements regarding the NDT temperature are met.

14.3.2.4 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) In the case of bars with a length equal to or greater than 3000 mm the hardness test shall be performed on both end faces and on the outer surface along one surface line beginning near the edge and continuing in length intervals of not more than 1000 mm.

14.4 Non-destructive tests and inspections

Note:

The requirements specified for the non-destructive tests and inspections also apply to the product forms under Sec. 20 and 21. Therefore, hexagonal and quadratic bars are also dealt with in this section.

14.4.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8, however the requirements under Sec. 3.3.8.3.1 (5) cb) and 3.3.8.3.1 (6) d) do not apply.

14.4.2 Ultrasonic testing

14.4.2.1 General

(1) The bars shall either be subjected to global ultrasonic testing as per (2) or to selected ultrasonic testing as per (3).

Whether global or selected ultrasonic testing is to be performed shall be agreed between purchaser and manufacturer and be laid down in the design review documents.

The type of testing shall be indicated in the test report as “global UT” or “selected UT”.

(2) For global ultrasonic testing no detailed knowledge on the components to be fabricated from the test objects is required. In such tests, indications that do reach or exceed the recording level are not permitted. In the case of later use of a bar subjected to global UT it shall be ensured that the final product meets the requirements of selected ultrasonic testing. Where required, additional selected tests are necessary.

(3) For selected ultrasonic testing it is required that the shape and the final dimensions of the components to be fabricated from the bar as well as their locations in the bar are known. To be able to correctly use the recording levels and evaluation criteria referring to the nominal wall thickness, shape and location it is required that, at the time of testing, drawings of the components to be fabricated from the bar are available to show these data. These drawings shall be made available by the purchaser.

14.4.2.2 Sound beam angles

(1) In the case of a diameter or a width across flats or a side width of more than 30 mm up to including 60 mm, straight-beam scanning shall be performed in radial direction.

(2) In the case of a diameter or a width across flats or a side width of more than 60 mm, straight-beam scanning shall be performed each in radial direction and axial direction. Where, during the straight-beam scanning in axial direction the distance of at least 6 dB between the recording level and noise level cannot be maintained over the entire length of the bar, the bar shall be tested in the cut-to-length condition or by means of a 45 degrees angle-beam scanning in both axial directions.

(3) In the case of a diameter or a width across flats or a side width exceeding 120 mm, in addition to (2) an angle-beam scanning shall be performed in both circumferential directions.

(4) The beam angle for the angle-beam scanning in circumferential direction shall normally be 35 degrees.

14.4.2.3 Recording levels

(1) In the case of global ultrasonic testing as per Sec. 14.4.2.1 (2) the recording levels shall be set equal to the acceptance criteria as per Sec. 14.4.2.4.

(2) In the case of selected ultrasonic testing as per Sec. 14.4.2.1 (3) the recording levels listed in **Table 5-1** apply.

14.4.2.4 Acceptance criteria

(1) In the case of global ultrasonic testing as per Sec. 14.4.2.1 (2) the acceptance criteria shall be laid down by the purchaser with respect to the later utilization of the bar.

(2) In the case of selected ultrasonic testing as per Sec. 14.4.2.1 (3) the recording levels as per Section 5.4.2.4 apply.

14.4.3 Surface inspection

The requirements under Sec. 5.4.3 apply.

14.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

14.6 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

14.7 Verification of quality characteristics

The results of the tests in accordance with Secs. 14.3.2.1, 14.3.2.2 (5) and 14.3.2.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all

the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

15 Hollow-bored or hollow-forged parts made of forged or rolled bars

(1) This section applies to pressure-retaining parts, e.g. nozzles and pipes, made of forged or rolled bars and hollow-bored or hollow-forged prior to tempering.

(2) The requirements under Sec. 5 apply accordingly in which case the word “nozzles” shall be replaced by “nozzles and pipes”.

(3) The non-destructive tests and inspections shall basically be performed in accordance with Sec. 5.4. However, if it is known at the point of time of testing that the bars will be used for pipes, then the requirements under Sec. 16.4 shall apply.

(4) The requirements regarding materials for these product forms are specified in Sec. A 1.

16 Seamless pipes

16.1 Scope

(1) This section applies to seamless, rolled, pressed or forged pipes with a quenched and tempered wall thickness between 15 and 200 mm.

(2) The requirements regarding materials for these product forms are specified in Sec. A 1.

16.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

16.3 Tests and examinations

16.3.1 General requirements

(1) The following requirements apply under the assumption that the direction of main forming of the pipe lies in the head-to-tail direction of the ingot. If, in the case of forged pipes, this assumption does not apply, possibly supplementary requirements regarding specimen-taking shall be specified in the initial material appraisal.

(2) The mechanical-technological material characteristics shall be demonstrated on simulation heat treated test coupons (cf. Sec. 16.3.3.2). Notwithstanding this requirement it may be agreed, in the case of pipes from which seamless pipe elbows are fabricated, to perform the tests in the quenched and tempered condition.

16.3.2 Specimen-taking locations

(1) Pipes with a quenched and tempered length exceeding 3000 mm shall be tested both at the head and tail end. The specimen-taking location shall be offset by 180 degrees to each other.

(2) Pipes with a quenched and tempered length equal to or less than 3000 mm shall be tested from only one end face in which case the specimen-taking location with respect to the ingot shall be specified in the initial material appraisal.

(3) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness beneath the surface and at least one half of the quenched and tempered wall thickness beneath the end face edges levelled for heat treatment.

16.3.3 Extent of testing

16.3.3.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

For each pipe the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

16.3.3.2 Tests on test coupons subjected to simulation heat treatment

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), on at room temperature and one at design temperature. If transverse test specimens cannot be taken from un-straightened test coupons, the test may be performed on longitudinal test specimens.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C. The notch shall normally be perpendicular to the pipe surface.

(4) Impact energy-versus-temperature curve

For each pipe an impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens for one specimen-taking location from each pipe, it shall be demonstrated in accordance with Sec. 3.3.7.3 (5) that the requirements regarding the NDT temperature are met. If this cannot be demonstrated, then the NDT temperature shall be determined for each specimen-taking location. This test is not required for a quenched and tempered wall thickness of less than 25 mm.

(6) Metallographic examinations

For each pipe, the grain size shall be determined from a longitudinal cross section of one impact test specimen from one specimen-taking location and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

16.3.3.3 Measurement of the wall thickness

(1) In the case of pipes with a diameter equal to or smaller than 100 mm an ultrasonic measurement of the wall thickness is required only, if the excess wall thickness is less than 20 % of the design wall thickness. In this case, ultrasonic wall thickness measurement shall be specified as special requirement in the order of the customer.

(2) The wall thickness shall be measured by straight-beam scanning from the outside surface. Measurements shall be taken along three surface lines offset by 120 degrees to each other with the distance between measurement points being equal to or smaller than 1 000 mm.

(3) The accuracy of the equipment shall ensure that deviations of 1 % of the wall thickness or, in the case of a wall thickness smaller than 20 mm, a deviation of 0.2 mm can be ascertained.

16.3.3.4 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) In the case of pipes with a length equal to or greater than 4000 mm, the hardness test shall be performed in mid-wall on each end face and on the outer surface along one surface line, beginning near the pipe ends and continuing in length intervals of not more than 1000 mm.

16.4 Non-destructive tests and inspections

16.4.1 General requirements

(1) The requirements under Sec. 16.4.2 and 16.4.3 shall apply to the testing of rolled and pressed pipes with a nominal wall thickness equal to or less than 30 mm. Rolled and pressed pipes with a nominal wall thickness exceeding 30 mm as well as forged pipes shall be tested to comply with the requirements of section 5.4.

(2) It is at the discretion of the pipe manufacturer to perform the ultrasonic testing by means of automated, mechanized or manual testing.

(3) The following requirements apply in addition to the requirements under clause 3.3.8, however, the requirements under Sec. 3.3.8.3.1 (5) cb) and 3.3.8.3.1 (6) d) do not apply.

16.4.2 Ultrasonic testing

16.4.2.1 Sound beam angles

(1) Angle-beam scanning shall be performed from the outside surface in both circumferential directions to detect longitudinal flaws.

(2) In the case of pipes with an outside diameter equal to or greater than 100 mm, additional angle-beam scanning shall be performed from the outside surface in both axial directions to detect transverse flaws and also a straight-beam scanning from the outside surface to detect lamination flaws.

(3) Where during mechanical testing untested pipe ends are obtained, they shall be cut off or be tested by manual methods.

(4) The tests shall be performed after the last forming and heat treatment process.

16.4.2.2 Performance of the tests and evaluation

16.4.2.2.1 Testing of sub-surface areas for longitudinal and transverse flaws

(1) Testing for longitudinal flaws shall be carried out to DIN EN ISO 10893-10, acceptance class U2, sub-class A.

(2) Testing for transverse flaws shall be carried out to DIN EN ISO 10893-10, acceptance class U2, sub-class C.

16.4.2.2.2 Testing of the centre range of the tube wall with s > 20 mm for longitudinal and transverse flaws

(1) Testing shall be carried out to the DGS, DAC or reference block methods. When applying the DAC or reference block method, side-drilled holes to Sec. 3.3.8.3.1 (3) b) shall be used as reference reflectors.

(2) The beam angles shall be selected such that reflectors oriented in wall thickness direction are hit as vertical as possible.

16.4.2.2.3 Testing for lamination flaws

The test shall be performed in accordance with DIN EN ISO 10893-8, acceptance class U0.

16.4.2.2.4 Recording levels

All indications shall be recorded that have an echo amplitude

a) equal to or greater than the smallest echo height of the reference reflectors as per section 16.4.2.2.1 when testing the sub-surface area to detect longitudinal and transverse flaws,

b) equal to or greater than

   ba) KSR 1.5 when applying the DGS method

   bb) the smallest echo height of the reference reflectors as per section 16.4.2.2.2 plus a sensitivity allowance of 6 dB when applying the DAC or the reference block method

   when testing the centre range of a pipe wall with a wall thickness exceeding 20 mm to detect longitudinal and transverse flaws,

c) equal to or greater than the smallest echo height of the reference reflectors as per section 16.4.2.2.3 when testing to detect lamination flaws.

16.4.2.2.5 Acceptance criteria

(1) All pipes with indications, the echo heights of which reach or exceed the recording level shall be rejected.

(2) Rejected pipes may be dressed mechanically within the permitted dimensional tolerances. The dressed areas shall be subjected again to an ultrasonic testing. Indications on rejected product forms may be tested by other non-destructive procedures (e.g. visual inspection, radiography) to detect the type and size of the respective defect. The manufacturer shall demonstrate harmlessness of the defect. Defects not removed shall be recorded and shall not impair periodic inspections.

(3) Dressed areas shall not impair periodic inspections. The deviations from the required shape of the testing surfaces referred to a reference area of 40 x 40 mm shall not exceed 0.5 mm. Where smaller reference areas are selected, the related deviation from shape shall be linearly converted with respect to the side length of the selected reference area.

16.4.3 Surface inspection

16.4.3.1 Extent, type and point of time

(1) The entire outside surface of all pipes in the delivery condition shall be examined for surface flaws.

(2) The inner surface of all pipes with an inner diameter equal to or greater than 600 mm shall likewise be examined completely. In the case of an inner diameter of more than 50 mm and less than 600 mm, the inner surface shall be examined at the pipe ends over a length equal to 1 times the inner diameter of the pipe.

16.4.3.2 Acceptance criteria

The requirements under Sec. 5.4.3 apply.

16.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

16.6 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) The requirements under Sec. 16.3.3.3 apply to the wall thickness measurements.

16.7 Verification of quality characteristics

The results of the tests in accordance with Secs. 16.3.3.1, 16.3.3.2 (6) and 16.3.3.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204 the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

17 Seamless pipe elbows

17.1 Scope

(1) This section applies to seamless pipe elbows (butt welding elbows) with a quenched and tempered wall thickness of 15 mm up to 200 mm which are fabricated from seamless rolled, pressed or forged pipes and quenched and tempered after forming.

(2) Pipe elbows are required to have cylindrical ends only if this is necessary with regard to the non-destructive tests in accordance with Sec. 12 of KT 3201.3 (taking into account possible requirements due to in-service inspections).

Note:

In the case of pipe elbows with a large nominal diameter, e.g. primary coolant piping system, this in general is not required.

(3) This section does not apply to pipe elbows fabricated in inductive bending machines or on a bending plate. These types of pipe elbows are dealt with in Sec. 6 of KTA 3201.3.

(4) The requirements for the materials of this product form are specified in Sec. A 1.

17.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

17.3 Tests and examinations

17.3.1 General requirements

The following requirements apply under the assumption that the direction of main forming of the initial pipe lies in the head-to-tail direction of the ingot. If, in the case of forged pipes, this assumption does not apply, possibly supplementary requirements regarding specimen-taking shall be specified in the initial material appraisal.

17.3.2 Tests of the initial pipes

(1) If the pipe manufacturer delivers the pipes in a quenched and tempered condition to the elbow manufacturer, then the initial pipes shall be completely tested at the plant of the pipe manufacturer and in accordance with Sec. 16.

(2) If the pipe manufacturer fabricates the pipe elbows himself, only the determination of the chemical composition of the initial pipes by a product analysis of each specimen-taking location in accordance with Sec. 16.3.3.1 is required.

17.3.3 Tests of the pipe elbows (after forming and tempering)

17.3.3.1 Specimen-taking locations

(1) The specimen-taking locations shall be at a depth of at least one quarter of the quenched and tempered wall thickness beneath the surface of the pipe and at least one half of the quenched and tempered wall thickness beneath the pipe elbow's end face (edges levelled for heat treatment).

(2) If only one elbow blank is manufactured from an initial pipe or, if the chord measure determined for the extrados of the bend is greater than 3000 mm, then the tests of the pipe elbow shall be performed for specimen-taking locations on both elbow ends at the extrados of the bend.

(3) If, prior to tempering, the initial pipe is cut into sections for manufacturing individual elbow blanks or, if the chord measure of the pipe elbow is smaller than 3000 mm, then each elbow blank shall be tested after tempering at one specimen-taking location on the extrados of the bend, with both ends of the initial pipe to be covered by the test.

Note:

In case of the "Hamburg" pipe elbow, the specimen-taking locations shall be distributed over the entire circumference, unless specified otherwise in the initial material appraisal. Irrespective of this requirement, impact test specimens shall always be taken as transverse test specimens from the intrados of the bend.

17.3.3.2 Extent of testing

17.3.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

For each initial pipe the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

17.3.3.2.2 Tests on tests coupons subjected to simulation stress relief heat treatment

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature. Longitudinal test specimens are permitted if transverse test specimens cannot be taken from un-straightened test coupons.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from one specimen-taking location.

(3) Impact test

One set of transverse test specimens from each specimen-taking location shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 0 °C and, for one specimen-taking location additionally at 33 °C and 80 °C.

(4) Impact energy-versus-temperature curve

For one elbow blank from each initial pipe and impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using transverse test specimens from one specimen-taking location.

(5) Nil-ductility transition temperature

On two longitudinal or transverse test specimens from one specimen-taking location of each elbow blank it shall be demonstrated in accordance with Sec. 3.3.7.3 (5), that the requirements regarding the NDT temperature are met. If this cannot be demonstrated, then the NDT temperature shall be determined for each specimen-taking location. This test is not required for a quenched and tempered wall thickness of less than 25 mm.

(6) Metallographic examinations

For each elbow blank, the grain size shall be determined from a longitudinal cross section of one impact test specimen from one specimen-taking location, the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

17.3.3.3 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) On each pipe elbow, the hardness test shall be performed on the extrados of the bend along one surface line, beginning near the pipe elbow ends and continuing in length intervals of not more than 1000 mm.

17.4 Non-destructive tests and inspections

17.4.1 General requirements

(1) The requirements under Sec. 17.4.2 and 17.4.3 shall apply to the tests of elbows with nominal wall thicknesses equal to or less than 30 mm fabricated from seamless rolled or pressed pipes. Product forms with a nominal wall thickness exceeding 30 mm and elbows fabricated from forged pipes shall be tested in accordance with the requirements under Sec. 5.4.

(2) The following requirements apply in addition to the requirements under clause 3.3.8, however, the requirements under Sec. 3.3.8.3.1 (5) cb) and 3.3.8.3.1 (6) d) do not apply.

(3) If the wall thickness is equal to or less than 15 mm, the ultrasonic testing by means of angle beam scanning can be replaced by radiographic testing in accordance with Sec. 17.4.3. It is allowed to combine ultrasonic and radiographic testing.

17.4.2 Ultrasonic testing

17.4.2.1 Sound beam angles

(1) An angle-beam scanning shall be performed from the outside surface in both circumferential directions to detect longitudinal flaws.

(2) In the case of outside diameters equal to or greater than 1000 mm, an angle-beam scanning in both axial directions to detect transverse flaws and a straight-beam scanning to detect lamination type flaws shall be performed additionally from the outside surface.

(3) When testing for longitudinal flaws from the cylindrical section it shall be ensured that the angle of incidence exceeds 38 degrees.

(4) For the test, reference blocks as per Sec. B 4.2 shall be used. The reference reflectors shall be positioned in the formed section of the elbow.

(5) The tests shall be performed upon the last forming and heat treatment process.

17.4.2.2 Performance of testing and evaluation

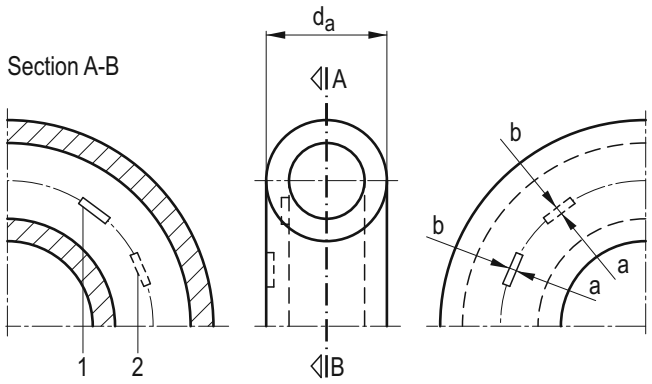
17.4.2.2.1 Testing of sub-surface regions for longitudinal and transverse defects

(1) Rectangular notches in compliance with the requirements according to DIN EN ISO 10893-10, acceptance class U2, shall be used as reference reflectors, in which case the testing for longitudinal flaws shall be based on sub-class A and the testing for transverse flaws on sub-class C.

(2) The following shall apply when testing for longitudinal defects: The notches shall be machined into the inner and outer surface of the pipe elbow near its average radius of curvature (cf. **Figure 17-1**). The testing level adjustment shall be performed using the inner and the outer notch. The testing level adjustment may also be performed on a pipe-shaped reference block, provided the transfer differences due to the bent coupling surfaces on the component is taken into account.

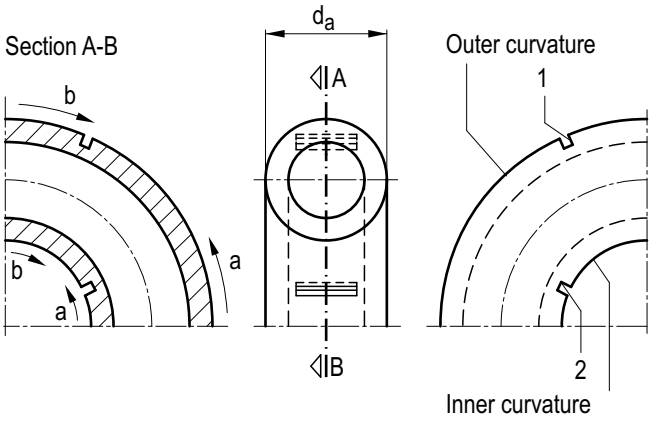
(3) The following shall apply when testing for transverse defects: The notches shall be machined into the outer surface of the pipe elbow at its inner and outer radius of curvature (cf. **Figure 17-2**). The testing level adjustment on a pipe-shaped reference block is not allowed when using contoured probes.

(4) Testing shall basically be carried out for the total formed area from the outside surface. In the case of wall thicknesses exceeding 15 mm, when testing for transverse flaws, testing may also be carried out from the inside surface in the bent region of the intrados with a correspondingly adapted beam angle.



a, b: Calibration direction
1: Longitudinal reference reflector (inside surface)
2: Longitudinal reference reflector (outside surface)

Figure 17-1: Location of reference reflectors with respect to the pipe elbow geometry for longitudinal flaw testing



a, b: Calibration direction
1: Transverse reference reflector (extrados and outer surface)
2: Transverse reference reflector (intrados and outer surface)

Figure 17-2: Location of reference reflectors with respect to pipe elbow geometry for transverse flaw testing

17.4.2.2.2 Testing of the centre range of the tube wall with s > 20 mm for longitudinal and transverse flaws

(1) Testing shall be carried out to the DGS, DAC or reference block methods. When applying the DAC or reference block method, side-drilled holes to Sec. 3.3.8.3.1 (3) b) shall be used as reference reflectors.

(2) The beam angles shall be selected such that reflectors oriented in wall thickness direction are hit as vertical as possible.

(3) Testing shall basically be carried out for the total formed area from the outside surface. In the case of wall thicknesses exceeding 15 mm, when testing for transverse flaws, testing may also be carried out from the inside surface in the bent region of the intrados with a correspondingly adapted beam angle.

17.4.2.2.3 Testing for lamination type flaws

(1) Testing shall be carried out by straight-beam scanning from the outside or inside surface.

(2) A circular milled flat-bottom recess shall be used as reference reflector to meet the requirements of DIN EN ISO 10893-8, acceptance class U0, in which case its depth shall not exceed 10 mm. The milled flat-bottom recess shall be located in the area of the middle radius of the reference block (pipe elbow section) at the inside surface.

17.4.2.2.4 Recording levels

All indications shall be recorded that have an echo amplitude

a) equal to or greater than the smallest echo height of the reference reflectors as per section 17.4.2.2.1 when testing the sub-surface area to detect longitudinal and transverse flaws,
b) equal to or greater than
   ba) KSR 1.5 when applying the DGS method
   bb) the smallest echo height of the reference reflectors as per section 17.4.2.2.2 plus a sensitivity allowance of 6 dB when applying the DAC or the reference block method

   when testing the centre range of a pipe wall with a wall thickness exceeding 20 mm to detect longitudinal and transverse flaws,
c) equal to or greater than the smallest echo height of the reference reflectors as per section 17.4.2.2.3 when testing to detect lamination flaws.

17.4.2.2.5 Acceptance criteria

(1) All product forms with indications, the echo heights of which reach or exceed the recording level shall be rejected.

(2) Rejected product forms may be dressed mechanically within the permitted dimensional tolerances. The dressed areas shall be subjected again to an ultrasonic testing. Indications on rejected product forms may be tested by other non-destructive procedures (e.g. visual inspection, radiography) to detect the type and size of the respective defect. The manufacturer shall demonstrate harmlessness of the defect. Defects not removed shall be recorded and shall not impair periodic inspections.

(3) Dressed areas shall not impair periodic inspections. The deviations from the required shape of the testing surfaces referred to a reference area of 40 x 40 mm shall not exceed 0.5 mm. Where smaller reference areas are selected, the related deviation from shape shall be linearly converted with respect to the side length of the selected reference area.

17.4.3 Radiographic testing

Note:
See Sec. 17.4.1 (3) as to the application of radiographic testing.

17.4.3.1 Procedural requirements

(1) Radiographic testing shall be performed in accordance with DIN EN ISO 5579.

(2) The requirements of class B to DIN EN ISO 5579 shall be met, however X-ray emitters shall be used.

(3) Image quality indicators to DIN EN ISO 19232-1 shall be used.

(4) The image quality values of image quality class B to DIN EN ISO 19232-3 shall be adhered to.

(5) Vacuum-packed film/foil combinations shall be used.

(6) The focal spot size of the X-ray equipment shall be determined in accordance with DIN EN 12543-1, DIN EN 12543-2 or DIN EN 12543-3 and shall be demonstrated with a certificate. Upon each repair of the X-ray tube, the focal spot size shall be measured anew and be certified. The largest dimension of the focal spot size (d) mentioned in the certificate shall be used to determine the exposure parameters.

(7) The documentation on the control of film processing to DIN EN ISO 11699-2 shall be made available for the acceptance of the radiographic films. In this case, sufficient film archiving capability shall be demonstrated by means of an archiving check.

17.4.3.2 Performance of the test

(1) A detailed film location plan and a radiation source plan shall be established stating a reference-point grid.

(2) The maximum permissible increase of the radiographed wall thickness due to angular radiation in the area to be evaluated shall not exceed 10 %.

17.4.3.3 Acceptance criteria

(1) Indications suggesting cracks are not permitted.

(2) Indications caused by non-metallic inclusions are permitted up to an extension of $0.7 \cdot s$, but not exceeding 6 mm. The proof that non-metallic inclusions are present may be made by spot checking for several similar indications in the tested area.

(3) The requirements under clauses 17.4.2.2.5 (2) and (3) shall apply to the corrective work of products with recorded indications.

17.4.4 Surface inspection

17.4.4.1 Extent

(1) The entire outside surface of all pipe elbows shall be tested for surface flaws.

(2) The inner surface of all pipe elbows shall likewise be tested completely if technically feasible. Zones of the inner surface not covered by the test shall be indicated in the test report.

17.4.4.2 Acceptance criteria

The requirements laid down in **Tables 5-4** and **5-5** apply.

17.5 Identification marking

In addition to the requirements under Sec. 3.5, the following applies:

a) If more than one pipe elbow are manufactured from one initial pipe the correct correlation of the elbow to this initial pipe shall be ensured.
b) The pipe elbows shall be individually numbered.

17.6 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

17.7 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) For each pipe elbow, the wall thickness shall be determined over its entire chord length including the elbow ends and over its entire circumference, furthermore, depending on the order specification, either the outside or the inside diameter shall be measured. In addition, the out-of-roundness shall be determined.

17.8 Verification of quality characteristics

The results of the tests in accordance with Secs. 17.3.3.2.1, 17.3.3.2.2 (6) and 17.3.3.3 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

18 Steam generator heat exchanger tubes

18.1 General requirements

18.1.1 Scope

(1) This section applies to seamless straight and U-tubes made from one tube without circumferential welds with a wall thickness less than 2 mm.

(2) The requirements for the materials of these product forms are specified in Sec. A 2 or A 9.

18.1.2 Allowable fabrication procedures

(1) The required values for the mechanical-technological material properties may be achieved by applying different combinations of heat treatment and cold forming processes.

(2) Special surface treatments (e.g. surface blasting) to achieve internal compressive stress are allowed. This is to be covered by the initial material appraisal.

(3) The requirements under Sec. 3.2.3 shall apply to the heat treatment.

18.1.3 Corrective work

(1) Surface defects may be dressed mechanically within the permitted dimensional tolerances.

(2) After corrective work, the corresponding tests shall be performed.

(3) The details on post-repair tests on blasted tubes shall be specified.

18.2 Requirements

18.2.1 Corrosion resistance

The corrosion resistance shall be demonstrated in accordance with Sec. 3.3.7.6.

18.2.2 Surface roughness

The mean deviation of the profile shall not exceed the following values:

a) straight tubes
   $Ra \leq 1.6$ µm, inside and outside,
b) U-bends
   $Ra \leq 2.5$ µm , inside and outside,
c) surface treated tubes
   $Ra \leq 3.5$ µm, outside.

18.2.3 Unallowed flaws

(1) Surface flaws with a depth exceeding 0.1 mm are not allowed.

(2) Any other flaw, even with less depth, is not allowed if its effect cannot be properly judged.

(3) Further details are specified under Sec. 18.4.

18.2.4 Surface condition

The requirements regarding the surface cleanliness shall be specified.

18.3 Tests and examinations

18.3.1 General requirements

18.3.1.1 Forming of lots

The tubes shall be divided into lots of 100 tubes, however a remainder of up to 50 tubes may be uniformly distributed over the individual lots. Quantities and remaining tubes between 51 and 100 shall be considered an individual lot. All remaining tubes of one lot shall originate from one melt and proceed completely through the straight-tube fabrication processes and acceptance tests.

18.3.1.2 Lot-correlation of tubes

Throughout the fabrication procedure an unambiguous correlation of the tubes to their respective lot shall be ensured.

18.3.1.3 Specimen-taking

The test coupons shall be taken from tube ends.

18.3.2 Extent of testing

18.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 2-1** or **Table A 9-1** shall be determined.

(2) Product analysis

The content by mass of elements specified in **Annex A**, **Table A 2-1** or **Table A 9-1** shall be determined for each melt on one intermediate product (rolled or forged bar) or on one tube .

18.3.2.2 Mechanical-technological tests

The following tests shall be performed on the tubes in a condition as specified under Sections A 2 and A 9.

a) Tensile test

   One tube in each lot shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

b) Drift test

   On one end of each tube a drift test to DIN EN ISO 8493 shall be performed with a 60°-cone and up to a diameter expansion of 20 %.

   Where the tubes cannot be unambiguously correlated with regard to their orientation in the tube fabrication run, both ends of the tube shall be subjected to a drift test.

18.3.2.3 Metallographic examinations

(1) For one tube in each lot, the grain size shall be determined and the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

(2) The degree of cleanliness shall be checked and be evaluated to the manufacturer’s specifications. To this end, two metallographic sections shall be taken from the intermediate

product (bar in the diameter range from 90 mm to 120 mm) such that the head and tail end of the initial block are covered.

18.3.2.4 Corrosion resistance

The corrosion resistance shall be demonstrated in accordance with Sec. 3.3.7.6 on one test specimen of each melt.

18.4 Non-destructive tests and inspections

18.4.1 General requirements

(1) The following requirements apply in addition to the requirements under clause 3.3.8.

(2) Each tube shall be tested in the unbent condition over its entire length. Untested ends shall be discarded.

(3) The non-destructive tests shall be performed by means of mechanized ultrasonic testing to determine longitudinal and transverse flaws.

(4) Other test procedures are permitted provided, it has been demonstrated that a testing level comparable to that of ultrasonic testing is obtained. In this case the procedural requirements and the performance of the test shall be specified in consideration of Sec. 18.4.2.

18.4.2 Procedural requirements and performance of ultrasonic testing

(1) Reference block

The testing level setting shall be performed on a reference block (reference tube). Rectangular notches with the following dimensions shall be machined into the inside and outside surfaces both in longitudinal and transverse direction of the reference tube:

length: 12.5 mm $\pm$ 5 %

depth: $0.10 \cdot s \pm 10$ %, at least 0.10 mm $\pm$ 10 %

width: 0.12 mm $\pm$ 10 %

where s : nimal wall thickness

The distance between the individual reference notches to each other and their distances to the tube end shall be such that each reference notch can be clearly and separately detected.

(2) Test facility

The test shall be performed by the tube manufacturer using automatic test facilities that are equipped with automatic recording equipment. In addition, automatic sorting facilities may also be employed.

(3) Adjustment and check of the test facility

As to the adjustment and check of the test facility, the requirements of DIN EN ISO 10893-10, Section 7, with the following additional requirements apply:

a) As regards the test for longitudinal flaws, a sensitivity allowance of 6 dB shall be used.

b) The distance between the trigger/alarm level and the noise level shall not be less than 6 dB.

c) The reference tube as per (1) shall pass 6 times through the test facility in which case the reference tube shall be turned after 3 passes.

(4) Sound beam angles

The ultrasonic test shall be performed in both circumferential and in both axial directions.

(5) Relative movement of tube and probe unit

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.

Multiple transducers where the distance between the individual transducers is less than 1 mm, are considered to be one transducer.

(6) Test-runs during testing

In the course of one shift and at random intervals, however, at least after every hundredth tube, test-runs shall be performed with the reference tube to check the settings of the facility. The reference tube shall be turned between two successive test-runs. In each test-run each individual indication shall be above the trigger/alarm level. If this requirement is not met, an additional test-run shall be performed. This shall consist of six additional through transmissions of the reference tube under the specified test conditions with the reference tube being turned after the third through transmission. Where during the follow-up inspection all individual indications are above the trigger/alarm level, during ultrasonic testing at least from one of the opposite sound beam entry directions, the test may be continued. If this condition is not met, a readjustment of the test facility is required. In this case, a re-testing of all tubes tested since the last successful test-run is required.

18.4.3 Acceptance criteria

(1) Acceptance limits

Before the start of fabrication the acceptance limit shall be specified on the basis of an available flaw catalogue and by mutual agreement between tube manufacturer, customer and authorized inspector such that the requirements of Sec. 18.2.3 are met. This flaw catalogue may be based either on the fabrication prior to the test of about 400 tubes with a typical production length or on the previous order unless essential changes in fabrication or testing have occurred.

(2) Evaluation

Tubes with indications equal to or exceeding the acceptance limit shall be rejected. The evaluation shall be carried out either on the basis of the recorded data or by an automatic sorting facility. In the latter case, the reliability of the sorting facility shall be randomly checked with regard to the recorded indications. In this case, the dimensional checks as per Sec. 18.6 shall also be performed. The acceptance limit shall be continuously reviewed by means of the flaw catalogues of the running fabrication in accordance with para (3).

Where the acceptance limit is lowered in the course of the running fabrication, the test results of the tubes tested so far shall be evaluated again (e.g. by means of the recorded data).

(3) Flaw catalogue of the running fabrication

A flaw catalogue shall be established for the running fabrication which covers about 1 % of the tested tubes. The indications shall be selected, examined and evaluated by mutual agreement with all parties involved and under consideration of the following criteria:

a) Half of all examined locations shall have echo amplitudes below the acceptance limit.

b) The echo amplitudes of the examined locations shall be distributed over the entire recording range as uniformly as possible.

c) The examination of indications shall be uniformly distributed over the entirety of fabrication lots.

d) The indications shall be evaluated with regard to flaw type and flaw depth and shall be shown as example in micrographs.

e) The relationship between echo amplitude on the one hand and flaw type and flaw depth on the other shall be evaluated appropriately.

The same applies correspondingly to the establishment of a pre-fabrication flaw catalogue in accordance with para (1).

18.4.4 Documentation

(1) All indications obtained shall be documented over the entire length of each tube in automatic recording facilities. It shall be ensured that the test results can be clearly correlated to the individual tube delivered.

(2) The trigger/alarm level shall be documented. The flaw catalogue of the running fabrication shall become part of the documentation.

18.5 Verification of surface quality

(1) Visual inspection

All tubes shall be visually inspected for any irregularities. Straight tubes shall be inspected in the finished condition, U-bends before bending and in the finished condition after bending.

(2) Surface roughness

The surface roughness Ra shall be determined for the inside and outside surfaces of end sections from one tube per lot. Straight tubes shall be examined in the finished condition, U-bends in the finished condition after bending. The surface roughness shall additionally be determined in the bending region of two test bends with the smallest bending radius of the tube set. Tube set means the total number of tubes intended for one component.

18.6 Check for dimensional accuracy

18.6.1 Extent, type and point of time

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) Straight tubes shall be checked in the finished condition. U-bends shall be checked before bending.

(3) The wall thickness of each tube shall be determined over the entire length by automatic ultrasonic testing.

(4) The outer diameter shall be determined for each tube. If done by automated ultrasonic testing, the outer diameter shall be determined over the entire length of the tube. If done manually, the outer diameter shall be determined with limit caliper gauges at both ends of the tube and at random positions over its length.

(5) In addition, the wall thickness and outer diameter of 0.5 % of evenly distributed tubes shall be measured at the tube ends with a micrometer and shall be documented.

(6) The U-bends shall be checked for dimensional accuracy and out-of-roundness after bending. The extent and details of these checks shall be specified in the test and inspection sequence plan.

18.6.2 Procedural requirements for the check of dimensional accuracy with automated ultrasonic facilities

(1) The checks for dimensional accuracy shall be performed with testing facilities that have been approved for the intended dimensional range by the authorized inspector (by substitution, an individual certification).

(2) It shall be ensured that the check is carried out for at least four locations offset by 90 degrees around the circumference and that the distance between measurement locations in axial direction is not larger than one quarter of the outer tube diameter.

(3) The reference reflectors used for the wall thickness measurements shall be tube pieces from materials with similar testing characteristics and with a wall thickness in the specified tolerance range. They shall have an outer diameter in the allowable diameter range.

(4) The reference reflectors used for checking the outer diameter shall be tube pieces from materials with similar testing characteristics and with the outer diameter in the specified tolerance range.

(5) The acceptance limits are the indications resulting from the reference reflectors during a single through transmission.

(6) At random intervals during the course of one work shift, however, at least after every hundredth tube, the settings of the facility shall be checked. To this end, the reference reflectors of the reference tube shall be indicated in one single control run under the specified testing conditions. If these indications are below the acceptance limits for wall thickness measurement then these values define the new acceptance limit with regard to the evaluation of the recorded indications of the tests carried out since the last successful control-run.

(7) All wall thickness measurements shall be documented over the entire length of each tube in automatic recording facilities. It shall be ensured that the documented results can be clearly correlated to the individual tube delivered. The acceptance limits shall be appropriately documented.

18.7 Hydrostatic test

(1) Each tube in its finished condition shall be subjected to a hydrostatic test at 1.3 times the design pressure. Only freshly prepared de-mineralized water shall be used. The required maximum pressure shall be kept up for at least 10 seconds.

(2) Where surface blasting is intended for the tubes, the hydrostatic test shall be performed prior to blasting.

18.8 Check for cleanliness

(1) Each tube in its finished condition shall be examined for obstructions and cleanliness by blowing a felt plug through them. The pressurized air or nitrogen used in this test shall be free of moisture and fat.

(2) The discoloration of the felt plug shall not be stronger than a sample specimen to be agreed upon with the authorized inspector.

18.9 Materials identification check

All tubes shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

18.10 Identification marking

(1) Care shall be taken not to damage the tubes in the course of identification marking.

(2) All tubes shall be identification marked such that a correlation to the tube manufacturer, melt and fabrication lot is possible. The identification mark may be codified.

18.11 Verification of quality characteristics

The results of the tests in accordance with Secs. 18.3.2.1, 18.3.2.3, 18.3.2.4, 18.5 (2), 18.7, 18.8 and 18.9 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

19 Seamless extrusion-clad composite tubes

19.1 Scope

(1) This section applies to extrusion-clad composite tubes, e.g. for the control rod nozzles and core instrumentation nozzles, with a wall thickness of the base metal tube between 10 and 30 mm.

(2) The requirements for the materials of these product forms are specified in Sec. A 7.

19.2 Requirements

(1) The absorbed impact energy on transverse test specimens of the base material shall be at least 68 J at 33 °C and the lateral expansion at least 0.9 mm.

Note:

The basis for specifying the test temperature of the notched bar impact test is the consideration that the pressure test temperature which is lower than the operating temperature, however, under most detrimental conditions shall be not lower than 0 °C, that this temperature may be not more than 33 K below the temperature at which the requirements regarding absorbed impact energy and lateral expansion are met by each individual test specimen.

If the above requirements are not met at 33 °C, additional notched bar impact tests (on transverse test specimens) shall be carried out on sets of three test specimens each to determine the temperature T_{AV} at which these requirements are met. Hereby, the tests for determining the impact energy versus temperature curves on transverse test specimens shall be utilized. The pressure test temperature T_D shall then be not lower than T_{AV} - 33 K. In the case of notched bar impact tests, the repetition of the test at original temperature is allowed under the following conditions:

a) The average values of absorbed impact energy and lateral expansion shall be not lower than the specified single values.

b) Only one test specimen shall show values lower than the specified single values.

c) The test specimen which failed by not obtaining the specified values shall not show values of the absorbed impact energy and the lateral expansion that are lower than the specified single values by 14 J and 0.13 mm, respectively.

When repeating a test, the failed test specimen shall be replaced by two additional test specimens. These two test specimens shall be taken from a location as close as possible to the specimen-taking location of the failed test specimen. Both of these test specimens are required to obtain the individually specified values. Where the specified single values are not obtained in the re-examination, then that higher temperature shall be determined at which each individual value meets the specified requirements. To this end, the available impact energy-versus-temperature-curves shall be taken, which, if required, shall be extended by further tests.

(2) The thickness of the cladding shall be 2.5 mm ± 0.4 mm. When removing penetrant testing indications from the cladding surface, up to 30 % of the inside surface may be ground over. By this procedure, however, the cladding thickness may not, at any location, be reduced to a value lower than 1.5 mm.

(3) The surface of the cladding material shall be resistant to intergranular corrosion down to a depth of 1.5 mm under all conditions of planned fabrication procedures, especially after welding upon heat treatment.

(4) The cladding material on those parts which, in the course of further fabrication, will be subjected to welding without weld filler metals, shall show a delta-ferrite content in the weld zone of between 2 % and 10 %. The cladding material on those parts which, in the course of further fabrication, will be subjected to welding with weld filler metals, shall show a delta-ferrite content in the weld zone of between 1 % and 10 %. A continuous ferritic structure is not allowed in either case. Deviations from these requirements are allowed provided the characteristics of the welded joints meet the requirements of KTA 3201.3.

19.3 Tests and examinations

19.3.1 Condition of test coupons

The tubes shall be tested in the delivery condition. However, if in the course of further fabrication, the tubes are subjected to stress relief heat treatment, e.g. after welding, they shall be tested in the condition of simulation stress relief heat treatment; the specifications in **Annex A** regarding stress relief heat treatment shall be considered.

19.3.2 Specimen-taking locations

The number of specimen-taking locations is specified with respect to each test under Sec. 19.3.3. The test coupons shall be taken from the ends of the tubes in their fabrication lengths.

19.3.3 Extent of testing

(1) General requirements

Unless otherwise specified in the individual sections, the tests shall always be related to test lots. One test lot shall only consist of tubes from one base material melt and from one heat treatment lot and shall contain not more than 20 fabrication lengths. In the case of continuous tempering, 40 tubes from one melt shall be considered to be one heat treatment lot.

(2) Chemical analysis

a) Ladle analysis

For each melt of the base material and of the cladding material the content by mass of elements specified in **Annex A**, **Table A 7-1** and **Table A 7-2** shall be determined.

b) Product analysis

For one fabrication length of each melt the content by mass of elements specified in **Annex A**, **Table A 7-1** and **Table A 7-2** shall be determined for the base material and for the cladding material.

(3) Disk pickling test

a) The head end of the ferritic initial material (ingot) shall be subjected to a disk pickling test to determine if the head end has been cut off far enough.

b) Alternatively, an ultrasonic test of the ferritic initial material (ingot) may be performed to detect blowholes. This test shall be performed by straight-beam scanning from the circumferential face at the head end over the full circumference on a length equal to the diameter of the initial material. The test frequency shall be at least 4 MHz. The test shall be performed to the DGS method with the recording level KSR 2 (disc shaped reflector 2). Where indications suggest the presence of shrinkage cavities, this area shall be removed and the test be repeated on the new end.

(4) Hardness test

a) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

b) Prior to specimen-taking, an adequate hardness test shall be performed on both end faces of each fabrication length of the base material.

(5) Tensile test

Two longitudinal test specimens (circular tensile test specimens) for each fabrication length shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(6) Impact test

One set each of longitudinal and transverse test specimens for each fabrication length shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at 33 °C.

(7) Impact energy-versus-temperature curve

For one fabrication length from each test lot an impact-energy-versus-temperature curve in accordance with Sec. 3.3.7.3 (4) shall be plotted using longitudinal and transverse test specimens from one tube end. One of the test temperatures shall be 33 °C.

(8) Delta-ferrite content

The delta-ferrite content of the cladding material shall be determined in accordance with Sec. 3.3.7.5 either by a bead-on-plate test or by calculation under consideration of the nitrogen content for each chemical composition determined in a product analysis.

(9) Resistance to intergranular corrosion

The resistance to intergranular corrosion in the outer 1.5 mm of the cladding shall be demonstrated for each clad material melt and each heat treatment lot. With regard to the test for resistance to intergranular corrosion in accordance with Sec. 3.3.7.6, the sensitization conditions shall be specified with regard to the intended subsequent fabrication and reported to the tube manufacturer by the customer when placing the order. The test specimens shall be prepared in consideration of DIN EN ISO 3651-2.

(10) Ring flattening test

One test specimen each from both ends of every fabrication length shall be subjected to a ring flattening test in accordance with DIN EN ISO 8492.

(11) Adhesion test of cladding

For each fabrication length one test specimen shall be subjected to a side-bend test.

(12) Metallographic examinations

For each fabrication length, the grain size of the base material shall be determined and the microstructure of the transition zone between base material and cladding shall be evaluated and documented in accordance with Sec. 3.3.7.4.

On one test specimen in each test lot, the course of hardness HV 0.5 shall be determined and graphically displayed for the transition zone along one line of about 15° to the cladding.

19.4 Non-destructive tests and inspections

19.4.1 General requirements

(1) All tubes shall be subjected to

a) an ultrasonic testing to detect defects orientated longitudinally, transversely and parallel to the surface as well as

b) a surface inspection to detect surface defects.

(2) The ultrasonic tests shall basically be performed by mechanized testing facilities.

(3) Manual ultrasonic tests are allowed provided the authorized inspector agrees.

(4) The following requirements apply in addition to the requirements under clause 3.3.8.

19.4.2 Ultrasonic testing (mechanized)

19.4.2.1 Sound beam angles

(1) The test shall be performed from both circumferential directions by means of angle-beam scanning from the outside surface to detect longitudinal defects.

(2) To detect transverse defects a test from both axial directions shall be performed by means of angle-beam scanning from the outside surface.

(3) When testing for longitudinally or transversely orientated defects, the beam angles shall be selected such that the incidence angle lies between 35 degrees and 55 degrees. If necessary, a test using an additional beam angle shall be performed when testing the centre range of a pipe with wall thicknesses in the test condition s_p exceeding 20 mm (including cladding) to hit reflectors oriented in wall thickness direction as vertical as possible.

(4) The test to detect defects parallel to the surface shall be performed by means of straight-beam scanning from the outside surface.

19.4.2.2 Procedural requirements and performance of the tests

(1) Surface condition

The surface of the test objects shall be in a condition according to Sec. 3.3.8 adequate for fulfilling the test objective. This generally is the tube fabrication condition.

(2) Test density

The sonic probes shall be guided along helical or straight lines. To ensure a complete testing of the entire tube volume, it is required to choose the sonic beam spread angle, forward travel rate, number of test tracks, sonic pulse frequency and testing speed such that the following values are obtained:

a) track superposition $\geq$ 20 % relative to the width of the crystal or transducer,

b) sonic pulse density 1 pulse per mm for $d_a \leq 50$ mm,

c) sonic pulse density 2 pulse per mm for $d_a > 50$ mm.

(3) Testing level adjustment and recording level

The testing level shall be adjusted on reference notches in reference blocks.

a) Testing the sub-surface area for longitudinally and transversely orientated defects

Rectangular notches with a depth of 1 mm or less shall be used as reference reflectors. The width of the notches shall normally not exceed a value of 1.0 mm. The acoustically effective length of the notches shall normally be 20 mm.

The notches used in the test for longitudinally orientated defects shall be axially aligned and those used in the test for transversely orientated defects - in circumferential direction.

The testing level adjustment for testing the sub-surface area close to the inside surface shall be carried out on notches at the inner surface.

The testing level adjustment for testing the sub-surface area close to the outside surface shall be carried out on notches at the outer surface.

The recording levels for the individual testing regions correspond to the echo heights of the related reference reflectors plus a sensitivity allowance of 6 dB.

b) Testing the centre range of a pipe with $s_p > 20$ mm for longitudinally and transversely orientated defects

The testing level adjustment shall be carried out to the DGS, DAC or reference block methods. When applying the DAC or reference block method, side-drilled holes to Sec. 3.3.8.3.1 (3) b) shall be used as reference reflectors.

The recording levels are defined by

ba) KSR 1.5 when applying the DGS method

bb) the echo height of the reflector mentioned in Section 3.3.8.3.1 (3) b) plus a sensitivity allowance of 6 dB when applying the DAC or the reference block method.

c) Testing to detect defects orientated parallel to the surface

Flat bottom holes with a diameter of 10 mm and a depth equal to the cladding thickness shall be used as reference reflectors.

The recording level is equal to the echo height of the reference reflector plus a sensitivity allowance of 6 dB.

19.4.2.3 Acceptance criteria

19.4.2.3.1 Longitudinally or transversely orientated defects

(1) Tubes showing flaws with echo amplitudes equal to or greater than the recording levels under Sec. 19.4.2.2 (3) shall be rejected.

(2) Remedial work by mechanical processing is allowed within the permitted dimensional tolerances.

19.4.2.3.2 Defects parallel to the surface

(1) In the case of tubes showing flaws with echo amplitudes equal to or greater than the recording levels under Sec. 19.4.2.2 (3), these flaws shall be examined for areal expansion with the half-value method.

(2) Flaws between base material and cladding up to 500 mm^2 as well as lamination flaws in the base metal up to 80 mm^2 are allowed.

(3) A maximum of two allowable indications per running tube meter are acceptable provided the distance between two indications is at least equal to the length of the larger reflector.

19.4.2.3.3 Welding edge zones

In the region within 20 mm of the welding edge zone, no flaws with echo amplitudes equal to or greater than the recording levels under Sec. 19.4.2.2 (3) are allowed.

19.4.3 Surface inspection

(1) The entire inside and outside surface in the finished condition shall be subjected to a surface inspection.

(2) A raw surface that, in the course of fabrication, will not anymore be subjected to any mechanical processing shall be considered to be in the “finished condition”.

(3) Where the test of the inner surface is performed by the ultrasonic or eddy-current method, the recording level corresponds to a notch with a depth of 5% of the nominal wall thickness. The requirements for the notch design as well as for adjusting the testing level shall be laid down in the test instruction.

(4) No indication that might indicate the existence of cracks is allowed.

(5) The requirements laid down in **Tables 5-4** and **5-5** apply to the acceptance criteria for penetrant and magnetic particle testing. When applying the ultrasonic or eddy-current testing, any indication is not acceptable that reaches or exceeds the recording level.

(6) Remedial work by mechanical processing is allowed within the permitted dimensional tolerances.

19.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

19.6 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) After separation into finished lengths, each tube shall be subjected to a check for dimensional accuracy including a measurement of the cladding thickness. The values determined shall be recorded in an as-built drawing or an as-built record. The as-built records shall normally be available for the acceptance test.

19.7 Hydrostatic test

Each tube (in fabrication lengths) shall be subjected to a hydrostatic test at 1.3 times the design pressure. The required maximum pressure shall be maintained for at least 30 seconds.

19.8 Verification of quality characteristics

The results of the tests in accordance with Secs. 19.3.3 (2), 19.3.3 (3), 19.3.3 (4), 19.3.3 (8), 19.3.3 (9), and 19.3.3 (12) shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

20 Bars and rings for bolts, nuts and washers, as well as bolts, nuts and washers (dimensions exceeding M 130)

20.1 Scope

(1) This section applies to rolled or hammer forged bars, forged stepped bars as well as individually forged rings from quenched and tempered steel from which, by further machining procedures, the bolts for the main cover flange of the reactor pressure vessel and other bolts with dimensions in excess of M 130 as well as the corresponding nuts and washers are produced.

(2) This section also deals with the tests and examinations of the finished bolts, nuts and washers.

(3) The requirements for the materials of these product forms are specified in Sec. A 10.

20.2 Requirements

The requirements under Sec. 3.2.4.4 shall apply.

20.3 General fabrication requirements

(1) Bars intended for nuts and washers shall be hollow bored before tempering.

(2) Repair welding is not allowed.

20.4 Tests and examinations

20.4.1 Specimen-taking locations and specimen orientation

Note:
*Examples for specimen-taking locations see **Figure 20-1**.*

20.4.1.1 Bars

(1) In the case of bars, longitudinal test specimens shall be tested. The specimen-taking locations shall be positioned such that the middle of the test coupon is at least one half of the quenched and tempered diameter beneath the end face edges levelled for heat treatment. The specimen axis shall lie at least one sixth of the quenched and tempered diameter beneath the cylindrical outside surface. Where a larger difference exists between finished diameter and quenched and tempered diameter, the region of the finished part shall be included in the test.

(2) Where the bars are hollow bored prior to tempering, the specimen-taking locations shall meet the same requirements as specified for rings under Sec. 20.4.1.2.

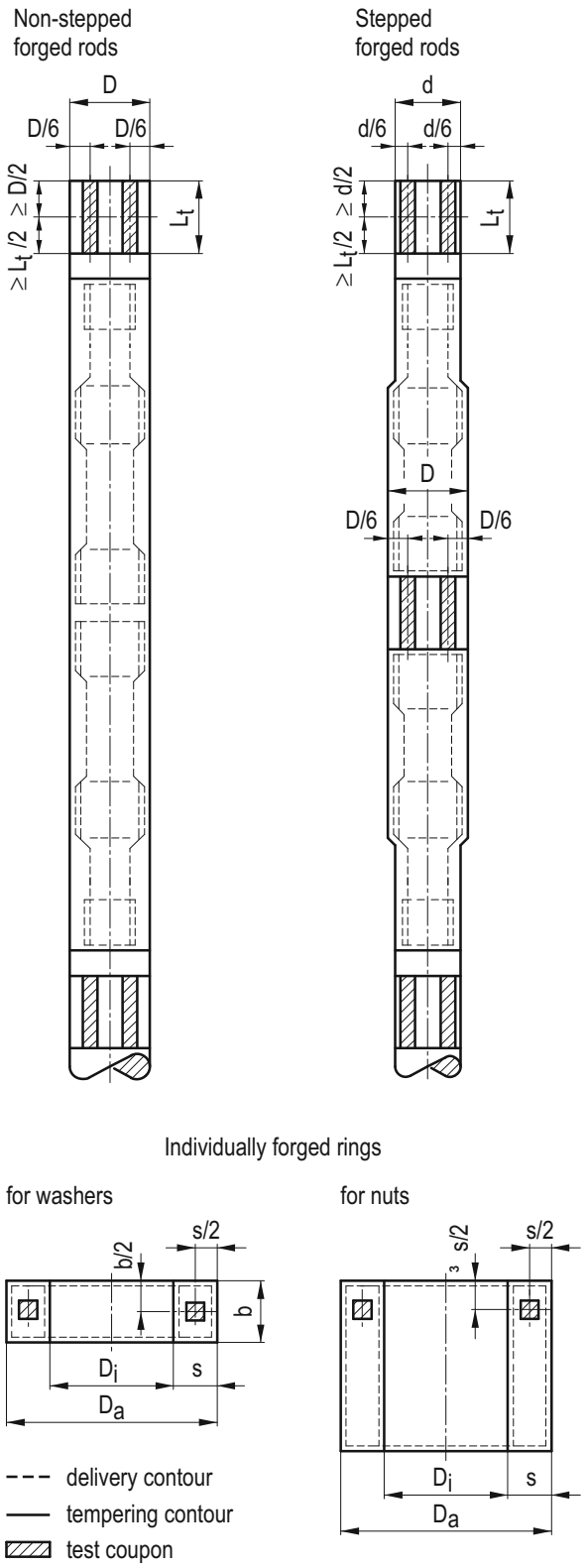


Figure 20-1: Examples for specimen-taking locations

(3) Non-stepped bars with a length up to and including 4000 mm shall be tested at one end and with a length exceeding 4000 mm at both ends.

(4) Stepped bars with a length up to and including 4000 mm shall be tested at the largest cross-section, unless otherwise specified in the initial material appraisal. Stepped bars with a length exceeding 4000 mm shall be tested at both ends and additionally at the largest cross section.

20.4.1.2 Rings

In the case of forged rings for nuts and washers, tangential test specimens shall be tested. The specimen-taking locations shall be positioned such that the middle of the test coupon is at least one half of the quenched and tempered diameter beneath the end face edges levelled for heat treatment. The specimen axis shall lie at one half of the quenched and tempered wall thickness.

20.4.2 Extent of testing on bars and rings

20.4.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 10-1** shall be determined.

(2) Product analysis

For each melt and heat treatment lot the content by mass of elements specified in **Annex A**, **Table A 10-1** shall be determined.

20.4.2.2 Mechanical-technological tests

(1) General requirements

The mechanical-technological properties shall be determined for the final heat treatment condition, i.e. the quenched and tempered condition or the quenched and tempered and stress relief heat treated condition.

(2) Hardness test

Each bar shall be subjected to a hardness test along one surface line and continuing in length intervals of about 1000 mm. The two bar ends shall be included in this test.

Each forged ring shall be subjected to a hardness test on one end face. In the case of rings from which more than one finished product is fabricated, both end faces shall be subjected to a hardness test.

(3) Tensile test

In the case of non-stepped bars, a tensile test in accordance with Sec. 3.3.7.3 (1) shall be carried out for each specimen-taking location at room temperature. Additionally, for each dimension, each melt and heat treatment lot, one tensile test specimen from the softest bar end shall be subjected to a hot tensile test in accordance with Sec. 3.3.7.3 (1) at design temperature. In the case of stepped bars, a tensile test in accordance with Sec. 3.3.7.3 (1) shall be carried out for each specimen-taking location at room temperature. Additionally, for each dimension, melt and heat treatment lot, one tensile test specimen from the largest cross-section of the softest bar shall be subjected to a hot tensile test in accordance with Sec. 3.3.7.3 (1) at design temperature.

In the case of forged rings for nuts, for each dimension, melt and heat treatment lot, however, from at least 25 pieces, two tensile test specimen each from the hardest and softest rings shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one each at room temperature and at design temperature.

(4) Impact test

a) In the case of bars, for each specimen-taking location one set of impact test specimen shall be tested in accordance with Sec. 3.3.7.3 (3) at 20 °C.

b) In the case of forged rings for nuts, for each dimension, melt and heat treatment lot, however, for at least every 25 pieces, one set of impact test specimens from the hardest and the softest rings shall be tested in accordance with Sec. 3.3.7.3 (3) at 20 °C.

c) In the case of forged rings for washers, for each dimension, melt and heat treatment lot, however, for at least every 100 pieces, one set of impact test specimens from the hardest and the softest rings shall be tested in accordance with Sec. 3.3.7.3 (3) at 20 °C.

20.4.2.3 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

20.4.2.4 Check for dimensional accuracy

Prior to subsequent fabrication, each part shall be subjected to a check for dimensional accuracy in accordance with Sec. 3.3.7.8.

20.4.2.5 Materials identification check

Prior to subsequent fabrication, all parts shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

20.4.3 Extent of tests on bolts, nuts and washers in the finished condition

20.4.3.1 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

20.4.3.2 Check for dimensional accuracy

Each part in its finished condition shall be subjected to a check for dimensional accuracy in accordance with Sec. 3.3.7.8.

20.4.3.3 Materials identification check

Each part in its finished condition shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9. In those cases where the part is manufactured from a bar or ring that was identification checked in accordance with Sec. 20.4.2.5 and to which the identification mark was subsequently transferred by the authorized inspector, no further identification check is required.

20.5 Non-destructive tests and inspections

20.5.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8, however, the requirements under Sec. 3.3.8.2.1 (5) cb) and 3.3.8.3.1 (6) d) do not apply.

20.5.2 Ultrasonic testing

20.5.2.1 Sound beam angles

(1) Bars shall be tested in accordance with the requirements under Sec. 14.4.2.2. In addition, straight beam scanning shall be performed. The beam angle for angled-beam scanning in circumferential direction shall be 35 degrees.

(2) In the case of hollow bored bars and hollow forged rings, the requirements under Sec. 5.4 apply. The requirements of Secs. 5.4.2.3, 5.4.2.4 and 5.4.3 shall not apply.

20.5.2.2 Recording levels

All indications shall be recorded the echo amplitudes of which are equal to or exceed the echo amplitude values of the disc shaped reflectors specified in **Table 20-1**.

20.5.2.3 Acceptance criteria

Indications whose echo amplitude reaches or exceeds the recording level to Sec. 20.5.2.2 are not permitted.

Diameter, width across flats, side length d or wall thickness s in the test condition, mm	Diameter of the disc shaped reflector (KSR), mm	
	Straight beam scanning	Angle-beam scanning
30 < d (s) ≤ 60	2	2
60 < d (s) ≤ 120	3	2
d (s) > 120	3	3

Table 20-1: Recording levels for ultrasonic testing

20.5.3 Surface inspection

20.5.3.1 Extent and point of time of testing

The entire surface of each bolt, nut and washer shall be subjected to a surface inspection in accordance with Sec. 3.3.8.3.2 in the finished condition of the product.

20.5.3.2 Procedural requirements

(1) The bolt shaft shall be subjected to a magnetic particle or eddy-current testing.

(2) The threaded region of bolts and nuts shall be subjected to a penetrant or eddy-current testing.

20.5.3.3 Acceptance criteria

(1) The acceptance criteria of **Tables 5-4** and **5-5** apply, however, non-metallic inclusions are only permitted up to a length of 3 mm.

(2) No indication that might indicate the existence of cracks or crack-type flaws is allowed.

20.6 Identification marking

The identification marking shall normally contain the following information:

a) identification of the material manufacturer,
b) material identification,
c) melt number of identification code,
d) test coupon number,
e) certification stamp of the authorized inspector.

20.7 Verification of quality characteristics

The results of the tests in accordance with Secs. 20.4.2.1, 20.4.2.2 (2), 20.4.2.5, and 20.4.3.3 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

21 Bars for bolts, nuts, washers and expansion sleeves as well as finished product forms fabricated from them (dimensions equal to or smaller than M 130)

21.1 Scope

(1) This section applies to rolled or forged bars from which stud screws or necked-down bolts with dimensions equal to or smaller than M 130 as well as the corresponding nuts, washers and expansion sleeves are produced by machining procedures.

This section does not apply to hot-pressed or cold-shaped parts. Only the threads of bolts may also be rolled.

(2) This section also deals with the tests and examinations of the finished bolts, nuts and washers as well as expansion sleeves.

(3) The requirements for the materials of these product forms are specified in Secs. A10 or A11.

21.2 Requirements

The requirements under Sec. 3.2.4.4 shall apply.

21.3 Fabrication requirements

Repair welding is not permitted.

21.4 Tests and examinations

21.4.1 Specimen-taking locations and specimen orientation

(1) The tests shall be performed on longitudinal test specimens.

(2) The specimen-taking locations shall be positioned such that the middle of the test specimens is at least one half of the heat treatment diameter beneath the end faces levelled for heat treatment. In the case of bars with a diameter equal to or smaller than 40 mm, the test specimen axis shall lie in the longitudinal axis of the bars. In the case of bars for screws and bolts with a diameter exceeding 40 mm, the test specimen axis shall lie at least one sixth of the heat treatment diameter, or as close to this position as possible, beneath the cylindrical outside surface. In the case of bars for nuts, washer and expansion sleeves the test specimen axis shall lie in the middle of the wall thickness of the finished product.

21.4.2 Extent of testing on bars

21.4.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 10-1** or in DIN EN 10269 shall be determined.

(2) Product analysis

For each melt and heat treatment lot the content by mass of elements specified in **Annex A**, **Table A 10-1** or in DIN EN 10269 shall be determined.

21.4.2.2 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) The hardness shall be determined at both ends of each bar to verify the uniformity of heat treatment.

21.4.2.3 Mechanical-technological tests

(1) General requirements

The mechanical-technological properties shall be determined for the final heat treatment condition, i.e., in the quenched and tempered condition or in the quenched and tempered and stress relief heat treated condition.

Equally dimensioned bars from the same melt and same heat treatment lot shall be grouped into test lots of not nor than 500 kg. From each test lot the hardest and the softest bar shall be tested.

Bars with a heat treatment length up to and including 4000 mm shall be tested on one end only.

Bars with a heat treatment length exceeding 4000 mm shall be tested on both ends.

(2) Tensile test

In the case of bars intended for screws, bolts, nuts and expansion sleeves, one tensile test in accordance with Sec. 3.3.7.3 (1) shall be carried out for each specimen-taking location at room temperature.

Additionally, one tensile test specimen from one end of the softest bar shall be subjected to a hot tensile test in accordance with Sec. 3.3.7.3 (1) at design temperature.

In the case of bars intended for washers, one tensile test in accordance with Sec. 3.3.7.3 (1) shall be carried out for each specimen-taking location at room temperature.

(3) Impact test

For each specimen-taking location one set of impact test specimens shall be tested in accordance with Sec. 3.3.7.3 (3) at 20 °C.

21.4.2.4 Non-destructive tests and inspections

Each bar shall be tested in accordance with the requirements of Secs. 20.5.1 and 20.5.2. Differing therefrom, straight beam scanning shall be performed on the front ends in the case of diameters and widths across flats or side lengths greater than 30 mm, and where these dimensions exceed 60 mm angle-beam scanning shall be performed in both circumferential directions.

21.4.2.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

21.4.2.6 Check for dimensional accuracy

Prior to subsequent fabrication, each bar shall be subjected to a check for dimensional accuracy in accordance with Sec. 3.3.7.8.

21.4.2.7 Materials identification check

Prior to subsequent fabrication, each bar shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

21.4.3 Extent of testing for screws, bolts, nuts, washers and expansion sleeves in the finished condition

21.4.3.1 Non-destructive tests and inspections

Each piece in its finished condition shall be subjected to a surface inspection in accordance with Sec. 20.5.3.

21.4.3.2 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

21.4.3.3 Check for dimensional accuracy

Each screw, bolt, nut, washer, and expansion sleeve in its finished condition shall be subjected to a check for dimensional accuracy in accordance with Sec. 3.3.7.8.

21.4.3.4 Materials identification check

(1) Each part in its finished condition shall be subjected to an accepted materials identification check in accordance with Sec. 3.3.7.9.

(2) In those cases where the part is manufactured from a bar that was identification checked in accordance with Sec. 21.4.2.7 and to which the identification mark was subsequently transferred by the authorized inspector, no further materials identification check is required.

21.5 Identification marking

The identification marking shall normally contain the following information:

a) identification of the material manufacturer,

b) material identification,

c) melt number or identification code,

d) test lot number,

e) certification stamp of the authorized inspector.

In the case of small parts where a complete identification marking cannot be applied due to lacking space, the identification of the material manufacturer, the material identification, the melt number, and the test lot number may be combined in a single identification code.

21.6 Verification of quality characteristics

The results of the tests in accordance with Secs. 21.4.2.1, 21.4.2.2, 21.4.2.7, and 21.4.3.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance DIN EN 10204.

22 Sheets, plates, bars and forgings from stainless austenitic steels as well as bars from nickel alloys

22.1 Scope

(1) This section applies to stainless austenitic steels in the following product forms:

a) sheets and plates, hot fabricated,

b) bars, hot or cold fabricated, or

c) forgings except for plates,

as well as hot or cold fabricated bars from nickel alloys with a diameter equal to or less than 60 mm for pressure-retaining components.

(2) The requirements for the materials for these product forms are specified in Sec. A 3 or A 9.

(3) For hot (operating temperature $T \geq 200$ °C during continuous operation) reactor water containing product forms and components in BWR plants only the steel grade X 6 CrNiNb 18 10 S, and only with the additional requirements of **Table A-3-1**, footnote 4, shall be used.

22.2 Requirements

The requirements under Sec. 3.2.4.3 shall apply.

22.3 Tests and examinations

22.3.1 Specimen-taking locations

22.3.1.1 Sheets and plates

(1) The test specimens shall be taken as transverse test specimens.

(2) DIN EN 10028-1 applies regarding the depth of specimen-taking.

(3) The following requirements apply to plates on the assumption that the direction of main forming of the initial plate lies in the head-to-tail direction of the ingot and that it is possible to identify the head and tail ends of the plate.

(4) If this assumption does not apply in part or as a whole, possibly deviating requirements regarding specimen-taking locations as well as test specimen position and orientation shall be specified in the initial material appraisal.

(5) The test specimens shall be taken from the middle of the head and the tail of each rolled plate and about 25 mm beneath the end face surfaces. In the case of rolled plates with a length equal to or less than 5000 mm and a thickness equal to or less than 20 mm the test specimens may be taken only from one end face.

22.3.1.2 Bars

(1) In the case of bar diameters or bar widths equal to or less than 100 mm longitudinal test specimens and for bar diameters or bar widths exceeding 160 mm transverse test specimens shall be tested. In the range of dimensions greater than 100 mm, but smaller than 160 mm transverse test specimens may be taken instead of longitudinal test specimens.

(2) The distance of the specimen-taking location beneath the end face surfaces shall be 25 mm.

(3) In the case of bars with a raw weight (i.e., the weight at the time of heat treatment) exceeding 500 kg and a length exceeding 2000 mm, the test specimens shall be taken from both ends of each bar.

(4) In the case of bars with a raw weight exceeding 500 kg and a length equal to or less than 2000 mm, the test specimens may be taken from only one end of each bar.

(5) In the case of bars with a raw weight equal to or smaller than 500 kg the test specimens shall be taken from only one end.

(6) Bars from the same melt and heat treatment and similar dimensions shall be grouped together in lots of 500 kg each. From each lot two sets of test specimens shall be tested. Overall, only four sets of test specimens need to be tested for each melt.

22.3.1.3 Forgings (except for plates)

(1) The specimen-taking locations shall be specified in the specimen-taking plan (cf. Sec. 2.6.4.2.4). The test specimens shall, as far as possible, be taken transverse to the major direction of forming.

(2) The test specimens (longitudinal and transverse test specimens) shall be taken from specimen-taking locations that lie 25 mm beneath the end face surfaces.

(3) In the case of forgings with a raw weight exceeding 5000 kg, each piece shall be tested at not less than three specimen-taking locations.

(4) In the case of forgings with a raw weight exceeding 500 kg and equal to or smaller than 5000 kg, each piece shall be tested from two specimen-taking locations which shall be offset by 180 degrees to each other. In the case of a diameter-to-length ratio equal to or greater than 1, the two specimen-taking locations shall be either at the head or the tail end face. In the case of a diameter-to-length ratio less than 1, one of the two specimen-taking locations shall be at the head and the other at the tail end face.

(5) Forgings from the same melt and with the same heat treatment and similar dimensions having a raw weight equal to or smaller than 500 kg shall be grouped into lots of 500 kg each. Two sets of test specimens shall be tested from each lot.

22.3.2 Extent of testing

22.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 3-1** or **Table A 9-1** shall be determined.

(2) Product analysis

The content by mass of elements specified in **Annex A**, **Table A 3-1** or **Table A 9-1** shall be determined:

a) for each rolled plate and plate at the head end,

b) for each bar with a raw weight exceeding 500 kg at the head end,

c) for one piece in each lot in the case of bars and forgings with a raw weight equal to or smaller than 500 kg,

d) for one forging at the head end in the case of forgings with a raw weight exceeding 500 kg, but equal to or smaller than 5000 kg,

e) for each forging with a raw weight exceeding 5000 kg at the head and the tail end.

The nitrogen content shall be determined.

22.3.2.2 Mechanical-technological tests

(1) Tensile test

For each specimen-taking location two test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

For each specimen-taking location one set of impact test specimens shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at room temperature.

22.3.2.3 Metallographic examinations

(1) From one piece of each lot in the case of bars and forgings with a raw weight of equal to or smaller than 500 kg and for one specimen-taking location from each piece in the other cases the grain size and microstructure shall be determined and be documented in accordance with Sec. 3.3.7.4.

(2) In the case of bars made of nickel alloys the degree of cleanliness shall be checked and be evaluated to the manufacturer's specifications. To this end, two metallographic sections shall be taken from the intermediate product (bar in the diameter range from 90 mm to 150 mm) such that the head and tail end of the initial block are covered.

22.3.2.4 Delta ferrite content

The delta ferrite content shall be determined in accordance with Sec. 3.3.7.5 on parts made of austenitic stainless steels which, in the course of further fabrication, will be subjected to welding; the method used may be by a bead-on-plate test or by calculation under consideration of the nitrogen content from each chemical composition determined on an individual piece (cf. 22.3.2.1).

22.3.2.5 Corrosion resistance

The corrosion resistance shall be demonstrated in accordance with Sec. 3.3.7.6 on one test specimen of each melt and heat treatment lot.

22.4 Non-destructive tests and inspections

22.4.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8, however the requirements under Sec. 3.3.8.3.1 (5) cb) and 3.3.8.3.1 (6) d) do not apply.

22.4.2 Ultrasonic testing

22.4.2.1 Procedural requirements

(1) The ultrasonic testing shall basically be performed as selected ultrasonic testing in accordance with Sec. 14.4.2.1 (3). 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 in accordance with Sec. 14.4.2.1 (2). Whether a global or selective ultrasonic testing is to be performed shall be agreed between the purchaser of the forging and the manufacturer and be recorded in the design review documents.

The type of testing shall be indicated in the test instruction and in the test report as "global UT" or "selected UT".

(2) 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.

(3) 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.

(4) If, during the 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.

(5) 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.

22.4.2.2 Sound beam angles

22.4.2.2.1 Forged or rolled steels

(1) For diameters exceeding 30 mm straight-beam scanning in axial direction shall be performed.

(2) For diameters and side lengths exceeding 60 mm, straight-beam scanning shall be performed in axial direction additionally from the head end. Where during straight-beam scanning in axial direction, the distance of at least 6 dB between the recording level and noise level cannot be maintained over the entire length of the bar, the tests shall be performed on the cut-off bar or by means of 45° angle-beam scanning in both axial directions.

(3) In the case of diameters exceeding 120 mm angle-beam scanning shall be performed additionally in both circumferential directions. Here, the beam angle shall be 35 degrees.

22.4.2.2.2 Initial material for drop forging

(1) Initial materials with diameters or side lengths exceeding 30 mm shall be tested by means of straight-beam scanning from the shell surface.

(2) The initial material may also be tested in the non-solution heat treated conditions unless restrictions as to the testability exist.

22.4.2.2.3 Drop forgings

(1) For drop-forged parts greater than DN 100, an ultrasonic testing 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 test 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.

22.4.2.2.4 Open-die forged valve bodies

The entire volume shall be tested from all external surfaces by straight-beam scanning. Additionally, the cylindrical regions shall be tested in the pre-machined or in the finished condition by angle-beam scanning in both circumferential directions.

22.4.2.2.5 Seamless hollow parts

The test shall be performed from one cylindrical surface and both end faces by means of straight-beam scanning as well as from one cylindrical surface in both circumferential directions by means of angle-beam scanning. Where the prescribed straight-beam scanning is not possible for geometric reasons, each impracticable straight-beam scanning direction shall be substituted by two opposite angle-beam scanning directions on the respective plane.

22.4.2.2.6 Forged blocks and plates

The requirements of Sec. 3.3.8.3.1 (4) apply.

22.4.2.2.7 Plates

The requirements of Sec. 7.4 apply.

22.4.2.3 Testing technique and testability

22.4.2.3.1 Testing technique

(1) For the straight-beam scanning frequencies between 2 and 5 MHz and for the angle-beam scanning a frequency of 2 MHz shall be selected where during the test of weld edges and nozzle areas miniature transverse wave probes shall basically be used. The test shall be performed to detect longitudinal defects (defect orientation parallel to the direction of welding progress). Here, the beam angle shall be selected such that the angle of incidence at the inner surface lies within the usable range of the corner effect (angle of incidence possibly 35 degrees up to 55 degrees).

(2) The test technique for testing the weld edge and nozzle areas shall be determined on a similar reference block or if practicable (e.g. where excess lengths are available) on the test object. When using a reference block it shall be representative for the test object with respect to geometry, acoustic properties and surface condition.

(3) To obtain a signal-to-noise ratio of at least 6 dB or to be within the recording levels the test technique may be optimized upon agreement with the authorized inspector, e.g. by the following measures:

a) probes with a lower nominal frequency,

b) use of frequency selective equipment,

c) use of dual-element probes,

d) use of highly attenuated probes,

e) use of longitudinal waves also for the angle-beam scanning.

22.4.2.3.2 Determination of testability

(1) The testability shall be determined for each test object. 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.

(4) For plates the back wall echo shall be determined in all centre ranges of a grid of 200 mm and at the border line by means of straight-beam scanning and at intended testing 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 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 echoes shall be used (e.g. existing boreholes, edges or through-transmission) for this test.

(6) The number and density of measuring 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.

(9) For the weld edges and nozzle areas the testability shall be determined for the conditions of testing the weld. This shall be done, like for the test 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 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 wall thickness of the finished part in accordance with **Table 22-1**.

Wall thickness s, mm	$8 < s \leq 20$	$20 < s \leq 40$	$40 < s$
Notch depth, mm	1.5	2	3

Table 22-1: 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.

22.4.2.3.3 Unrestricted testability

If it can be proved for the area to be tested with the greatest sound attenuation that a distance of at least 6 dB between the noise level and

a) the recording limits required to Sec. 7.4.2.3 for plates,

b) the recording limits required to Sec. 22.4.2.7 for all the other product forms with respect to the straight-beam and each angle-beam scanning

can be satisfied, the test object has unrestricted testability.

22.4.2.3.4 Restricted testability

(1) Where for one or more sound beam entry directions in a sound attenuation region the recording level according to Sec. 22.4.2.7 or the required signal-to-noise ratio of at least 6 dB cannot be maintained even with an optimized testing technique (see Sec. 22.4.2.3.1 (2)), these volumetric regions with restricted testability and the corresponding degree of restriction shall be determined.

(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.

22.4.2.4 Testing level adjustment

(1) During the testing level adjustment the largest sound wave attenuation values shall be considered for all probes and beaming directions.

(2) The evaluation of the echo indications shall be carried out under consideration of the sound wave attenuation determined in the immediate vicinity of the echo indications.

(3) When testing the weld edge and nozzle areas the testing level shall be adjusted to the reference block method. The notch depth shall be fixed in dependence of the wall thickness of the finished part in accordance with **Table 22-1.**

22.4.2.5 Size of reflectors

Deviating from Sec. 3.3.8.2.1 (8) the reflector size is given by the probe movement at which the echo height has dropped by 6 dB under the maximum echo amplitude (half-value method according to Sec. B 11.2.3).

22.4.2.6 Recording levels and acceptance criteria

22.4.2.6.1 Plates

(1) The requirements of Sec. 7.4.2.3 apply to the recording levels.

(2) The quality class S_3 to DIN EN 10307, Tables 3 and 4, shall apply to the acceptance criterion with regard to size and frequency of indications.

22.4.2.6.2 Forgings, bars and plates

22.4.2.6.2.1 Selective testing

(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) To obtain a distance of at least 6 dB between the recording level and noise level the recording level may partially be raised by 6 dB for the respective sound beam entry positions and volumetric regions. These regions as well as the recording levels obtained for the different beam entry directions shall be recorded.

In this case no indications are permitted that reach or exceed the recording level.

(4) In addition, the following requirements shall apply:

a) All indications liable to record during angle-beam scanning which are not liable to record during straight-beam scanning shall be thoroughly examined with respect to their orientation. Indications with a size exceeding 10 mm in thickness direction are not permitted.

b) The allowable frequency of recordable indications shall be, in the case of nominal wall thicknesses or diameters of:

ba) s or d $\leq$ 60 mm — 3 per m^2 locally and 2 per m^2 overall,

bb) s or d > 60 mm — 5 per m^2 locally and 3 per m^2 overall.

In the case of testing with raised recording level in accordance with Sec. 22.4.2.7 (3) only half the number of recordable indications is permitted.

c) The minimum distance of the recorded reflections from the final surface shall not be less than the values specified in **Table 5-2**.

22.4.2.6.2.2 Global testing

(1) The determination of the recording levels and the acceptability assessment of indications shall be made in accordance with DIN EN 10228-4. The required quality class to 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 10228-4 the locations mentioned in Sec. 3.3.8.3.1 (5) c) shall be documented.

22.4.2.6.3 Initial material for drop forgings

(1) For the testing of initial material used for drop forgings the recording levels to **Table 22-2** apply.

(2) Echo indications up to the recording levels specified in **Table 22-2** are permitted.

22.4.2.6.4 Regions of weld edges and nozzles

(1) All indications shall be recorded which are equal to or greater than the reference echo amplitude. The reference echo

amplitude is the echo height of the reference reflector to **Table 22-1** reduced by 12 dB. In addition, regions shall be recorded where the signal-to-noise ratio is less than 6 dB.

(2) Indications exceeding the recording level by up to 6 dB are permitted if their number per meter of weld edge length at a maximum recording length of 10 mm is limited to 3 indications, and at a maximum recording length of 20 mm to one indication.

(3) Where these limits are exceeded or areas are present where the distance between the notch or weld edge echo and noise level is less than 6 dB, further steps shall be decided jointly with the authorized inspector.

Scanning directions	Wall thickness in test condition, mm	Reference block method Recordable echo amplitudes referenced to the echo height of a 4 mm cylindrical bore hole	DGS method Disc shaped reflector (KSR)
All	≤ 60	50 % (-6 dB)	3
	> 60	100 %	4

Table 22-2: Recording levels and acceptance limits for ultrasonic testing on initial material for drop-forged parts

22.4.3 Surface inspection

22.4.3.1 Extent and point of time of testing

All accessible surfaces on the finished product shall be subjected to a penetrant testing.

22.4.3.2 Acceptance criteria

The requirements specified in **Table 5-4** apply.

22.5 Materials identification check

All parts shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9. Those parts which were subjected to a product analysis in accordance with Sec. 22.3.2.1 (2) may be exempted from this check.

22.6 Identification marking

In addition to the requirements under Sec. 3.5 the following applies:

In the case of a lot-wise testing in accordance with Secs. 22.3.1.2 and 22.3.1.3, each part shall be marked with the lot number.

22.7 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

22.8 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

22.9 Verification of quality characteristics

The results of the tests in accordance with Secs. 22.3.2.1, 22.3.2.3, 22.3.2.4, 22.3.2.5, and 22.6 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

23 Seamless pipes from stainless austenitic steels

23.1 Scope

(1) This section applies to seamless hot or cold fabricated heat treated pipes from stainless austenitic steels with a wall thickness of up to 50 mm.

(2) The requirements for the materials of these product forms are specified in Sec. A 3.

(3) For hot (operating temperature T ≥ 200 °C during continuous operation) reactor water containing product forms and components in BWR plants only the steel grade X 6 CrNiNb 18 10 S, and only with the additional requirements of **Table A-3-1**, footnote 4, shall be used.

23.2 Requirements

The requirements under Sec. 3.2.4.3 apply.

23.3 Tests and examinations

23.3.1 Specimen-taking locations

(1) The test coupon shall be taken from the end of the pipe.

(2) The minimum distance between pipe end and specimen-taking location shall be at least equal to the wall thickness but not exceed 25 mm.

(3) Wherever possible, transverse test specimen shall be taken. In the case of tensile tests on outer diameters equal to or smaller than 200 mm, longitudinal test specimens shall be taken.

(4) The requirements in accordance with DIN EN ISO 377 apply with respect to the specimen-taking depth.

23.3.2 Extent of testing

23.3.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 3-1** shall be determined.

(2) Product analysis

Pipes (fabrication lengths) of the same melt and similar dimensions shall be grouped in lots with each lot containing not more than 10 fabrication lengths. The content by mass of elements specified in **Annex A**, **Table A 3-1** shall be determined on one fabrication lengths in each lot. The nitrogen content shall be determined.

23.3.2.2 Tensile test

For each fabrication length two test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

23.3.2.3 Impact test

As far as it is possible to take 10 mm wide test specimens, one set of impact test specimens from each fabrication length shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at room temperature.

23.3.2.4 Technological tests

For each fabrication length the following technological tests shall be performed in accordance with Sec. 3.3.7.3 (6) on one end of the pipe:

a) ring expanding test or drift expanding test on pipes with an outer diameter equal to or greater than 146 mm and a wall thickness equal to or greater than 2 mm,

b) ring flattening test on pipes with an outer diameter greater than 146 mm and a wall thickness greater than 40 mm,

c) ring tensile test on pipes with an outer diameter greater than 146 mm and a wall thickness equal to or smaller than 40 mm.

23.3.2.5 Metallographic examinations

Metallographic examinations shall be performed to determine and document the grain size and microstructure in accordance with Sec. 3.3.7.4. Fabrication lengths of the same melt and similar dimensions and heat treatment shall be grouped in lots. For each lot one metallographic examination shall be performed.

23.3.2.6 Determination of the delta ferrite content

The delta ferrite content shall be determined in accordance with Sec. 3.3.7.5 for those pipes which, in the course of further fabrication, will be subjected to welding; the method used may be by a bead-on-plate test or by calculation under consideration of the nitrogen content from each chemical composition determined on each individual piece (cf. Sec. 23.3.2.1).

23.3.2.7 Resistance to intergranular corrosion

(1) Pipes (fabrication lengths) of the same melt and similar dimensions shall be grouped in lots with each lot containing not more than 10 fabrication lengths.

(2) From each lot one fabrication lengths shall be tested for resistance to intergranular corrosion in accordance with Sec. 3.3.7.6.

23.4 Non-destructive tests and inspections

(1) Forged pipes and pipes with a nominal wall thickness exceeding 30 mm shall be tested in the same way as seamless hollow bodies in accordance with Sec. 22.4. All other pipes shall be tested in accordance with the specifications under Sec. 16.4, in which case the testability of the weld edge and nozzle areas shall be additionally checked in accordance with Sec. 22.4.2.3.

(2) The sound attenuation and transfer correction shall be determined in accordance with **Annex B** at four measuring points offset by 90° each at both pipe 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 testing directions as used during the test for longitudinal and transverse defects as well as during the test for lamination flaws. 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 increased.

Where it is ascertained during the tests that sufficiently equal sound attenuation values 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.

23.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

23.6 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) On each pipe the wall thickness shall be checked on both ends and, depending on the order specification, either the inside or outside diameter.

23.7 Leak tightness test

Each pipe shall be tested for leak tightness by an internal hydrostatic pressure test. The test shall be carried out at a test pressure of 7 MPa. The required maximum pressure shall be kept up for at least 10 seconds. No leakage or visible deformation is permitted.

23.8 Materials identification check

Each pipe shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

23.9 Identification marking

In addition to the requirements under Sec. 3.5 the following applies:

a) The pipes shall be individually numbered.

b) The fabrication procedure (hot or cold) shall be specified.

23.10 Verification of quality characteristics

(1) The results of the tests in accordance with Secs. 23.3.2.1, 23.3.2.5, 23.3.2.6, 23.3.2.7, 23.7 and 23.8 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

(2) For each heat treatment lot the heat treatment condition including temperature, holding time and cooling-down conditions shall be certified. The correlation of the pipes to the heat treatment lots shall be specified.

24 Seamless elbows from stainless austenitic steels

24.1 Scope

(1) This section applies to hot or cold fabricated seamless pipe elbows with a wall thickness equal to or smaller than 50 mm from stainless austenitic steels and, in particular, pipe elbows that are solution annealed and quenched after heat treatment. The pipe elbows may be fabricated from seamless pipes as well as hollow-hammered or hollow-bored forgings.

(2) Pipe elbows are required to have cylindrical ends only if this is necessary with regard to the non-destructive examinations in accordance with Sec. 12 KTA 3201.3 (taking into account possible requirements from in-service inspections).

(3) This section does not apply to pipe elbows taken from pipe bends which e.g. are fabricated on inductive bending machines or on a bending plate or by cold bending. These types of pipe elbows are dealt in with Sec. 6 of KTA 3201.3.

(4) The requirements for the materials of this product form are specified in Sec. A 3.

(5) For hot (operating temperature $T \geq 200$ °C during continuous operation) reactor water containing product forms and components in BWR plants only the steel grade X 6 CrNiNb 18 10 S, and only with the additional requirements of **Table A-3-1**, footnote 4, shall be used.

24.2 Requirements

The requirements under Sec. 3.2.4.2 apply.

24.3 Tests and examinations

24.3.1 General requirements

The following requirements apply under the assumption that the direction of main forming of the initial pipe lies in the head-to-tail direction of the ingot. If, in the case of forged pipes, this assumption does not apply in part or as a whole, possibly deviating requirements regarding specimen-taking shall be specified in the initial material appraisal.

24.3.2 Tests of the initial product forms

(1) If the manufacturer delivers the initial product forms in a completed heat treatment condition, i.e. in the solution annealed and quenched condition, to the elbow manufacturer, then the initial product forms shall be completely tested at the plant of its manufacturer, that is in the case of seamless pipes specified under 23.3 and in the case of forgings as specified under Sec. 22.3.

(2) If the manufacturer of the initial product forms fabricates the pipe elbow himself, only the determination of the chemical composition for the initial pipes by the ladle analysis and a product analysis are required. In this case the following applies: for each melt the content by mass of elements specified in **Annex A**, **Table A 3-1** shall be determined. In the case of the product analysis, the initial product forms shall be grouped in lots of not more than 10 fabrication lengths. In each lot one fabrication length shall be subjected to a product analysis.

24.3.3 Tests of the pipe elbows

24.3.3.1 Specimen-taking locations

(1) The test specimens shall be taken from the elbow ends.

(2) The distance between elbow end and specimen-taking location shall be at least equal to the wall thickness but not exceed 25 mm.

(3) If practicable, transverse test specimens shall be taken. In the case of tensile tests on outer diameters equal to or smaller than 200 mm, longitudinal test specimens shall be taken.

(4) In the case of elbows with a wall thickness equal to or greater than 20 mm, the test specimens shall be taken from a location close to the mid-wall of the pipe as possible.

24.3.3.2 Extent of testing

24.3.3.2.1 Extent of testing on elbows fabricated from product forms tested as specified under 24.3.2 (1)

24.3.3.2.1.1 General requirements

Unless specified otherwise in the following section, the tests shall be performed in lots consisting of elbows from the same melt, of similar dimensions and in the same heat treatment condition; the size of the lot shall not exceed 10 pieces.

24.3.3.2.1.2 Chemical analysis

(1) For each lot a product analysis shall be performed to determine the content by mass of elements specified in **Annex A**, **Table A 3-1**. In this case, the members of the lot do not have to be in the same heat treatment condition.

(2) The nitrogen content shall be determined.

24.3.3.2.1.3 Tensile test

From each lot two tensile tests in accordance with Sec. 3.3.7.3 (1) shall be carried out, one at room temperature and one at design temperature.

24.3.3.2.1.4 Impact test

If possible to remove 10 mm wide test specimens, one set of impact test specimens from each lot shall be subjected to an impact test in accordance with Sec. 3.3.7.3 (3) at room temperature. In general, transverse test specimens shall be tested. If it is impossible to remove transverse test specimens, longitudinal test specimens shall be used.

24.3.3.2.1.5 Technological tests

If it is not possible to remove 10 mm wide impact test specimens, the following technological tests shall be performed in accordance with Sec. 3.3.7.3 (6) instead of the impact test; these tests shall be performed at one end on one piece from each lot:

a) ring expanding test or drift expanding test on elbows with an outer diameter equal to or smaller than 146 mm and a wall thickness eual to or greater than 2 mm,
b) ring tensile test on elbows from pipes with an outer diameter greater than 146 mm.

24.3.3.2.1.6 Metallographic examination

One metallographic examination shall be performed for each lot to determine and document the grain size and microstructure in accordance with Sec. 3.3.7.4.

24.3.3.2.1.7 Determination of the delta ferrite content

The delta ferrite content shall be determined in accordance with Sec. 3.3.7.5 for those parts which, in the course of further fabrication, will be subjected to welding; the method used may be by bead-on-plate test or by calculation under consideration of the nitrogen content from each chemical composition determined on each individual piece (cf. Sec. 24.3.3.2.1.2 (2)).

24.3.3.2.1.8 Resistance to intergranular corrosion

From each lot (lot size equal to or smaller than 50) one test specimen shall be tested in accordance with Sec. 3.3.7.6 for resistance to intergranular corrosion.

24.3.3.2.2 Extent of tests on elbows fabricated from product forms tested as specified under Sec. 24.3.2 (2)

(1) The specifications under Sec. 23.3.2 shall apply accordingly to the extent of tests on elbows from seamless pipes; however, it shall be observed that the extent of tests shall be related to individual elbows instead of fabrication lengths. Deviating from Sec. 23.3.2, the chemical composition shall be determined by a product analysis as specified under Sec. 24.3.3.2.1.2 and the check for resistance to intergranular corrosion as specified under Sec. 24.3.3.2.1.8.

(2) Elbows fabricated from forgings shall be individually tested. Beyond that, the specifications under Secs. 24.3.3.2.1.2 through 24.3.3.2.1.8 apply.

24.4 Non-destructive tests and inspections

(1) Elbows with a nominal wall thickness exceeding 30 mm and fabricated from forged product forms shall be tested like seamless hollow bodies in accordance with Sec. 22.4. All other elbows shall be tested in accordance with the specifications under Sec. 17.4 in which case the testability of the weld edge and nozzle regions shall additionally be checked in accordance with Sec. 22.4.2.3.

(2) The sound attenuation and transfer correction shall be determined in accordance with Sec. 23.4 (2).

24.5 Identification marking

In addition to the requirements under Sec. 3.5 the following applies:

a) If several elbows are fabricated from one initial product form, the correlation shall be ensured.

b) The elbows shall be individually numbered.

c) The fabrication procedure (hot or cold) shall be specified.

24.6 Materials identification check

Each elbows shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

24.7 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

24.8 Check for dimensional accuracy

(1) The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

(2) On each elbow, the wall thickness shall be determined to a sufficient extent over the entire chord length including the elbow ends and over its entire circumference, furthermore, depending on the order specification, either the outside or the inside diameter shall be measured. In addition, the out-of-roundness shall be determined.

24.9 Verification of quality characteristics

(1) The results of the tests in accordance with Sec. 24.3.3.2.1.2, 24.3.3.2.1.6, 24.3.3.2.1.7, 24.3.3.2.1.8, and 24.6 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

(2) For each heat treatment lot the heat treatment condition including temperature, holding duration and cooling-down conditions shall be certified. The correlation of the pipes to the heat treatment lots shall be specified.

25 Primary coolant pump casings from ferritic cast steel

25.1 Scope

(1) This section applies to primary coolant pump casings made of quenched and tempered ferritic cast steel.

(2) The requirements for the material of these product forms are specified in Sec. A 4.

25.2 Requirements

(1) Chaplets are not allowed in the finished condition of the casting.

(2) Feeders as well as large cast-integral reinforcements that detrimentally affect quenching and tempering of the casting shall be removed prior to heat treatment.

(3) The upper shelf impact energy of the base metal shall be at least 100 J.

(4) The NDT temperature shall be equal to or smaller than 0 °C. Where the required NDT temperature is exceeded, the customer, by agreement with the authorized inspector, shall decide on the further steps to be taken in due consideration of the safety analysis.

(5) The absorbed impact energy shall be determined for a temperature that is 33 K over the required NDT temperature. The absorbed impact energy shall be not less than 68 J and the lateral expansion not be less than 0.9 mm. If these requirements are not met for one test specimen, additional tests shall be carried out to determine the temperature at which these requirements are met in the notched bar impact test. Regarding the application of such a product, it shall be considered that these higher temperatures must be lower than the temperatures possible under critical conditions (e.g. pressure test, incidents). In the case of the notched bar impact test a repetition of the test at the original temperature is allowed under the following conditions:

a) The average values of absorbed impact energy and lateral expansion shall not fall below the specified single values.

b) Only one test specimen may show values that are lower than the specified single values.

c) The test specimen which failed by not reaching the specified single values shall not show values of the absorbed impact energy and lateral expansion that are lower than the specified single values by more than 14 J and more than 0.13 mm, respectively.

When repeating a test, the failed test specimen shall be replaced by two additional test specimens. These two test specimens shall be taken from a location as close as possible to the specimen-taking location of the failed test specimen. Both of these test specimens are required to reach the individually specified values. Where the specified single values are not achieved in the re-examination, then that higher temperature shall be determined at which each individual value meets the specified requirements. This should be done on the basis of the available impact energy versus temperature curves which, as required, shall be extended by further tests.

25.3 General requirements regarding fabrication

(1) In addition to the manufacturing documents specified under Sec. 2.5.4, test and inspection sequence plans for the production and constructional welds, welding plans as well as lists of the corresponding production weld test shall be submitted to the authorized inspector for design review. In the case of production and constructional welds a design review of the test and inspection sequence plans may be dispensed with, provided the welding is performed and tested in accordance with **Table 25-1**. Together with the instructions for non-destructive testing, a plan with the co-ordinate system (reference grid points) shall be submitted.

(2) Besides these design review documents, the gating and feeding techniques describing the casting technology shall be documented by the saturation calculations depicting the locations of the feeders and the feeder regions. Furthermore, the locations and dimensions of integrally cast test blocks shall be depicted and justified. These documents shall serve as information only. They do not require a formal acceptance stamp by the authorized inspector.

(3) The description of the casting technology as well as the specifications under Sec. 25.6 shall be considered in establishing the instructions for non-destructive testing. In the case of regions of limited testability, the adequacy of component safety shall be demonstrated by sufficient replacement measures.

25.4 Weldings

25.4.1 General requirements

(1) The requirements to DIN EN 1559-1 and DIN EN 1559-2 as well as the requirements in KTA 3201.3 for welded joints shall apply to production and constructional weldings, unless specified otherwise in Sections 25.4.2 and 25.4.3.

(2) The surface of the weld bead for production weldings shall be subjected to a surface inspection in accordance with Sec. 25.6.

(3) Production and constructional weldings generally require renewed quenching and tempering. This shall be taken into account in the choice of welding consumables.

(4) Quenching and tempering of production and constructional weldings may be waived only by agreement with the authorized inspector. In this case, the welding locations shall be numbered and the number, size and location of the weldings shall be documented (final file).

(5) The authorized inspector shall be informed about any relatively large production and any constructional welding. These weldings shall be documented, the documents becoming part of the interim file.

Each area prepared for production 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.

(6) Minor production welds, e.g. for the removal of surface flaws, shall be avoided as far as possible. If they cannot be avoided, a subsequent stress-relief heat treatment is required.

(7) Any welds subjected only to a stress-relief heat treatment shall be welded higher by two bead layers; these shall, subsequently be ground flush to base metal height.

25.4.2 Procedure qualification

25.4.2.1 General requirements

Procedure qualification in accordance with the following specification are required for production welding (full and partial penetration welding) and for constructional welding.

25.4.2.2 Procedure qualification for production welding

25.4.2.2.1 General requirements

(1) Production welding

The weldings of the procedure qualification shall correspond to the conditions of the component welding as far as possible.

The test coupons shall be dimensioned such that the tests in accordance with **Table 25-2** can be performed.

The test coupons for production welding shall be subjected to a heat treatment similar to the one planned for the component, i.e., the quenched and tempered test coupons shall be heat treated again after welding. The temperature-over-time sequence for the simulation stress-relief treatment shall be specified under consideration of Sec. 3.3.5.1.

(2) Partial penetration welding

In the procedure qualification for partial penetration welding on castings with a wall thickness equal to or greater than 100 mm a planar steel casting plate of the same material with a wall thickness of at least 100 mm shall be used. In the case of castings with a wall thickness less than 100 mm, a planar steel casting plate of the same material with a wall thickness of at least 50 mm may be used.

In preparation for welding, the plates shall be chipped down to about 40 % of the wall thickness corresponding to the expected production welding.

(3) Full penetration welding

The procedure qualification for full penetration welding on a wall thickness d_p shall apply to any wall thickness d_B of the final component up to $d_B = 1.5 \cdot d_p$.

A procedure qualification for full penetration welding applies to any partial penetration welding under para (2) if the wall thickness is equal to or greater than 50 mm. Where the wall thickness of the procedure qualification for full penetration welding is less than 50 mm, then, for a larger wall thickness, procedure qualifications for partial penetration welding as under para (2) are required.

25.4.2.2.2 Procedure qualifications for quenched and tempered and simulation stress relief heat treated production welding

(1) Specimen-taking

Test specimens shall be taken in accordance with **Figures 25-1** and **25-2**.

(2) Extent of testing

a) Mechanical-technological tests

The extent of testing is specified in **Table 25-2**.

b) Non-destructive tests and inspections

The surfaces prepared for welding shall be subjected to a surface inspection.

A surface inspection, radiographic and ultrasonic testing shall be performed on the test coupon in the final heat treatment condition - quenched and tempered and simulation stress-relief heat treated. The extent of non-destructive testing as well as the procedural details is specified under Sec. 25.6.

c) Other tests

The extent of other tests is specified in **Table 25-2.**

(3) Evaluation of the test results

The results of the mechanical-technological tests and the other test shall meet the requirements under **Table 25-3**. The results of the non-destructive testing shall be within the acceptance criteria specified in Sec. 25.6.4.

25.4.2.2.3 Procedure qualification for stress-relief heat treated fabrication welding

(1) Specimen-taking

Test specimens shall be taken in accordance with **Figures 25-1** and **25-2**.

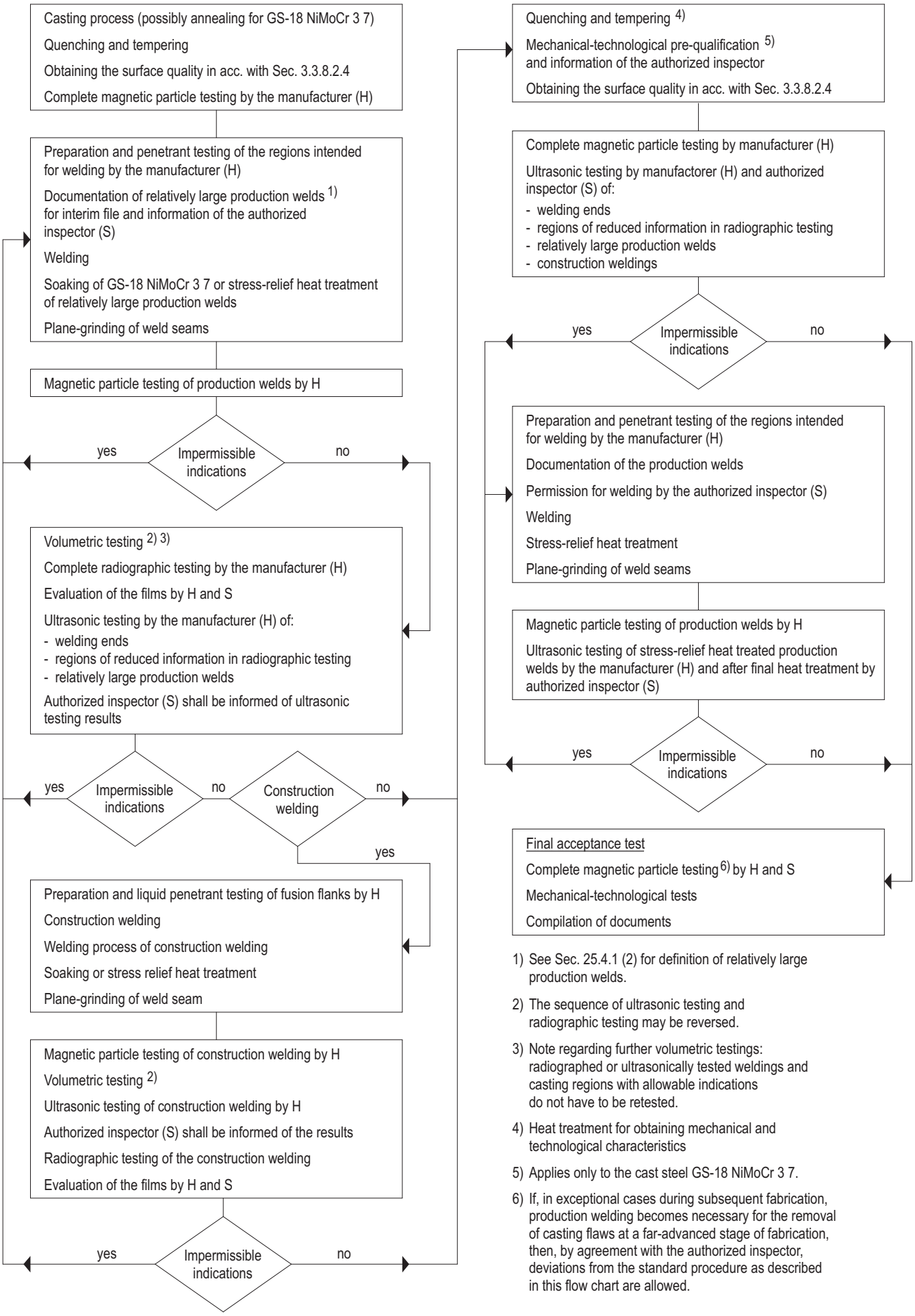
(2) Extent of tests and evaluation of results

The specifications under Sec. 9.2 of KTA 3201.3 shall be applied with regard to extent of tests and evaluation of results.

25.4.2.3 Procedure qualification for constructional welding

(1) The requirements under Sec. 25.4.2.2.2 apply accordingly to constructional welding if the welding is quenched and tempered and simulation stress-relief heat treated, those under 9.3 of KTA 3201.3 if the welding is simply stress-relief heat treated.

(2) The non-destructive testing shall be performed in accordance with Sec. 12 of KTA 3201.3.



1) See Sec. 25.4.1 (2) for definition of relatively large production welds.

2) The sequence of ultrasonic testing and radiographic testing may be reversed.

3) Note regarding further volumetric testings: radiographed or ultrasonically tested weldings and casting regions with allowable indications do not have to be retested.

4) Heat treatment for obtaining mechanical and technological characteristics

5) Applies only to the cast steel GS-18 NiMoCr 3 7.

6) If, in exceptional cases during subsequent fabrication, production welding becomes necessary for the removal of casting flaws at a far-advanced stage of fabrication, then, by agreement with the authorized inspector, deviations from the standard procedure as described in this flow chart are allowed.

Table 25-1: Fabrication flow chart for pressure-retaining components made of ferritic cast steel

Type of specimen	Test temp.	Test in accordance with	Value to be determined	Test specimen location Fig./Sketch	Test specimen layer Fig. 25-2	Number of test specimen 1)		Inspection certificate to DIN EN 10204
						partial penetration weld	full penetration weld	
a) Weld metal Tensile test specimens	Room temperature	DIN EN ISO 6892-1	R_m, $R_{p0.2}$, A, Z	25-1/I	—	1	—	3.2
	350 °C	DIN EN ISO 6892-2	R_m, $R_{p0.2}$, A, Z	25-1/I	—	1	—	
	Room temperature	DIN EN ISO 6892-1	R_m, $R_{p0.2}$, A, Z	25-2/I	O	—	1	
					M	—	1	
	350 °C	DIN EN ISO 6892-2	R_m, $R_{p0.2}$, A, Z	25-2/I	O	—	1	
					M	—	1	
Impact test specimens	2)	DIN EN ISO 148-1	KV_2-T-curve 2), lateral expansion, mat fracture surface	25-1/IV	—	3 each	—	
	33 °C		KV_2, lateral expansion, mat fracture surface	25-1/IV	—	3	—	
	2)	DIN EN ISO 148-1	KV_2-T-curve 2), lateral expansion, mat fracture surface	25-2/IV	O	—	3 each	
					M	—	3 each	
	33 °C		KV_2, lateral expansion, mat fracture surface	25-2/IV	O	—	3	
					M	—	3	
Drop weight test specimens	5 °C	SEP 1325, P2	broken/not broken	25-1/VI	—	2	—	
	5 °C	SEP 1325, P2	broken/not broken	25-2/VI	M	—	2	
b) Welded joint Tensile test specimens	Room temperature	DIN EN ISO 6892-1	R_m, fracture location	25-1/II	—	1	—	3.2
	350 °C	DIN EN ISO 6892-2	R_m, fracture location	25-1/II	—	1	—	
Tensile test specimens	Room temperature	DIN EN ISO 6892-1	R_m, fracture location	25-2/II	O	—	1	
					M	—	1	
	350 °C	DIN EN ISO 6892-2	R_m, fracture location	25-2/II	O	—	1	
					M	—	1	
Bend test specimens	Room temperature	DIN EN ISO 5173	bending angle to first crack	25-1/III	—	1	—	
	Room temperature	DIN EN ISO 5173	bending angle to first crack	25-2/III	O	—	1	
					M	—	1	
Impact test specimens 3)	2)	DIN EN ISO 148-1	KV_2-T-curve 2), lateral expansion, mat fracture surface	25-1/V	—	3 each	—	
	33 °C		KV_2, lateral expansion, mat fracture surface	25-1/V	—	3	—	
	2)	DIN EN ISO 148-1	KV_2-T-curve 2), lateral expansion, mat fracture surface	25-2/V	O	—	3 each	
					M	—	3 each	
	33 °C		KV_2, lateral expansion, mat fracture surface	25-2/V	O	—	3	
					M	—	3	
Drop weight test specimens	5 °C	SEP 1325, P2	broken/not broken	25-1/VII	—	2	—	
	5 °C	SEP 1325, P2	broken/not broken	25-2/VII	O	—	2	
					M	—	2	
c) Base metal 4) Tensile test specimens	Room temperature	DIN EN ISO 6892-1	R_m, $R_{p0.2}$, A, Z	—	—	1	—	3.2
	Room temperature	DIN EN ISO 6892-1	R_m, $R_{p0.2}$, A, Z	—	O	—	1	
					M	—	1	
Impact test specimens	33 °C	DIN EN ISO 148-1	KV_2, lateral expansion, mat fracture surface	—	—	3	—	
	33 °C	DIN EN ISO 148-1	KV_2, lateral expansion, mat fracture surface	—	O	—	3	
					M	—	3	

Table 25-2: Pressure-retaining components from ferritic cast steel; Extent of procedure qualification and production control tests on production welds (continued on next page)

d) Other tests and examinations

Where a weld is tested and examined in more than one heat treatment condition (e.g., simulation heat treatment condition, accompanying heat treatment condition), then the following tests shall be performed only in the simulation heat treatment condition

(1) Production of a photograph of an etched macrosection of the entire cross-section of the production weld.
Certification by inspection certificate 3.2 in accordance with DIN EN 10204.

(2) Analysis of the alloying elements of the weld metal, in the case of full penetration welds in the test layers O and M for: C, Mn, Si, P, S, Cr, Mo, Ni, Al, V, N, Cu.
Certification by inspection certificate 3.1 in accordance with DIN EN 10204.

(3) The hardness traverse HV 5 from the base metal to weld metal to base metal, in the case of full penetration welds in the test layers O and M, as well as over the entire weld depth at the centre of the weld metal.
Certification by inspection certificate 3.2 in accordance with DIN EN 10204.

(4) Micrograph of a transverse microsection, generally at a 200:1 enlargement, one each of the test layers in accordance with **Figure 25-1** and **Figure 25-2**.
Certification by inspection certificate 3.2 in accordance with DIN EN 10204.
The following shall be covered by this microphotograph:
- all-weld metal,
- transition between all-weld metal and base metal and
- (uninfluenced) base metal.

1) In the case of procedure qualifications for quenched and tempered and simulation stress-relief heat treated production weldings with a wall thickness equal to or less than 30 mm, only one test layer is required even for full penetration weldings.

2) See Sec. 3.3.7.3 (4). In the case of production control tests, no KV_2-T-curve is required.

3) In the case of procedure qualifications for quenched and tempered and simulation stress-relief heat treated production weldings the impact energy on the fusion line and 0.5 ± 0.3 mm next to the fusion line in the weld material at 0 °C and 33 °C shall be determined additionally.

4) A test or examination of the base metal is only required if no corresponding values of the base metal in the test layers O and M are available.

Table 25-2: Pressure-retaining components from ferritic cast steel; Extent of procedure qualification and production control tests on production welds (continued)

Tests and examinations		Requirements
a)	**Weld metal**	
	Tensile test (room temperature and 350 °C)	Like the base metal or as specified in the qualification testing of welding consumables.
	Impact test	KV_2 (0 °C), KV_2 (33 °C) and lateral expansion (33 °C) corresponding to the requirements specified for the base metal.
	Drop weight test	Demonstration of NDT temperature ≤ 0 °C
	Chemical analysis	Like qualification testing of the welding consumable.
b)	**Welded joint**	
	Tensile test (room temperature and 350 °C)	Like the minimum tensile strength specified for the base metal. Fracture location not specified.
	Impact test	KV_2 (0 °C), KV_2 (33 °C) and lateral expansion (33 °C) corresponding to the requirements specified for the base metal.
	Bend test	Bending angle 180° with a mandrel diameter 3a. Determination of the bending strain in accordance with DIN EN ISO 5173. Tear-ups are allowable, provided, they are caused by pores and incomplete fusion. Cracks without identifiable cause are allowable up to a length of 1.6 mm.
	Drop weight test	Demonstration of NDT temperature ≤ 0 °C
	Metallographic examination over the cross-section	The structure of the all-weld metal and of the heat-affected zone of the base metal shall show a perfect bead sequence and complete penetration of the joint (macrosection) as well as a perfect crystalline structure (microsection). Material discontinuities (microsection) are allowed, provided, they are definitely individual defects judged by their number and location. Not allowed are accumulations of such defects in the form of connected fields.
	Hardness traverse over a macro-section	The hardness 350 HV 5 shall normally not be exceeded in the heat affected zones. Any hardness peaks beyond this value occurring in small zones require additional examinations. In this case 350 HV 10 shall not be exceeded. Individual peak values beyond this specified hardness are allowed, provided, they are shown to be strictly localized.
c)	**Base metal**	
	Tensile test (room temperature) Impact test (33 °C)	Like specified in **Annex A** or in the appraisal, in so far as specified for the individual test layers.

Table 25-3: Pressure-retaining components from ferritic cast steel; requirements for procedure qualification and production control tests on production welds

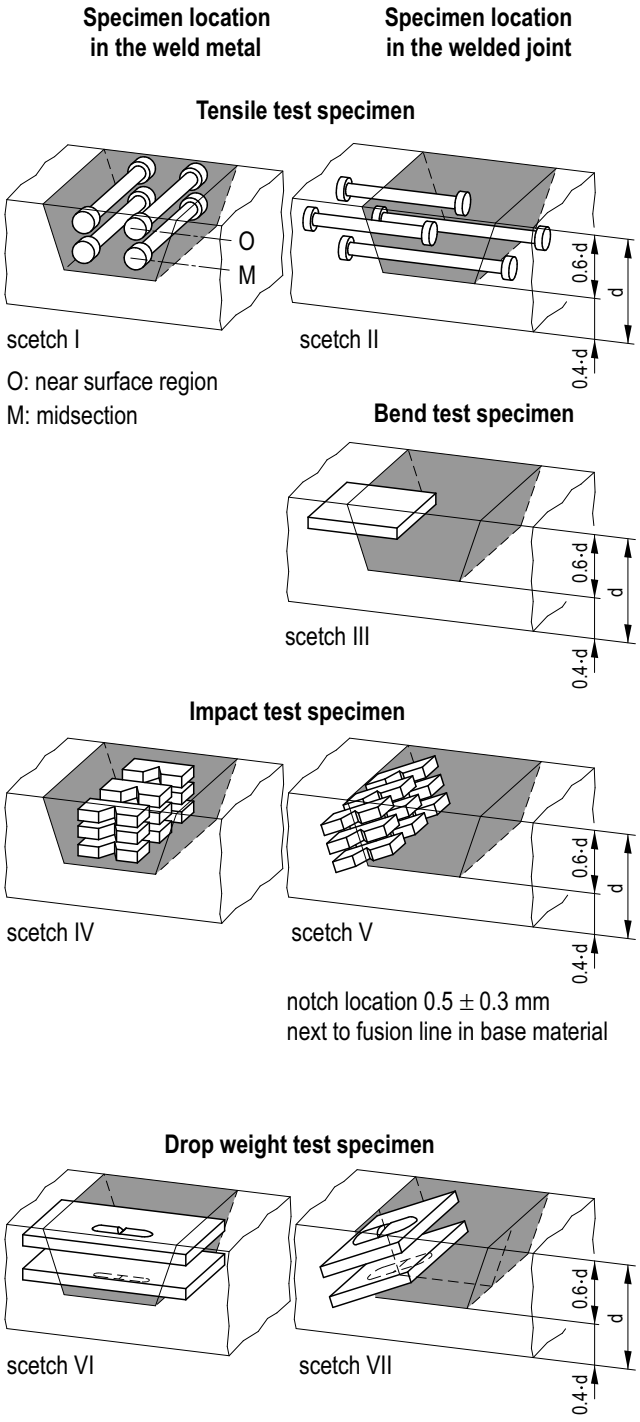


Figure 25-1: Specimen taking for procedure qualification of partial penetration welds

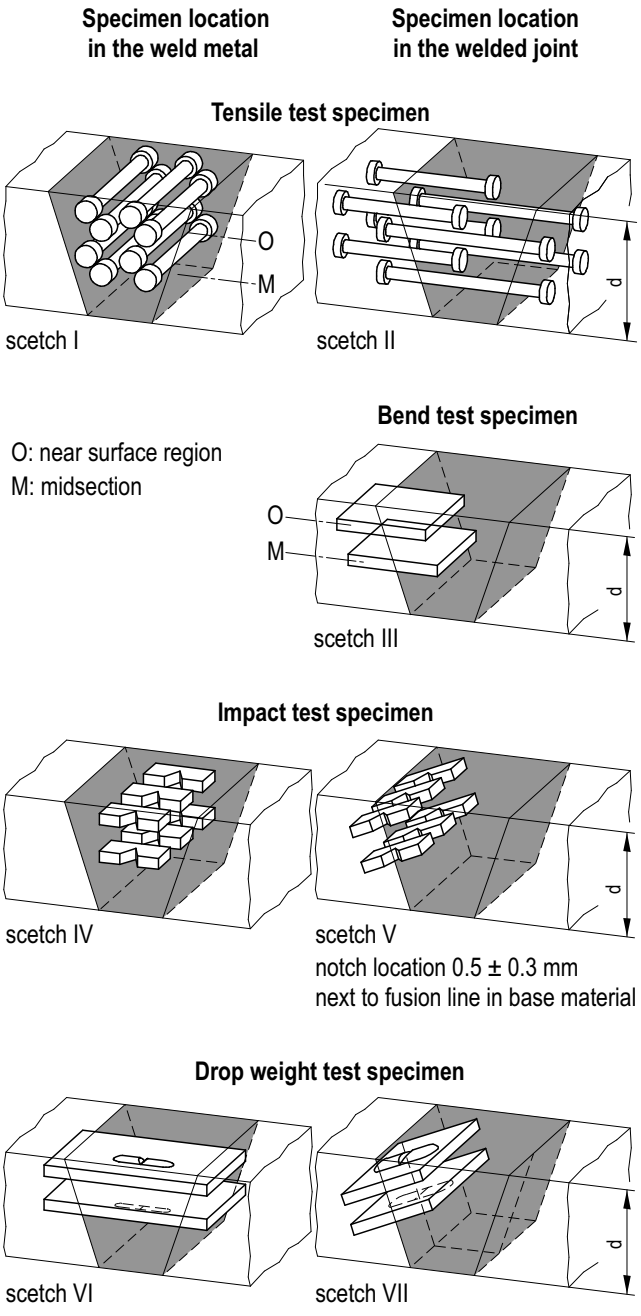


Figure 25-2: Specimen taking for procedure qualification of full penetration welds

25.4.3 Production control tests

25.4.3.1 Production control tests of production welding

(1) General requirements

The production control tests for production weldings shall be performed in accordance with the following requirements. One production control test correlated to a particular component weld may include other component welds within the same scope of the procedure qualification, provided these are welded within 12 months from completion of the production control test correlated to a particular component weld.

The test coupons shall be dimensioned such that the tests required in accordance with **Table 25-2** can be performed. It shall be ensured that sufficient reserve material is available. Sec. 11.1.4 of KTA 3201.3 applies to the storage of reserve material.

The test coupons shall be heat treated as is required for the component, i.e., the quenched and tempered test coupons shall be heat treated again after welding. The temperature-time sequences for the simulation stress-relief heat treatment shall be specified in consideration of Sec. 3.3.5.1.

(2) Specimen-taking

The test specimens shall be taken in accordance with **Figure 25-1** and **25-2.**

(3) Extent of testing

a) Mechanical-technological tests

The extent of tests for a quenched and tempered and simulation stress-relief treated production welding depends on the requirements of **Table 25-2**, however, the KV_2-T curves specified in **Table 25-2** are not required. If the test coupon

is attached to the corresponding casting from the same melt to be mutually quenched and tempered, or, if a similar temperature-time sequence is adequately demonstrated, a test of the mechanical properties of the base material is not required since these are obtained from the test on the casting itself.

Regarding the extent of tests for a stress-relief heat treated production welding, the specifications under Sec. 11 of KTA 3201.3 shall apply.

b) Non-destructive tests and inspections

A surface inspection, a radiographic testing and an ultrasonic testing shall be performed in the final heat treatment condition - quenched and tempered and stress-relief heat treated or simply simulation stress-relief heat treated condition. The extent of the non-destructive tests and inspections as well as the procedural details is specified under Sec. 25.6.

c) Other tests

The extent of other tests is specified in **Table 25-2**.

(4) Evaluation of the test results

The results of the mechanical-technological tests and the other tests shall meet the requirements under **Table 25-3**. The results of the non-destructive tests and inspections shall meet the acceptance criteria under Sec. 25.6.4.

25.4.3.2 Production control tests for construction weldings

(1) The requirements under Sec. 25.4.2.2.2 apply accordingly to construction weldings if the welding is anew quenched and tempered and stress-relief heat treated and those under Sec. 11.2 of KTA 3201.3 if the welding is simply stress-relief heat treated.

(2) The non-destructive tests and inspections shall be performed in accordance with Sec. 12 of KTA 3201.3.

25.5 Tests on the casting

25.5.1 Specimen-taking

(1) The test specimen shall be taken from cast-integral blocks that shall not be cooled (cast-integral coupons, surplus lengths, nozzle cut-outs).

(2) The number and distribution of the specimen-taking locations on the casting shall be as follows:

Casting weight, kg	Number of specimen-taking locations and distribution over the casting
≤ 6000	two specimen-taking locations as close to the feeder as possible
> 6000	two specimen-taking locations as close to the feeder as possible and one specimen-taking location as far away from the feeder as possible

(3) One test block shall be provided for each specimen-taking location. If cast-technology so demands, the block may also be divided into several parts.

(4) The thickness of the test blocks shall correspond to the governing wall thickness of the casting.

(5) The test blocks shall be taken after the last quenching and tempering, provided the non-destructive tests and inspections are not detrimentally affected. If on account of the non-destructive tests and inspections the removal must occur at an earlier time, then the test blocks shall subsequently be welded onto the casting to be mutually quenched and tempered.

(6) A removal by flame cutting is allowed, if

a) the casting is not impermissibly subjected to thermal effects

or

b) a stress-relief heat treatment is is carried out after flame cutting in the course of further fabrication, e.g. after production or constructional welding on the casting, and the heat affected zone is removed mechanically from the flame cutting zone on the casting.

(7) If the test blocks are taken by mechanical means, no stress-relief heat treatment is required after cutting off the test blocks.

(8) Regarding the size of the test blocks, Sec. 3.3.3 shall be observed.

(9) The test specimens shall lie at least one quarter of the quenched and tempered wall thickness beneath the length-side surface and at least one half of the quenched and tempered wall thickness beneath the end face surface of the test blocks.

(10) When taking test specimens from test blocks that were taken by flame cutting, attention shall be paid to observing a sufficient distance to the heat affected zone.

25.5.2 Extent of testing

25.5.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 4-1** shall be determined.

(2) Product analysis

On each casting at the specimen-taking locations in accordance with Sec. 25.5.1 the content by mass of elements specified in **Annex A**, **Table A 4-1** shall be determined.

25.5.2.2 Tests on simulation heat treated test specimens

25.5.2.2.1 Mechanical-technological tests

(1) Tensile test

Two test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

One set of test specimens each from each specimen-taking location shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C and 33 °C.

For one specimen-taking location it shall be demonstrated that the requirements for the upper shelf impact energy specified in Sec. 25 are met.

(3) Impact energy-versus-temperature curve

The impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4) for one specimen-taking location.

(4) Nil-ductility transition temperature

On one specimen-taking location from each casting the Nil-ductility transition temperature shall be demonstrated in accordance with Sec. 3.3.7.3 (5).

25.5.2.2.2 Metallographic examinations

The grain size shall be determined from one impact test specimen from each specimen-taking location; the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

25.5.2.3 Tests on accompanying test coupons

25.5.2.3.1 General requirements

In order to check the workmanship, test coupon material from one of the specimen-taking locations in accordance with Sec.

25.5.1 shall be provided for the following tests and shall be added to the corresponding component. Test coupon material from the other specimen-taking locations shall be kept in the as-removed condition.

25.5.2.3.2 Mechanical-technological tests

(1) Tensile test

Two test specimens shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

One set of test specimens each shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C and 33 °C.

(3) Nil-ductility transition temperature

The nil-ductility transition temperature shall be demonstrated in accordance with Sec. 3.3.7.3 (5).

25.5.2.4 Hardness test

(1) The requirements under Sec. 3.3.7.2 apply to hardness test.

(2) The hardness tests shall be performed on the outer surface along one surface line that shall include both nozzle regions and the flange, beginning near the edge and continuing in length intervals of not more than 1000 mm.

25.6 Non-destructive tests and inspections

25.6.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8.

25.6.2 Extent, type and point of time

25.6.2.1 General requirements

(1) The interrelation between extent, type and point of time of the non-destructive tests and inspections and the course of fabrication as well as the attendance of the authorized inspector in these tests and inspections is shown in **Table 25-1**.

(2) In the case of deviations from this sequence, a test and inspection sequence plan shall be established by the material manufacturer and submitted to the authorized inspector for design review.

25.6.2.2 Extent and type

(1) The castings shall be fully subjected to volumetric testing.

(2) Ultrasonic testing may be employed as volumetric testing of the base material

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 at at least two incidence directions being vertical to each other.

(3) If ultrasonic testing is employed as volumetric testing in other zones, 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.

(4) Volumetric testing shall be supplemented by angle-beam ultrasonic testing in accordance with Sec. 25.6.3.2.3.2 in regions where hot cracking may occur.

(5) Ultrasonic testing on weldings shall be performed on

a) attachment weldings,

b) locations of major fabrication weldings,

c) construction weldings,

d) all production weldings that are simply stress-relief heat treated

and

e) all those locations where radiographic testing leads to less reliable results or where the design review has identified structural or cast-technological peculiarities.

(6) All production weldings that are performed due to the results of radiographic or ultrasonic testing shall be subjected again to radiographic or ultrasonic testing.

(7) A surface inspection - if possible by magnetic particle testing - shall be performed on all surfaces. All cavities obtained from grinding out flaws and all fusion faces prepared for construction welding shall, likewise, be tested. In these cases, penetrant testing shall preferably be used.

25.6.2.3 Point of time

(1) Radiographic testing shall be performed after at least one quenching and tempering process has been carried out.

(2) Final ultrasonic testing shall be performed after the final tempering process. Where production weldings are required after final tempering, these locations shall be tested after stress-relief heat treatment.

(3) Final surface inspection shall be performed after the last heat treatment with the surfaces in the condition intended for delivery. In those cases where the component manufacturer carries out subsequent fabrication, these newly created surfaces shall be subjected to a renewed surface inspection.

25.6.3 Procedural requirements

25.6.3.1 Radiographic testing

(1) The procedural details of radiographic testing shall not be described and design reviewed prior to the beginning of fabrication but after the first true-to scale casting is available; the written radiographic testing procedure shall be set up in the form of test instructions on the basis of a reference point grid and shall be design reviewed. However, production weldings may be radiographed regardless of these test instructions, simply under consideration of their geometry and location.

(2) The radiographs created in conjunction with the establishment of the test instructions may be used for the acceptance test of component provided they correspond to the design reviewed test instruction.

(3) The castings shall be tested in accordance with DIN EN 12681. Basically, the requirements of test class B in accordance with DIN EN 12681 and of image quality class B in accordance with DIN EN ISO 19232-3 shall be met. If reasons are given for deviating from this requirement (e.g. for regions with operating stresses equal to or smaller than 50 N/mm^2), the requirements of test class A in accordance with DIN EN 12681 and of image quality class A in accordance with DIN EN ISO 19232-3 shall be met.

(4) Deviating from DIN EN 12681, no thickness compensations for contrast reduction are allowed in the case of a varying wall thicknesses.

(5) The completeness of the radiograph shall be demonstrated by a radiographic representation of the reference point grid.

(6) If the geometrical dimensions in part or as a whole do not permit radiographic testing from an interior radiation source, then, instead of an exterior circumferential radiography, a double-wall radiography in the sense of the overview radiographs in accordance with Fig. 6 of DIN EN 12681 is allowed provided, this leads to more meaningful results and an increase in the radiographed volume. This specification also applies to volumetric regions with cast-specific geometries as shown in Figs. 8 through 11 of DIN EN 12681.

(7) In addition to radiographic testing an ultrasonic test with angle-beam scanning as per sub-clause 25.6.3.2.3.2 shall be performed for detecting hot cracking. The procedure to be followed shall be laid down in the test instruction.

25.6.3.2 Ultrasonic testing

25.6.3.2.1 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.

25.6.3.2.2 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.

(4) The casting is deemed to be unrestrictedly testable if the distance of the reference reflector echo height as per **Table 25-4** to the background noise is at least 6 dB.

Wall thickness s, mm	Region	Diameter d_{eq} [1] of equivalent flat bottom hole to be detectable, mm
s ≤ 100	—	2
100 < s ≤ 300	—	3
—	special edge zone, welding ends	1.5
[1] d_{eq} : diameter of (equivalent) flat bottom hole		

Table 25-4: Requirements for ultrasonic testability of castings

(5) If the distance of the reference reflector echo height as per **Table 25-4** to the background noise is less than 6 dB at the end of the test region to be evaluated, ultrasonic testability is considered to be restricted. In such case, the diameter of the flat-bottom hole which is still detectable with a signal-to-noise ratio of at least 6 dB, shall be noted in the test report. Further proceedings (e.g. additional tests) shall be agreed upon with the authorized inspector.

25.6.3.2.3 Performance of test

25.6.3.2.3.1 General requirements

(1) The regions to be tested, the test technique to be applied and the incidence conditions shall be taken from **Table 25-5**. The procedure for testing special edge zones shall be fixed in the course of the design review.

(2) The casting regions shall be subjected to straight-beam scanning from all accessible surfaces.

(3) 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.

(4) In the case of welding ends angle-beam scanning shall be performed on cylindrical casting areas accessible from the outside only.

25.6.3.2.3.2 Testing for hot cracks

(1) The test shall be performed upon quenching and tempering.

(2) Angel-beam scanning shall be performed in regions where hot cracking may occur, e.g. regions of risers and chill casting, cross-sectional transitions.

(3) Where these regions are not known, the castings shall be subjected in the initial test, where possible, to 100% testing in four incidence directions with a 60 degree angle-beam probe.

25.6.3.2.4 Testing of production weldings

(1) Testing shall be performed upon the final heat treatment.

(2) In the case of production weldings with a thickness less than or equal to 15 mm (except for full penetration weldings) the test shall be performed with a dual-element straight beam probe from the weld metal surface. In all other cases, production weldings shall be tested in two directions normal to each other, if 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.

25.6.3.2.5 Recording

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. 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.

25.6.3.3 Surface inspection

Magnetic particle testing shall be performed in accordance with DIN EN 1369 and penetrant testing in accordance with DIN EN 1371-1.

25.6.4 Acceptance criteria

25.6.4.1 Radiographic testing

(1) The severity levels assigned to the casting regions shall be taken from **Table 25-6** 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.

25.6.4.2 Ultrasonic testing

(1) The severity levels assigned to the casting regions shall be taken from **Table 25-6**.

(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.

25.6.4.3 Surface inspection

25.6.4.3.1 General requirements

For the evaluation of magnetic particle and penetrant testing the severity levels shown in **Table 25-6** 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.

25.6.4.3.2 Weld cavities in fabrication welding

(1) Only those indications are acceptable that do not detrimentally affect the welding and that are not caused by the particular surface or volumetric flaw that will be removed.

(2) By agreement with the authorized inspector the welding supervisor shall make a decision regarding the possible effects on the weldability of the remaining flaws.

25.6.4.3.3 Fusion faces

The evaluation shall be performed in accordance with Sec. 12 of KTA 3201.3.

25.6.4.4 Production weldings

Production weldings shall be evaluated like the base material as specified under Secs. 25.6.4.1 and 25.4.6.2. If, by agreement with the authorized inspector, indications inside the fabrication weld are clearly shown to be inclusions, these may be considered to be individual defects and may be left as they are, provided their maximum length does not exceed one third of the respective wall thickness.

25.6.4.5 Construction welding

The non-destructive tests shall be performed in accordance with Sec. 12 of KTA 3201.3.

25.6.5 Test reports

(1) Test reports shall be prepared in accordance with Sec. 3.3.8.5 of all required or performed tests and examinations.

(2) These shall contain all information and data required to be able to reproduce the execution of the tests. The description of the indications from the volumetric testing shall be clear and unambiguous and shall allow a definite correlation to every location on the component.

25.7 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

25.8 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

25.9 Leak tightness test

(1) Each casting shall be subjected to an interior pressure test to show that it is leak tight; this test is usually performed during subsequent fabrication with the component in a corresponding condition.

(2) The internal pressure test shall be performed in accordance with 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.

25.10 Identification marking

The identification marking of the casting shall contain the following information:

a) identification of the material manufacturer,

b) material identification,

c) melt number,

d) test block number,

e) certification stamp of the authorized inspector.

25.11 Verification of quality characteristics

The results of the tests in accordance with Secs. 25.5.2.1, 25.5.2.2.2 and 25.5.2.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

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 25-5: Test conditions for ultrasonic testing

Casting Area	Severity level to be applied			
	PT [1]	MT [2]	RT [3]	UT [4]
Welding ends	SP1, CP1 [5]	SM1 [5]	1	1
Cast body	SP1, CP1, LP1, AP1	SM1, LM1, AM1,	2	2
Adjoining zones [6]	SP2, CP2, LP2, AP2	SM2, LM2, AM2,	—	—

[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. For special edge zones severity level 1 applies.

[5] During surface inspection linear indications or indications grouped in a chain are not permitted.

[6] Adjoining zones are zones located outside the pressure-retaining wall, e.g. feet, brackets, lugs.

Table 25-6: Severity levels to be applied

26 Valve bodies made from ferritic cast steel

26.1 Scope

(1) This section applies to cast valve bodies made of quenched and tempered ferritic cast steels.

(2) The requirements for the materials of these product forms are specified in Sec. A 4 and A 5.

26.2 Requirements

(1) Chaplets are not allowed in the finished condition of the casting.

(2) Feeders as well as large, cast-integral reinforcements that detrimentally affect quenching and tempering of the casting shall be removed prior to heat treatment.

(3) The upper shelf impact energy of the base metal shall be as least 100 J.

(4) The NDT temperature shall be equal to or less than 0 °C. If the required NDT temperature is exceeded, the customer, by agreement with the authorized inspector, and taking the safety analysis into account, shall decide on the further steps to be taken.

(5) The absorbed impact energy shall be determined for a temperature that is 33 K higher than the required NDT temperature. The absorbed impact energy shall be equal to or greater than 68 J and the lateral expansion equal to or greater than 0.9 mm. If these requirements are not met for one test specimen, additional tests shall be carried out to determine the temperature at which these requirements are met in the notched bar impact test. Regarding the application of such a product, it shall be considered that these higher temperature must be lower than the possible temperature under critical conditions (e.g. pressure test, incidents). In the case of notched bar impact tests a repetition of the test at the original temperature is allowed under the following conditions:

a) The average values of absorbed impact energy and lateral expansion shall not fall below the specified single values.
b) Only one test specimen may show values that fall below the specified single values.
c) The test specimen which failed by not obtaining the specified single values shall not show values of the absorbed impact energy and lateral expansion that are lower than the specified single values by not more than 14 J and not more than 0.13 mm, respectively.

When repeating a test, the failed test specimen shall be replaced by two additional test specimens. These two test specimens shall be taken from a location as close as possible to the specimen-taking location of the failed test specimen. Both of these test specimens are required to obtain the specified single values. Where the specified single values are not obtained in the re-examination, then that higher temperature shall be determined at which each single value meets the specified requirements. This shall be done on the basis of the available impact energy versus temperature curves which, if required, shall be extended by further tests.

26.3 General requirements regarding fabrication

(1) In addition to the manufacturing documents specified under Sec. 2.6.4, test and inspection sequence plan for the production and construction welds and lists of the corresponding production control tests shall be submitted to the authorized inspector for design review. In the case of production and construction welds a design review of the test and inspection sequence plan is not required, provided, the weldings are performed and tested in accordance with **Table 25-1**. Together with the instructions for the non-destructive tests and inspections, a plan with the co-ordinate system (reference grid points) shall be submitted.

(2) Besides these design review documents, the gating and feeding techniques describing the casting technology shall be documented by the saturation calculations depicting the locations of the feeders and the feeder regions. Furthermore, the locations and dimensions of the cast-on test blocks shall be depicted and justified. These documents serve as information only. They do not require a formal acceptance stamp by the authorized inspector.

(3) The description of the casting technology as well as the specifications under Sec. 26.6 shall be considered in establishing the instructions for non-destructive tests and inspections. In the case of regions of limited testability, the adequacy of component safety shall be demonstrated by sufficient replacement measures. If the adequacy of component safety cannot be demonstrated, it may become necessary to perform a destructive test on a prototype. The procedure of this destructive test (e.g. arrangements of the cuts) shall be specified in the design review.

26.4 Weldings

26.4.1 General requirements

(1) The requirements of DIN EN 1559-1 and DIN EN 1559-2 and, unless otherwise specified in sections 26.4.2 and 26.4.3, the requirements of KTA 3201.3 regarding welded joints shall apply to production and construction weldings.

(2) The surface of the weld groove for production weldings shall be subjected to a surface inspection in accordance with Sec. 25.6.

(3) Production and construction weldings generally require a renewed quenching and tempering. This shall be taken into account in the selection of welding consumables.

(4) Quenching and tempering of production and constructional weldings may be waived only by agreement with the authorized inspector. In this case, the welding locations shall be numbered and the number, size and location of the weldings shall be documented (final file).

(5) The authorized inspector shall be informed about any relatively large production and any constructional welding. These weldings shall be documented, the documents becoming part of the interim file.

Note:
See Sec. 25.4.1 (2) for definition of relatively large production welds.

(6) Minor production welds, e.g. for the removal of surface flaws, shall be avoided as far as possible. If they cannot be avoided, a subsequent stress-relief heat treatment is required.

(7) Any welds subjected only to a stress-relief heat treatment shall be welded higher by two bead layers; these shall, subsequently be ground flush to base metal height.

26.4.2 Procedure qualification

26.4.2.1 General requirements

Procedure qualifications in accordance with the following specifications are required for production weldings (partial and full penetration welding) and for construction weldings.

26.4.2.2 Procedure qualification for production welding

26.4.2.2.1 General requirements

(1) Production weldings

The weldings of the procedure qualification shall largely correspond to the conditions of the component welding.

The test coupons shall be dimensioned such that the tests in accordance with **Table 25-2** can be performed.

The test coupons for production welding shall be subjected to a heat treatment similar to the one planned for the component, i.e., the quenched and tempered test coupons shall after welding, be subjected anew to a heat treatment. The temperature-over-time sequence for the simulation stress-relief treatment shall be specified in due consideration of Sec. 3.3.5.1.

(2) Partial penetration welds

In the procedure qualification for partial penetration weldings on castings with a wall thickness equal to or greater than 100 mm a planar steel casting plate of the same material with a wall thickness of at least 100 mm shall be used. In the case of casting with a wall thickness less than 100 mm a planar steel casting plate of the same material with a wall thickness of at least 50 mm may be used.

To prepare the plates for welding they shall be chipped down to about 40 % of the wall thickness corresponding to the expected production welding.

(3) Full penetration weldings

The procedure qualification for full penetration weldings with a wall thickness d_p shall apply to any wall thickness d_B of the component to be welded up to $d_B = 1.5 \times d_p$.

A procedure qualification for full penetration weldings applies to any partial penetration welding under para (2) if the wall thickness is equal to or greater than 50 mm. Where the wall thickness of the procedure qualification for full penetration weldings is less than 50 mm, then, for a larger wall thickness, procedure qualifications for partial penetration weldings as under para (2) are required.

26.4.2.2.2 Procedure qualifications for quenched and tempered and simulation stress-relief heat treated production weldings

(1) Specimen-taking

Test specimens shall be taken in accordance with **Figures 25-1** and **25-2**.

(2) Extent of testing

a) Mechanical-technological tests

The requirements of **Table 25-2** shall apply to the extent of testing.

b) Non-destructive tests and inspections

The surfaces prepared for welding shall be subjected to a surface inspection.

A surface inspection, radiographic and ultrasonic testing shall be performed on the test coupon in the final heat treatment condition - quenched and tempered and simulation stress-relief heat treated. The extent of non-destructive testing as well as the procedural details is specified under Sec. 25.6.

c) Other tests

The extent of other tests is specified in **Table 25-2**.

(3) Evaluation of the test results

The results of the mechanical-technological tests and the other tests shall meet the requirements under **Table 25-3**.

The results of the non-destructive tests and inspections shall meet the acceptance criteria under Sec. 25.6.4.

26.4.2.2.3 Procedure qualification for only stress-relief heat treated production weldings

(1) Specimen-taking

The test specimens shall be taken in accordance with **Figures 25-1** and **25-2**.

(2) Extent of testing and evaluation of test results

The specification under Sec. 9.2 of KTA 3201.3 shall apply with regard to extent of testing and evaluation of results.

26.4.2.3 Procedure qualification for construction weldings

(1) The requirements under Sec. 26.4.2.2.2 apply accordingly to construction weldings if the weld is anew quenched and tempered and stress-relief heat treated and those under Sec. 9.2 of KTA 3201.3 apply if the welding is stress-relief heat treated only.

(2) The non-destructive tests and inspections shall be performed in accordance with Sec. 12 of KTA 3201.3.

26.4.3 Production control tests

26.4.3.1 Production control tests of production weldings

(1) General requirements

The production control tests for the production welds shall be performed in accordance with the following requirements. One production control test correlated to a particular component weld may include other component welds within the same scope of the procedure qualification provided, these are welded within 12 months from completion of the production control test correlated to a particular component weld.

The test coupons shall be dimensioned such that the tests required in accordance with **Table 25-2** can be performed. It shall be ensured that sufficient reserve material is available. Sec. 11.1.4 of KTA 3201.3 applies to the storage of reserve material.

The test coupons shall be heat treated as is required for the component, i.e., the quenched and tempered test coupons shall be heat treated anew after welding. The temperature-time sequences for the simulation stress-relief heat treatment shall be specified under consideration of Sec. 3.3.5.1.

(2) Specimen-taking

The test specimens shall be taken in accordance with **Figures 25-1** and **25-2**.

(3) Extent of testing

a) Mechanical-technological tests

The extent of testing for quenched and tempered and simulation stress-relief treated production welds depends on the requirements of **Table 25-2**, however, none of the KV_2-T curves under **Table 26-2** are required. If the test coupon is attached to the corresponding casting from the same melt to be mutually quenched and tempered, or, if a similar temperature-time sequence is adequately demonstrated, a test of the mechanical-technological properties of the base material is not required since these are obtained from testing the casting itself.

Regarding the extent of tests for stress-relief heat treated production welds, the specifications under Sec. 11 of KTA 3201.3 shall apply.

b) Non-destructive tests and inspections

A surface inspection, radiographic and ultrasonic testing shall be performed in the final heat treatment condition - quenched and tempered and simulation stress-relief heat treated. The extent of non-destructive testing as well as the procedural details is specified under Sec. 25.6.

c) Other tests

The extent of other tests is specified in **Table 25-2**.

(4) Evaluation of the test results

The results of the mechanical-technological tests and the other tests shall meet the requirements under **Table 25-3**.

The results of the non-destructive tests and inspections shall meet the acceptance criteria under Sec. 25.6.4.

26.4.3.2 Production control tests for construction weldings

(1) The requirements under Sec. 26.4.2.2.2 apply accordingly to construction weldings if the welding is anew quenched and tempered and stress-relief heat treated, and those under Sec. 11.2 of KTA 3201.3 if the welding is simply stress-relief heat treated.

(2) The non-destructive tests and inspections shall be performed in accordance with Sec. 12 of KTA 3201.3.

26.5 Tests on the casting

26.5.1 Specimen-taking

(1) The test specimens shall be taken from cast-integral test blocks that shall not be cooled (cast-integral coupons, surplus lengths, nozzle cut-outs). The test blocks shall be distributed over different locations of the casting.

(2) The number of test coupons shall be as follows:

Casting weight, kg	Number of test blocks per casting
≤ 500	1
> 500 up to ≤ 1000	2
> 1000	3

(3) The thickness of the cast-integral test blocks shall correspond to the governing wall thickness of the casting.

(4) The test blocks shall be cut off after the last heat treatment, provided the non-destructive tests and inspections are not detrimentally affected. If on account of the non-destructive tests and inspections the test blocks are to be cut off at an earlier time, then the test blocks shall subsequently be welded again onto the casting to be mutually heat treated.

(5) A removal by flame cutting is allowed, if

a) no impermissible thermal affection of the casting occurs

or

b) a stress-relief heat treatment is carried out after flame cutting in the course of further fabrication, e.g. after production or constructional welding on the casting, and the heat affected zone is removed mechanically from the flame cutting zone on the casting.

(6) If the test blocks are taken by mechanical means, no stress-relief heat treatment is required after cutting off the test blocks.

(7) In special cases the test specimens may also be removed from separately cast test coupons. These special cases shall be agreed upon between all parties involved (material manufacturer, customer and authorized inspector).

(8) Regarding the size of the test blocks, Sec. 3.3.3 shall be observed.

(9) The test specimens shall lie at least one quarter of the quenched and tempered wall thickness beneath the length-side-surface and at least one half of the quenched and tempered wall thickness beneath the end face surface of the test blocks.

(10) When taking test specimens from test blocks that were taken by flame cutting, attention shall be paid to observing a sufficient distance to the heat affected zone.

26.5.2 Extent of testing

26.5.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 4-1** or **Table A 5-1** shall be determined.

(2) Product analysis

On each casting, the content by mass of elements specified in **Annex A**, **Table A 4-1** or **Table A 5-1** shall be determined at one test block in the vicinity of the feeder.

26.5.2.2 Tests on simulation heat treated test specimens

26.5.2.2.1 Mechanical-technological tests

(1) Tensile test

Two test specimens from each test block shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

On one set of test specimens from each test block shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C and 33 °C.

On one test block it shall be demonstrated that the requirements under Sec. 26.2 for the upper shelf impact energy are met.

(3) Impact energy-versus-temperature curve

The impact-energy-versus-temperature curve shall be determined in accordance with Sec. 3.3.7.3 (4) on one test block.

(4) Nil-ductility transition temperature

On one specimen-taking location from each casting the nil-ductility transition temperature shall be demonstrated in accordance with Sec. 3.3.7.3 (5).

On one test block from each casting the nil-ductility transition temperature shall be demonstrated in accordance with Sec. 3.3.7.3 (5).

26.5.2.2.2 Metallographic examinations

The grain size shall be determined from one impact test specimen for each test block; the microstructure shall be evaluated and documented in accordance with Sec. 3.3.7.4.

26.5.2.3 Hardness test

(1) The requirements under Sec. 3.3.7.2 shall apply to the hardness test.

(2) The hardness tests shall be performed on the outer surface along one surface line that shall include both nozzle regions and the flange, beginning near the edge and continuing in length intervals of not more than 1000 mm.

26.6 Non-destructive tests and inspections

The requirements under Sec. 25.6 shall apply. In addition to the stipulations of clause 25.6.3.1 the following shall apply to radiographic testing:

Steel castings with an outer diameter not exceeding 200 mm shall be radiographed as per DIN EN 12681, Figure 7. In the case of steel castings with an outer diameter exceeding 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.

26.7 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

26.8 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

26.9 Leak tightness test

(1) Each casting shall be subjected to pressure test to show that it is leak tight; this test is usually performed during subsequent fabrication with the component in a corresponding condition.

(2) The internal pressure test shall be performed in accordance with 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.

26.10 Identification marking

The identification marking of the casting pieces shall contain the following information:

a) identification of the material manufacturer,

b) material identification,

c) melt number,

d) test block number,

e) certification stamp of the authorized inspector.

26.11 Verification of quality characteristics

The results of the tests in accordance with Sec. 26.5.2.1, 26.5.2.2.2 and 26.5.2.3 shall be certified by inspection certificate 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificate 3.2 in accordance with DIN EN 10204.

27 Valve bodies from austenitic cast steel

27.1 Scope

(1) This section applies to valve bodies from austenitic cast steels.

(2) The requirements for the materials of these product forms are specified in Sec. A 6.

27.2 Requirements

(1) Chaplets are not allowed in the finished condition of the casting.

(2) Feeders as well as large, cast-integral reinforcements that detrimentally affect tempering of the casting shall be removed prior to heat treatment.

(3) The base material shall have a delta ferrite content of at least 2 % and not exceeding 12 %. A close ferrite lattice structure is not permitted.

27.3 General requirements regarding fabrication

(1) In addition to the manufacturing documents specified under Sec. 2.6.4, test and inspection sequence plans for production and construction welds, welding schedules as well as lists of the corresponding production control tests shall be submitted to the authorized inspector for design review. In the case of production and construction welds a design review of the test and inspection sequence plans is not required provided, the weldings are performed and tested in accordance with **Table 27-1**. Together with the instructions for the non-destructive tests and inspections, a plan with the co-ordinate system (reference point grid) shall be submitted.

(2) Besides these design review documents, the gating and feeding techniques describing the casting technology shall be documented by the saturation calculations depicting the locations of the feeders and the feeder regions. Furthermore, locations and dimensions of cast-integral test blocks shall be depicted and justified. These documents serve as information only. They do not require a formal acceptance stamp by the authorized inspector.

(3) The description of the casting technology as well as the specifications under Sec. 27.6 shall be considered in establishing the instructions for non-destructive tests and inspections. Where regions of limited testability are present, the adequacy of component safety shall be demonstrated by sufficient replacement measures. If the adequacy of component safety cannot be demonstrated, it may become necessary to perform a destructive test on a prototype. The procedure of this destructive test (e.g. arrangements of the cuts) shall be specified in the design review.

27.4 Weldings

27.4.1 General requirements

(1) The requirements of DIN EN 1559-1 and DIN EN 1559-2 and, unless otherwise specified in sections 27.4.2 and 27.4.3, the requirements of KTA 3201.3 regarding welded joints shall apply to production and construction weldings.

(2) Production welding shall generally be solution annealed (fabrication flow sheet, cf. **Table 27-1**). However, no solution annealing and quenching is required for production and construction weldings provided, it has been shown that the toughness requirements in accordance with KTA 3201.3, Table 9-6, are met. In this case, the welding locations shall be numbered and the number, size and location of the weldings shall be documented. A stress-relief heat treatment shall be avoided.

(3) The authorized inspector shall be informed about any relatively large production and any construction welding that requires solution annealing. These weldings shall be documented, with the documents becoming part of the interim file.

Note:
See Sec. 25.4.1 (2) for definition of relatively large production welds.

(4) All weldings shall be ground to base metal height.

27.4.2 Procedure qualification

27.4.2.1 General requirements

Procedure qualifications in accordance with the following specifications are required for production weldings (partial penetration and full penetration welding) and for construction welds.

27.4.2.2 Procedure qualifications for production weldings

27.4.2.2.1 General requirements

(1) Production weldings

The weldings of the procedure qualification shall largely correspond to the conditions of the component weldings including heat treatment. The test coupons shall be dimensioned such that the tests in accordance with **Table 27-2** can be performed. The test coupons shall be subjected to a heat treatment similar to the one planned for the component, i.e. solution annealing and quenching.

(2) Partial penetration welds

In the procedure qualification for partial penetration welds on castings with a wall thickness equal to or greater than 100 mm a planar cast steel plate of the same material and a wall thickness of at least 100 mm shall be used. In the case of castings with a wall thickness smaller than 100 mm a planar cast steel plate of the same material and a wall thickness of at least 50 mm may be used.

When preparing the plates for welding, they shall be chipped down to about 40 % of the wall thickness corresponding to the expected production weld.

(3) Full penetration welds

A procedure qualification for full penetration welds on the wall thickness d_p shall apply to any wall thickness d_B of the final component up to $d_B = 1.5 \times d_p$.

A procedure qualification for full penetration welds applies to any partial penetration weld under para. (2) if their wall thickness is equal to or greater than 50 mm. If the thickness of the procedure qualification for full penetration welds is less than 50 mm, then for a larger wall thickness procedure qualifications are required for partial penetration welds as under para (2).

27.4.2.2.2 Specimen-taking

The test specimens shall be taken in accordance with **Figures 27-1** and **27-2**.

27.4.2.2.3 Extent of testing

(1) Mechanical-technological tests

The extent of testing is specified in **Table 27-2**.

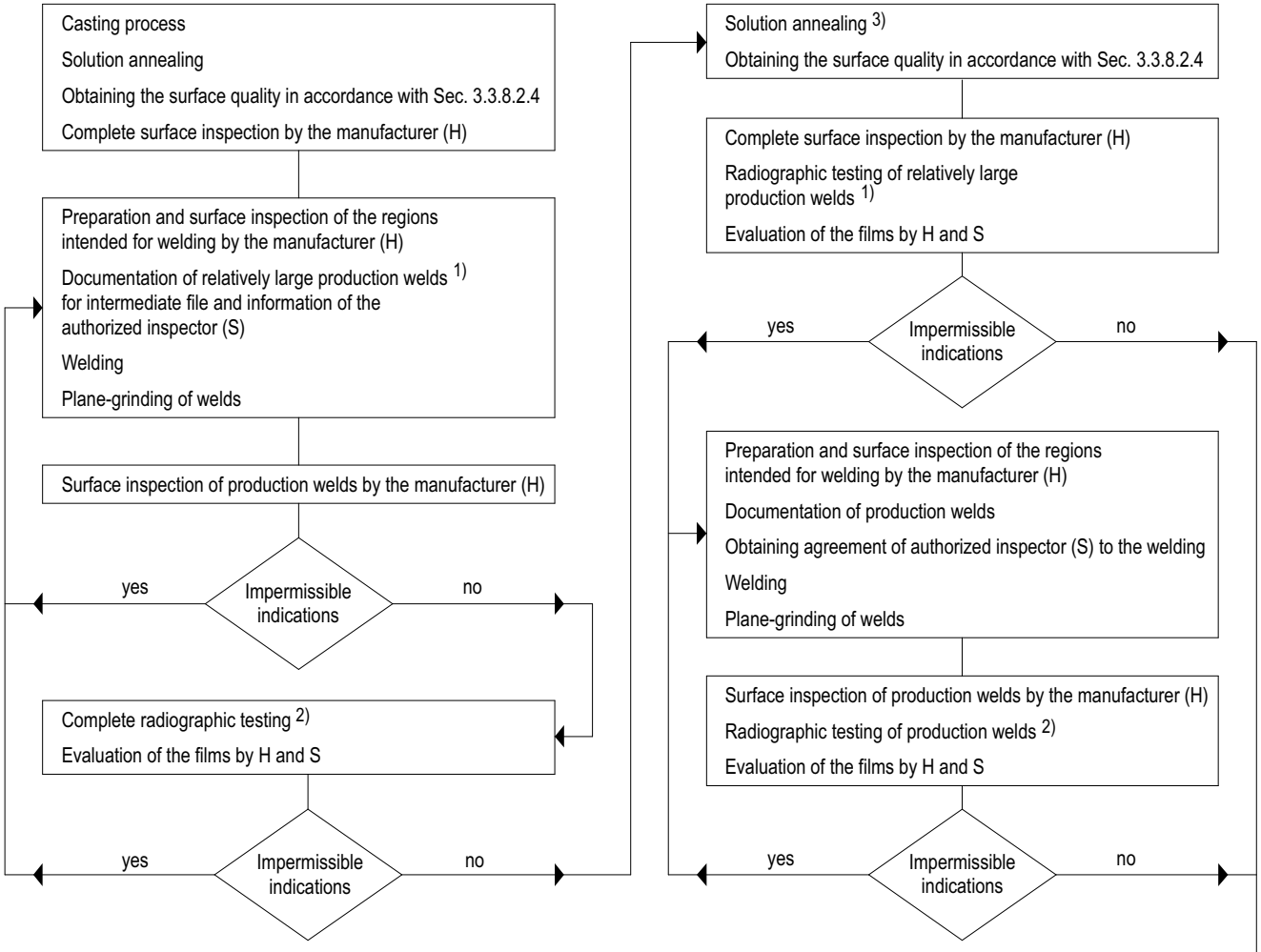
(2) Non-destructive tests and inspections

The surfaces prepared for welding shall be subjected to a surface inspection.

A penetrant testing and a radiographic testing shall be performed on the test coupon in the final heat treatment condition. The extent of non-destructive testing as well as the procedural details is specified under Sec. 27.6.

(3) Other tests

The extent of the other tests is specified in **Table 27-2**.



1) See Sec. 25.4.1 (2) for definition of relatively large production welds.

2) Note regarding further radiographic tests: radiographed casting regions with allowable indications do not have to be retested.

3) Heat treatment for obtaining mechanical-technological characteristics.

4) If, in exceptional cases during subsequent fabrication, production welding becomes necessary for the removal of casting flaws at a far-advanced stage of fabrication, then, by agreement with the authorized inspector, deviations from the standard procedure as described in this flow chart are allowed.

Table 27-1: Fabrication flow chart for pressure-retaining components made of austenitic cast steel

Type of specimen	Test temperature	Test in accordance with	Value to be determined	Test specimen location Fig./Sketch	Test specimen layer Fig. 27-2	Number of test specimen 1)		Inspection certificate to DIN EN 10204
						partial penetration weld	full penetration weld	
a) Weld metal Tensile test specimens	Room temperature	DIN EN ISO 6892-1	R_m, A, Z, $R_{p0.2}$, $R_{p1.0}$	27-1/I	—	1	—	3.2
	350 °C	DIN EN ISO 6892-2	R_m, A, Z, $R_{p0.2}$, $R_{p1.0}$	27-1/I	—	1	—	
	Room temperature	DIN EN ISO 6892-1	R_m, A, Z, $R_{p0.2}$, $R_{p1.0}$	27-2/I	O	—	1	
					M	—	1	
	350 °C	DIN EN ISO 6892-2	R_m, A, Z, $R_{p0.2}$, $R_{p1.0}$	27-2/I	O	—	1	
					M	—	1	
Impact test specimens	Room temperature	DIN EN ISO 148-1	KV_2	27-1/IV	—	3	—	
				27-2/IV	O	—	3	
					O	—	3	
b) Welded joint Tensile test specimens	Room temperature	DIN EN ISO 6892-1	R_m, fracture location	27-1/II	—	1	—	3.2
				27-2/II	O	—	1	
					M	—	1	
Bend test specimens	Room temperature	DIN EN ISO 5173	Bending angle to first crack	27-1/III	—	1	—	
				27-2/III	O	—	1	
					M	—	1	
Impact test specimens	Room temperature	DIN EN ISO 148-1	KV_2	27-1/V	—	3	—	
				27-2/V	O	—	3	
					M	—	3	
IK-Probe	Room temperature	DIN EN ISO 3651-2			—	1	—	3.1
					O	—	1	
c) Base metal 2) Tensile test specimens	Room temperature	DIN EN ISO 6892-1	R_m, A, Z, $R_{p0.2}$, $R_{p1.0}$		—	1	—	3.2
					O	—	1	
					M	—	1	
Impact test specimens	Room temperature	DIN EN ISO 148-1	KV_2		—	3	—	
					O	—	3	
					M	—	3	

d) Other tests and examinations

(1) Production of a photograph of an etched macrosection of the entire cross-section of the production weld.
Certification by inspection certificate 3.2 in accordance with DIN EN 10204.

(2) Analysis of the alloying elements of the weld metal, in the case of full penetration welds in the test layers O and M for: C, Mn, Si, P, S, Cr, Mo, Ni, Nb, Cu, Co.
Certification by inspection certificate 3.1 in accordance with DIN EN 10204.

(3) Micrograph of a transverse microsection, generally at a 200:1 enlargement, one each of the test layers in accordance with Figure 27-1 and 27-2, including determination of the delta ferrite content.
Certification by inspection certificate 3.2 in accordance with DIN EN 10204.
The following shall be covered by this microphotograph:
- all-weld metal,
- transition between all-weld metal and base metal as well as
- (uninfluenced) base metal.

1) In the case of wall thicknesses equal to or less than 30 mm, only one test layer is required even for full penetration weldings.

2) A test or examination of the base metal is only required if no corresponding values of the base metal in the test layers O and M are not available.

Table 27-2: Valve bodies made from austenitic cast steel
Extent of procedure qualification and production control tests on production welds

Tests and examinations	Requirements
a) Weld metal	
Tensile test (Room temperature and 350 °C)	Like the base metal or as specified in the qualification testing of welding consumables.
Impact test (Room temperature)	KV_2 Unannealed or solution annealed: ≥ 70 J / ≥ 60 J Stress-relief heat treated: ≥ 55 J / ≥ 40 J
Chemical analysis	Like qualification testing of the welding consumable.
b) Welded joint	
Tensile test (Room temperature)	Like the minimum tensile strength specified for the base metal.
Impact test (Room temperature)	KV_2 Unannealed or solution annealed: ≥ 70 J / ≥ 60 J Stress-relief heat treated: ≥ 55 J / ≥ 40 J
Bend test	Bending angle 180° with a mandrel diameter three times the specimen thickness a. Determination of the bending strain in accordance with DIN EN ISO 5173. Tear-ups are allowable, provided, they are caused by pores and incomplete fusion. Cracks without identifiable cause are allowable up to a length of 1.6 mm.
Metallographic examination over the cross-section	The structure of the all-weld metal and of the heat-affected zone of the base metal shall show a perfect bead sequence and complete penetration of the joint (macrosection) as well as a perfect crystalline structure (microsection). Material discontinuities (microsection) are allowed, provided, they are definitely individual defects judged by their number and location. Not allowed are accumulations of such defects in the form of connected fields.
c) Base metal	
Tensile test (Room temperature) Impact test (Room temperature)	Like specified in **Annex A** or in the appraisal, in so far as specified for the individual test layers.

Table 27-3: Valve bodies made from austenitic cast steel
Requirements for procedure qualification and production control tests on production welds

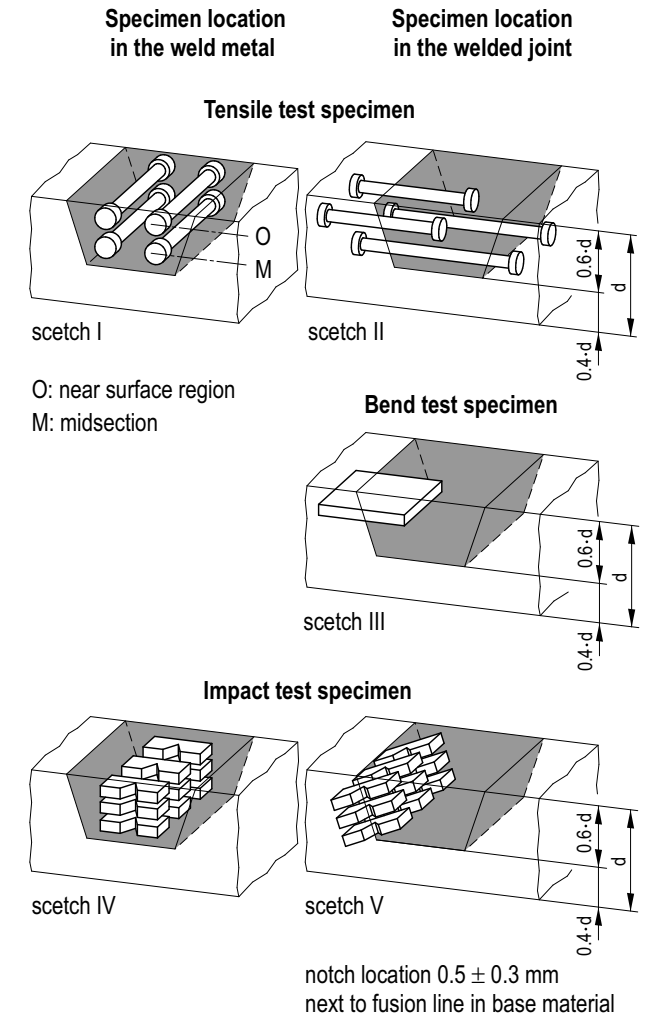


Figure 27-1: Specimen taking for procedure qualification of partial penetration welds

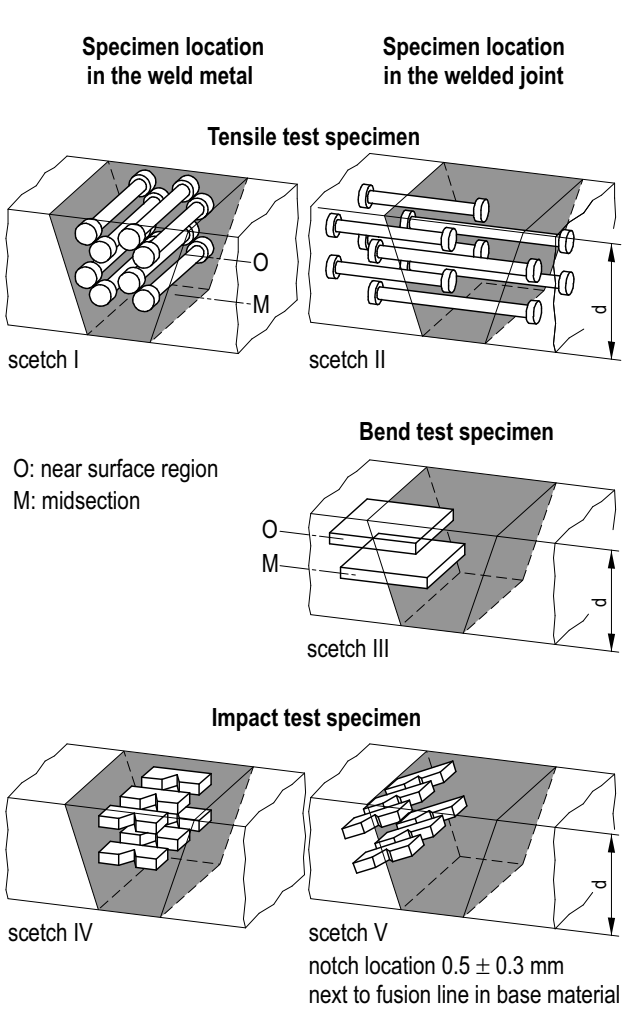


Figure 27-2: Specimen taking for procedure qualification of full penetration welds

27.4.2.2.4 Evaluation of the test results

The results of mechanical-technological tests and the other tests shall meet the requirements under **Table 27-3**.

The results of the non-destructive tests and inspections shall meet the acceptance criteria under 27.6.4.

27.4.2.3 Procedure qualification for construction weldings

(1) The requirements under Sec. 27.4.2.2 apply accordingly to construction weldings.

(2) The non-destructive tests and inspections shall be performed in accordance with Sec. 12 of KTA 3201.3.

27.4.3 Production control tests

27.4.3.1 Production control tests of production weldings

(1) General requirements

The production control tests for production weldings shall be performed in accordance with the following requirements. One production control test correlated to a particular component welding may include other component weldings within the same scope of the procedure qualification provided these are welded within 12 months from completion of the production control test correlated to a particular component weld.

The test coupons shall be dimensioned such that the tests specified in **Table 27-2** can be performed. It shall be ensured that sufficient reserve material is available. Sec. 11.1.4 of KTA 3201.3 applies to the storage of reserve material.

The test coupons shall be heat treated as is required for the component, i.e., solution annealed and quenched.

(2) Specimen-taking

The test specimen shall be taken in accordance with **Figure 27-1** and **27-2**.

(3) Extent of testing

a) Mechanical-technological tests

The extent of tests is specified in **Table 27-2**. If the test coupon is attached to the corresponding casting from the same melt to be mutually solution annealed and quenched, or, if a similar temperature-time sequence is adequately demonstrated, a test of the mechanical-technological properties of the base material is not required since these are obtained from testing the casting itself.

b) Non-destructive tests and inspections

Both penetrant radiographic testing shall be performed in the final heat treatment condition - solution annealed and quenched. The extent of testing as well as procedural details are specified under Sec. 27.6.

c) Other tests

The extent of the other tests is specified in **Table 27-2**.

(4) Evaluation of the test results

The results of the mechanical-technological tests and the other tests shall meet the requirements under **Table 27-3**.

The results of the non-destructive tests and inspections shall meet the acceptance criteria under 27.6.4.

27.4.3.2 Production control tests for construction welds

(1) The requirements under Sec. 27.4.3.1 shall apply accordingly.

(2) The non-destructive tests and inspections shall be performed in accordance with Sec. 12 of KTA 3201.3.

27.5 Tests on castings

27.5.1 Specimen-taking

(1) The test specimen shall be taken from cast-integral test blocks that shall not be cooled (cast-integral coupons, surplus lengths, nozzle cutouts). The test blocks shall be distributed over different locations of the casting.

(2) The number of test blocks shall be as follows:

Casting weight, kg	Number of test blocks per casting
≤ 500	1
> 500 up to ≤ 1000	2
> 1000	3

(3) The thickness of the test blocks shall correspond to the governing wall thickness of the casting.

(4) The test blocks shall be cut-off after the last solution annealing and quenching provided the non-destructive tests and inspections are not detrimentally affected. If on account of the non-destructive tests and inspections the test blocks are to be cut off at an earlier time, then the test coupons shall subsequently be welded again onto the casting to be mutually solution annealed and quenched.

(5) In special cases the test specimens may also be taken from cast melt test coupons. These special cases shall be agreed upon between the parties involved (material manufacturer, customer and authorized inspector).

(6) Regarding the size of the test blocks, Sec. 3.3.3 shall be observed. If possible, the test specimens shall lie at least one quarter of the wall thickness beneath the surface of the test blocks. When taking test specimens from test coupons that were taken by flame cutting, attention shall be paid to observing a sufficient distance to the heat affected zone.

27.5.2 Extent of testing

27.5.2.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 6-1** shall be determined.

(2) Product analysis

On each casting the content by mass of elements specified in **Annex A**, **Table A 6-1** shall be determined on one test block in the vicinity of the feeder.

27.5.2.2 Mechanical-technological tests

(1) Tensile test

Two test specimens from each test block shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Impact test

On one set of test specimens from each test block shall be tested in accordance with Sec. 3.3.7.3 (3) at 20 °C.

27.5.2.3 Resistance to intergranular corrosion

The resistance to intergranular corrosion shall be demonstrated in accordance with Sec. 3.3.7.6 on one test block from one casting for each melt and heat treatment lot.

27.5.2.4 Determination of the delta ferrite content

The delta ferrite content shall be determined by a metallographic analysis (see **Annex D**) on one test block for each casting after the final heat treatment.

27.6 Non-destructive tests and inspections

27.6.1 General requirements

The following requirements apply in addition to the requirements under clause 3.3.8.

27.6.2 Extent, type and point of time

27.6.2.1 General requirements

(1) The interrelation between extent, type and point of time of the non-destructive tests and inspections and the course of fabrication as well as the attendance of the authorized inspector in these tests and inspections is shown in **Table 27-1**.

(2) In the case of deviations from the sequence, a test and inspection sequence plan shall be established by the manufacturer and submitted to the authorized inspector for design review.

27.6.2.2 Extent and type

(1) The castings shall be fully radiographed.

(2) A surface inspection by means of penetrant testing shall be performed on all surfaces. All hollow portions arising from grinding out flaws shall be tested, too.

(3) All production weldings shall be subjected to both penetrant and radiographic testing.

27.6.2.3 Point of time

(1) The radiographic testing shall be performed after at least one solution annealing.

(2) Radiographic testing shall be performed on all production weldings after final solution annealing and on any relatively large solution annealed production weldings.

Note:
See Sec. 25.4.1 (2) for definition of relatively large production welds.

(3) In those cases where the valve manufacturer carries out subsequent fabrication, these newly created surfaces shall be subjected to a renewed surface inspection.

27.6.3 Procedural requirements

27.6.3.1 Radiographic testing

(1) The requirements under Sec. 25.6.3.1 shall apply

(2) Where the allowed radiation energies lead to indications caused by microstructural effects (e.g. due to X-ray diffraction), control radiographs shall be made with higher radiation energies or different radiographic arrangements or by enlarging the focus-to-object distance. The procedure as well as the evaluation of these additional measures shall be agreed upon with the authorized inspector.

(3) In addition, a selected radiographic testing of the base material shall be performed in regions where hot cracking may occur, e.g. regions of risers and chill casting, cross-sectional transitions, if these regions are not covered appropriately by the volumetric testing.

27.6.3.2 Surface inspection

The inspection shall be performed in accordance with DIN EN 1371-1.

27.6.4 Acceptance criteria

27.6.4.1 Radiographic testing

The requirements under Sec. 25.6.4.1 shall apply.

27.6.4.2 Surface inspection

The requirements under Sec. 25.6.4.3 shall apply.

27.6.4.3 Production weldings

Production welds shall be evaluated like the base material as specified under Sec. 26.4.1 (1). If, by agreement with the authorized inspector, indications inside the production weld are clearly shown to be inclusions, these may be considered individual flaws and may be left as they are provided their maximum length does not exceed one third of the respective wall thickness.

27.7 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

27.8 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

27.9 Leak tightness test

(1) Each casting shall be subjected to a pressure test to show that it is leak tight; this test is usually performed during subsequent fabrication with the component in a corresponding condition.

(2) The internal pressure test shall be performed in accordance with 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.

27.10 Identification marking

The identification marking of the casting shall contain the following information:

a) identification of the material manufacturer,

b) material identification,

c) melt number,

d) test block number,

e) certification stamp of the authorized inspector.

27.11 Verification of quality characteristics

The results of the tests in accordance with Secs. 27.5.2.1, 27.5.2.3 and 27.5.2.4 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of all the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

28 Bars and forgings from stainless martensitic steel

28.1 Scope

(1) This section applies to bars and forgings from stainless martensitic steels that are used, e.g., for the pressure tubes of control rod drives, sealing housing and sealing cover of the primary coolant pump as well as for parts of solenoid valves.

(2) The requirements for the materials of this product form are specified under Sec. A 8.

28.2 Tests and examinations

28.2.1 Test lots and specimen-taking locations

28.2.1.1 Bars

(1) Bars with a quenched and tempered weight equal to or smaller than 500 kg shall be tested in lots. Bars of the same melt and heat treatment and of similar dimensions shall be grouped into lots of 500 kg each, however, into lots of no more than 10 pieces. One bar from each lot shall be tested at one end.

(2) Bars with a quenched and tempered weight exceeding 500 kg shall be tested individually. Bars with a quenched and tempered length equal to or smaller than 2000 mm shall be tested at one end. Bars with a quenched and tempered length exceeding 2000 mm shall be tested at both ends in which case the specimen-taking locations shall normally be offset by 180 degrees to each other.

(3) Where practicable the tests shall be performed with transverse test specimens. Longitudinal test specimens are allowed in the case of bars with a quenched and tempered diameter, thickness or width equal to or less than 140 mm.

28.2.1.2 Forgings

(1) Forgings with a quenched and tempered weight equal to or smaller than 500 kg shall be tested in lots. Forgings of the same melt and heat treatment and of similar dimensions shall be grouped into lots of 500 kg each, however, into lots of no more than 10 pieces. One set of test specimens from each lot shall be tested.

(2) Forgings with a quenched and tempered weight of more than 500 kg but not exceeding 5000 kg shall be tested individually. Two test coupons shall be taken from each forging at locations which shall normally be offset by 180 degrees to each other. If the quenched and tempered diameter exceeds the quenched and tempered length, the two specimen-taking locations shall normally be located either at the head or the tail end of the forging. If the quenched and tempered diameter is smaller than the quenched and tempered length, one of the specimen-taking location shall normally be at the head end and the other at the tail end of the forging.

(3) Forgings with a quenched and tempered weight exceeding 5000 kg shall be tested individually. Three test coupons shall be taken from each forging. If the quenched and tempered diameter is equal to or larger than the quenched and tempered length (e.g. rings or discs), the three specimen-taking locations shall be located at one side of the forging and offset by 120 degrees to each other. If the quenched and tempered diameter is smaller than the quenched and tempered length (e.g. rod or hollow body), the three specimen locations shall be distributed over both sides of the forgings.

(4) As far as possible, the test coupons shall be taken with an orientation perpendicular to the direction of major deformation.

(5) The specimen-taking locations shall be specified in the materials specimen-taking plan in accordance with Sec 2.6.4.2.4.

28.2.2 Specimen-taking location

The test coupons shall be taken from a location that is T/4, however, not more than 80 mm under the lengthwise surface and under the end face surfaces, where T is equal to the quenched and tempered diameter or quenched and tempered wall thickness.

28.2.3 Extent of testing

28.2.3.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 8-1** shall be determined.

(2) Product analysis

A product analysis to determine the content by mass of elements specified in **Annex A**, **Table A 8-1** shall be performed:

a) for one piece from each lot in the case of product forms with a quenched and tempered weight equal to or smaller than 500 kg,

b) for one specimen-taking location from each piece in the case of product forms with a quenched and tempered weight of more than 500 kg but not exceeding 5000 kg, and

c) for one specimen-taking location from both ends of each piece in the case of product forms with a quenched and tempered weight exceeding 5000 kg.

28.2.3.2 Tests in the quenched and tempered condition

28.2.3.2.1 Mechanical-technological tests

(1) Tensile test

Two tensile tests in accordance with Sec. 3.3.7.3 (1) shall be performed for each specimen-taking location, one at room temperature and one at design temperature.

(2) Impact test

On one set of impact test specimens from each specimen-taking location shall be tested in accordance with Sec. 3.3.7.3 (3) at room temperature.

28.2.3.2.2 Hardness test

The hardness shall be determined on each piece to verify the tempering uniformity.

28.2.3.2.3 Non-destructive tests and inspections

The specifications under Sec. 14.4 shall apply to bars and those under Sec. 11.4 to forgings.

28.2.3.3 Tests on accompanying test coupons for pressure tubes of control rod drives

(1) If the products are stress-relief heat treated or tempered during subsequent fabrication, accompanying test coupons shall be kept available.

(2) Each heat treatment lot for stress-relief heat treatment or tempering during subsequent fabrication shall be accompanied by one set of accompanying test coupons for every test lot or test piece of the original product forms.

(3) Under consideration of the specimen orientation as specified under Secs. 28.2.1.1 or 28.2.1.2, the following tests shall be performed:

a) one tensile test in accordance with Sec. 3.3.7.3 (1) at room temperature,

b) one tensile test in accordance with Sec. 3.3.7.3 (1) at design temperature and

c) one impact test in accordance with Sec. 3.3.7.3 (3) at room temperature on one set of test specimens.

28.3 Identification marking

In addition to the specification under Sec. 3.5 the following applies:

In the case of a lot-wise testing in accordance with Secs. 28.2.1.1 or 28.2.1.2, each part shall be marked with the lot number.

28.4 Materials identification check

Each product shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9. Where the products have been subjected to a product analysis in accordance with Sec. 28.2.3.1 (2), this analysis shall be considered a valid materials identification check.

28.5 Visual inspection

The requirements under Sec. 3.3.7.10 shall apply to the visual inspection.

28.6 Check for dimensional accuracy

The requirements under Sec. 3.3.7.8 shall apply to the check for dimensional accuracy.

28.7 Verification of quality characteristics

The results of the tests in accordance with Secs. 28.2.3.1 and 28.2.3.2.2 shall be certified by inspection certificates 3.1 in accordance with DIN EN 10204, the results of the other tests by inspection certificates 3.2 in accordance with DIN EN 10204.

29 Product forms from ferritic steels for integral connections to the reactor coolant pressure boundary

29.1 Scope

This section applies to the product forms from ferritic steels for integral connections to components of the primary coolant system, e.g. for the component support structures and pipe-whip restraints.

29.2 Requirements

(1) With regard to the different product forms, the appropriate requirements laid down in Sec. 4, 7, 12, 14 or 15 of this safety standard apply to the

a) materials and

b) general and additional requirements.

(2) The requirements of Safety standard KTA 3205.1 apply to

a) taking and treatment of test specimens,

b) non-destructive tests and inspections,

c) identification marking, and

d) verification of quality characteristics.

(3) The requirements under Sec. 29.3 apply to the extent of tests required for demonstrating the chemical analysis and the material properties.

29.3 Extent of testing

29.3.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

(2) Product analysis

For each specimen-taking location the content by mass of elements specified in **Annex A**, **Table A 1-1** shall be determined.

29.3.2 Mechanical-technological tests

(1) Tensile test

Two transverse test specimens from each specimen-taking location shall be subjected to a tensile test in accordance with Sec. 3.3.7.3 (1), one at room temperature and one at design temperature.

(2) Test for reduction of area on perpendicular test specimens

The reduction of area shall be determined in accordance with clause 3.3.7.3 (2) on test specimens from each specimen-taking location.

(3) Impact test

On one set of transverse test specimens from each specimen-taking location the impact energy shall be tested in accordance with Sec. 3.3.7.3 (3) at 0 °C and 33 °C.

(4) Nil-ductility transition temperature

On two test specimens from each specimen-taking location it shall be shown in accordance with Sec. 3.3.7.3 (5) that the requirements regarding the NDT temperature are met.

30 Product forms from austenitic steels for integral connections to the reactor coolant pressure boundary

30.1 Scope

This section applies to the product forms from austenitic steels for integral connections to components of the primary coolant system, e.g. for the component support structures and pipe-whip restraints.

30.2 Requirements

(1) With regard to the different product forms, the requirements laid down in Sec. 22 of this safety standard apply to the

a) materials and

b) general and additional requirements.

(2) The requirements of safety standard KTA 3205.1 apply to

a) taking and treatment of test specimens,

b) non-destructive tests and inspections,

c) identification marking, and

d) verification of quality characteristics.

(3) The requirements under Sec. 30.3 shall apply with respect to the extent of tests.

30.3 Extent of testing

30.3.1 Chemical analysis

(1) Ladle analysis

For each melt the content by mass of elements specified in **Annex A**, **Table A 3-1** shall be determined.

(2) Product analysis

The product analysis shall be performed in accordance with clause 22.3.2.1 (2).

30.3.2 Tensile test

A tensile test in accordance with Sec. 3.3.7.3 (1) shall be carried out for each specimen-taking at room temperature.

30.3.3 Determination of the delta ferrite content

For parts which, in the course of subsequent fabrication, will be subjected to welding, the delta ferrite content shall be determined by calculation taking the nitrogen content from each chemical composition determined on the piece into account. If the resulting ferrite numbers are less than 3 or greater than 7 then a bead-on-plate test (cf. **Annex D**) shall be performed on that piece with the most unfavourable chemical composition with respect to the delta-ferrite content.

30.3.4 Resistance to intergranular corrosion

For each melt and heat treatment lot one test specimen shall be tested in accordance with Sec. 3.3.7.6 for resistance to intergranular corrosion.

30.3.5 Materials identification check

Each part shall be subjected to a materials identification check in accordance with Sec. 3.3.7.9.

Annex A

Material characteristics

A 1 Steel 20 MnMoNi 5 5 90
A 2 Austenitic steel X 2 NiCrAlTi 32 20 95
A 3 Stainless austenitic rolled and forged steels X 6 CrNiTi 18 10 S, X 6 CrNiNb 18 10 S and X 6 CrNiMoTi 17 12 2 S 96
A 4 Cast steel GS-18 NiMoCr 3 7 100
A 5 Heat-resistant cast steel GS-C 25 S 103
A 6 Austenitic cast steel G-X 5 CrNiNb 18 9 S 105
A 7 Quenched and tempered fine-grained structural steel as base material and stainless austenitic steel as cladding material for seamless, extrusion-clad composite tubes 107
A 8 Martensitic steel X 5 CrNi 13 4 109
A 9 Nickel Alloy 29 Fe 111
A 10 Quenched and tempered steels for bars and rings for bolts and nuts as well as extension sleeves 113
A 11 Quenched and tempered steels in accordance with DIN EN 10269 for bars and rings for bolts, nuts and washers as well as extension sleeves; supplementary requirements to DIN EN 10269 116

A 1 Steel 20 MnMoNi 5 5

A 1.1 Scope

(1) This Section A1 specifies the details with regard to chemical composition, characteristic mechanical-technological and physical properties of the steel 20 MnMoNi 5 5 as well as with regard to further fabrication for the product forms within the scopes of Secs. 4 through 17 and 29:

a) Seamless hollow parts, forged or rolled (Section 4)
b) Seamless hollow parts for nozzles, forged, rolled or pressed (Section 5)
c) Forged plates for tubesheets (Section 6)
d) Sheets and plates (Section 7)
e) Products dished, pressed, bent or rolled from sheets and plates (Section 8)
f) Straight pipe fittings (Section 9)
g) Seamless, forged hollow bodies for primary coolant pump casings (Section 10)
h) Forged valve bodies (Section 11)
i) Forged plates (Section 12)
j) Hot dished or pressed products from forged plates (Section 13)
k) Forged or rolled bars (Section 14)
l) Hollow-bored or hollow-forged parts made of forged or rolled bars (Section 15)
m) Seamless tubes for pipes (Section 16)
n) Seamless pipe elbows (Section 17)
o) Product forms from ferritic steels for integral connections to the reactor coolant pressure boundary (Section 29)

(2) Deviations from these requirements are allowed provided they are certified in the material appraisal of the authorized inspector.

A 1.2 Manufacturing of the material

(1) The material 20 MnMoNi 5 5 is a fine-grained quenched and tempered alloy steel and is characterised by its high strength at elevated temperatures.

(2) The material shall normally be molten in the electric arc furnace or by the basic oxygen process and be vacuum degassed. If other processes are used, a proof of equivalency is required.

A 1.3 Requirements

A 1.3.1 Chemical analysis

The required chemical composition for the material to be determined by the ladle and the product analysis is specified in **Table A1-1**.

A 1.3.2 Mechanical-technological properties

A 1.3.2.1 General requirements

(1) The requirements regarding material properties apply to the final condition of the component after heat treatment.

(2) The properties in accordance with Secs. 4 through 17 shall be demonstrated in the acceptance test on simulation stress-relief heat treated and accompanying test coupons. The required values given below are valid for the specimen-taking locations, test specimen locations and orientation as specified under Secs. 4 through 17.

(3) In the case of product forms within the scopes of Secs. 4 through 6 and 10 through 13 and a quenched and tempered wall thickness between 220 and 320 mm, up to 10 % lower values than the minimum specified $R_{p0.2}$ and R_m are allowed at

mid-wall than specified for the specimen-taking locations, and KTA 3201.1 Page 91 up to 20 % lower values for a quenched and tempered wall thickness exceeding 320 mm provided the impact energy and lateral expansion determined at a test temperature of 80 °C at mid-wall are greater than 68 J and 0.9 mm, respectively. However, testing at mid-wall shall only be considered if the fabrication process in accordance with Sec. 3.3.6 leads, e.g. to cut-outs from penetrations that are sufficiently large for the removal of trepanned plugs. The extent of tests shall be fixed upon jointly with the authorized inspector.

Note:

The material appraisal has shown that it is possible for the product forms under Secs. 7, 8, 9, 15, 16, and 17 with a quenched and tempered wall thickness up to 200 mm and for product forms under Secs. 4, 10, 11, 12, 13, and 14 up to 220 mm and finally for product forms under Sec. 5 up to 230 mm to maintain the required properties over the entire cross section.

A 1.3.2.2 Tensile test at room temperature

(1) The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Table A 1-2.**

(2) The elastic ratio shall normally not exceed 0.80.

(3) In the case of the product forms under Sec. 9, 16 and 17 with a quenched and tempered wall thickness equal to or less than 70 mm, a ratio up to 0.85 is permissible.

(4) In the case of product forms under Secs. 7 and 8 with a quenched and tempered wall thickness exceeding 30 mm and equal to but less than 70 mm, an elastic ratio up to 0,85 is permitted provided water quenching and tempering is carried out.

(5) The values of the tensile strength determined with test specimens of similar depth and orientation from the different specimen-taking locations on one product may not differ by more than 80 N/mm^2 with respect to each other.

A 1.3.2.3 Tensile test at elevated temperatures

The characteristic values for the mechanical properties determined by a tensile test at elevated temperatures are specified in **Table A 1-3**.

A 1.3.2.4 Impact test

(1) The values of the impact energy are specified in **Table A 1-4** and apply to the base metal and also under consideration of Secs. A 1.4.1 and A 1.5.1, to the heat affected zone of the weld seams in the component.

Note:

Additional requirements for the impact energy in transverse test specimens are specified in the product-form related sections.

(2) In the case of product forms under Sec. 7 and 8, the following applies additionally:

If the absorbed impact energy measured at 0 °C for a specimen-taking location depth of T/4 has an average value between greater 41 J and equal to or less than 51 J or a single value equal to or less than 41 J, an additional impact toughness test for a specimen-taking location depth of T/2 is required with T being the quenched and tempered wall thickness.

A 1.3.2.5 Nil-ductility transition temperature

(1) The test specimen shape chosen for the Pellini drop-weight test shall be P2 in accordance with SEP 1325.

(2) The NDT temperature of core belt line components is specified under Sec. 3.2.4.2.

A 1.3.3 Grain size

After quenching and tempering, the characteristic value of the grain size shall be equal to or greater than 5 in accordance with DIN EN ISO 643.

A 1.3.4 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 1.4 Heat treatment

A 1.4.1 Quenching and tempering

Note:

The temperature values specified are individual piece temperatures.

(1) The following applies to product forms under Secs. 7 and 8 as well as pressed seamless pipes under Sec. 16 and pipe elbows under Sec. 17 fabricated from them:

Quenching and tempering	
Quenching	Tempering
870 °C to 930 °C	630 °C to 690 °C

The following applies to the other product forms under Sec. A 1.1:

Quenching and tempering	
Quenching	Tempering
870 °C to 940 °C	630 °C to 680 °C

(2) The material manufacturer together with the component manufacturer shall specify the heat-up and cooling rates, the temperatures as well as the times at temperature depending on the component dimensions and chemical composition such that, under consideration of any subsequent heat treatment, the mechanical properties in accordance with Sec. A.1.3.2 are obtained in the final condition of the finished component.

A 1.4.2 Heat treatment during and after processing

(1) The last stress-relief heat treatment shall be performed at a temperature between 580 °C and 620 °C with subsequent cooling-down in the furnace or in still air.

(2) Necessary intermediate annealing may be performed at 550 °C.

Note:

Observe footnote 2 under Table A 1-1.

(3) The temperature of the stress-relief heat treatment shall normally be lower than the minimum annealing temperature of the products used in the component or of the component fabricated from the products.

(4) When specifying the annealing temperature, the heat-up times and cooling-down periods and times at temperature, attention shall be paid to the possible changes in material characteristics during annealing taking also claddings into account (corrosion resistance, ductility).

A 1.5 Further fabrication

A 1.5.1 Welding

(1) Product forms in the appraised range of dimensions are fusion weldable by the following procedures:

a) Connection welding and deposition welding

aa) metal-arc welding with basic coated electrodes,

ab) submerged-arc welding with basic flux,

ac) gas-tungsten-arc (TIG) welding with welding consumables,

b) Clad weldings

ba) metal-arc welding with basic coated electrodes or mixed types,

bb) submerged-arc welding with basic coated electrodes or flux mixtures,

bc) submerged-arc welding with wire electrodes,

bd) plasma cladding,

be) gas-metal-arc cladding,

bf) TIG cladding.

(2) The pre-heating, intermediate layer or working temperature depends on the thickness of the welded piece and shall be between 150 °C and 250 °C, for clad weldings the temperature shall be depending on the thickness of the clad piece and the welding process between 120 °C and 180 °C.

(3) The welding conditions apply to connection weldings in the filler layer region for cooling-down times $t_{8/5}$ between 7 and 25 sec.

Note:
The correlation between welding parameters and $t_{8/5}$ is shown in Stahl-Eisen-Werkstoffblatt SEW 088.

(4) When using basic coated rod electrodes or fluxes of basic characteristics the following diffusible hydrogen content shall be provided:

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).

(5) The component shall be saddened for a period of two or more hours at about 280 °C directly from the welding heat, unless a stress-relief heat treatment is performed directly from the welding heat.

(6) A hydrogen reduction heat treatment (soaking) subsequent to weld cladding may be omitted for product forms under Secs. 4 to 6 and 10 to 14, provided the wall thickness in the region to be clad is equal to or less than 100 mm, and for product forms under Secs. 9 and 15, provided the wall thickness in the cylindrical part without discontinuities is equal to or less than 70 mm. In such a case, the clad piece shall be held at the minimum pre-heating temperature for a longer time and shall only then be slowly cooled down unless a stress-relief heat treatment in accordance with Sec. A 1.4.2 is performed immediately from the welding heat.

(7) A hydrogen reduction heat treatment (soaking) subsequent to weld cladding is not required for product forms under Secs. 16 and 17, provided the wall thickness in the region to be clad does not exceed 70 mm. In these cases, the clad piece shall be kept at the minimum pre-heating temperature for a longer time and shall only then be slowly cooled down unless a stress-relief heat treatment in accordance with Sec. A 1.4.2 is performed immediately from the welding heat.

(8) In the case of product forms under Sec. 7 and 8, the weld-clad components shall be cooled down slowly directly from the welding heat. Prerequisite is, however, that no segregation zones have been cut and clad. If segregation zones must be clad, a saddening corresponding to that of the connection weld as per (5) is required.

(9) Any deviation from the requirements above, e.g. the reduction of the pre-heating temperature for clad welding, shorter duration of saddening or reduction of the saddening temperature, are permitted, if this was demonstrated by a welding procedure qualification or production control test in accordance with the KTA 3201.3.

(10) A stress-relief heat treatment in accordance with A 1.4.2 is always required after welding irrespective of the welding procedure and wall thickness involved.

A 1.5.2 Flame cutting

(1) A pre-heating temperature between 150 °C and 300 °C is required before any flame cutting. It is recommended to perform the pre-heating in a furnace in order to achieve a uniform temperature distribution (thorough heating).

(2) If the pre-heating is carried out locally, the heated region must be large enough to ensure thorough heating. The preheating temperature shall be maintained during the entire flame cutting process.

A 1.5.3 Forming

A 1.5.3.1 Hot forming

In consideration of the manufacturer specifications, any hot forming shall be performed

a) at temperatures between 750 °C and 1250 °C, in the case of product forms under Secs. 4 to 6 and 9 to 15,

b) at temperatures between 700 °C and 1100 °C, in the case of product forms under Secs. 7, 8, 16 and 17, and if necessary, within larger temperature ranges. The heat-up and cooling rates as well as the times at temperature shall be specified in accordance with the requirements of the material manufacturer. After hot forming, a quenching and tempering treatment is required.

A 1.5.3.2 Cold forming

(1) The cold forming of product forms under Secs. 7, 8, 16 and 17 shall normally not be performed at temperatures lower than 20 °C. Deviations shall be fixed jointly with the authorized inspector.

(2) Heat treatment is not required after cold forming with degrees of forming smaller than or equal to 2 %. Stress-relief annealing shall be required after forming with degrees of cold forming between 2 % and smaller than or equal to 5 %. A cold forming with a cold forming degree exceeding 5 % requires a renewed quenching and tempering.

A 1.6 Material appraisal

Material manufacturers possessing a completed material appraisal in accordance with Sec. 2.2.2 are listed in VdTÜV Material Specification Sheets 401/1 to 401/3 which specify the manufacturing procedures, the delivery conditions and range of dimensions.

Verification by		Content by mass, %						
		C [1]	Si	Mn	P [2]	S	Cr	Mo
Ladle analysis [3] [4]	min.	0.17	0.15	1.20	—	—	—	0.40
	max.	0.23	0.30	1.50	0.012	0.008	0.20	0.55
Product analysis [3] [4]	min.	0.15	0.10	1.15	—	—	—	0.40
	max.	0.25	0.35	1.55	0.012 [5]	0.012 [5]	0.20	0.55 [5]

Verification by		Content by mass, %						
		Ni	Al_{total}	Cu [2]	V	Sn	N_{total}	As
Ladle analysis [3] [4]	min.	0.50	0.010	—	—	—	—	—
	max.	0.80	0.040	0.12	0.020	0.011	0.013	0.025
Product analysis [3] [4]	min.	0.45	0.010	—	—	—	—	—
	max.	0.85	0.050	0.12 [5]	0.020	0.011 [5]	0.013 [5]	0.025

1) In the case of product forms under Sec. 16 and 17 with a wall thickness ≤ 30 mm, a carbon content in the range between 0.14 and 0.18 % is permitted in the ladle analysis and between 0.12 and 0.20 % in the product analysis.

2) In the case of parts used in the core belt line region, the maximum Cu content shall be limited to 10 % and a lower P content shall be strived for.

3) For use in the reactor pressure vessel, the content of tantalum and cobalt shall not exceed 0.030 % in both the ladle and product analysis.

4) If the limit values are exceeded in the ladle analysis, then the limit values of the product analysis shall be the determining limits.

5) If these values are exceeded and the limits for the contents determined in the product analysis are claimed to be P ≤ 0.015 %, S ≤ 0.015 %, Mo ≤ 0.63 %, Cu ≤ 0.18 %, Sn ≤ 0.016 % and N_{total} ≤ 0.015 %, then the authorized inspector shall ascertain whether or not examinations of the heat affected zone and, if necessary, of tangential cross sections are required. If further fabrication calls for intermediate tempering at 550 °C, the permissibility of this temperature shall be shown in these examinations. Extent and procedure of testing shall be fixed jointly with the authorized inspector.

Table A 1-1: Chemical composition determined by ladle and product analysis for various product forms made from the steel 20 MnMoNi 5 5

Product form under the following Sections	Test specimen orientation [1]	Quenched and tempered wall thickness mm	0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.	Reduction of area at fracture Z	
						Individual value % min.	Mean value of 3 specimens % min.
4 to 6 and 10 to 14	longitudinal, transverse	≤ 650 [2]	390	560 to 700	19	45	—
	perpendicular	≤ 650 [2]	390	560 to 770	—	35	45
9 [3], 15, 16 [4] and 17 [4]	longitudinal, transverse	> 15 to ≤ 150	430	570 to 710	19	45	—
		> 150 to ≤ 200	390	560 to 700			
	perpendicular	> 15 to ≤ 150	430	570 to 710	—	35	45
		> 150 to ≤ 200	390	560 to 700			
7 and 8	longitudinal, transverse [5]	> 30 to ≤ 70	450	590 to 730	18	45	—
		> 70 to ≤ 150	430	570 to 710	18	45	—
		> 150 to ≤ 200	390	560 to 700	18	45	—
	perpendicular	> 30 to ≤ 200	—	—	—	35	45

1) The definitions under Sec. 3.3.2 apply.

2) In the case of product forms under Sec. 6 and 10, the specified values apply only to a quenched and tempered wall thickness ≤ 1000 mm.

3) Independently of the quenched and tempered wall thickness of the nozzle region, the same requirements apply as for the pipe section.

4) The specified range of dimensions apply to forged pipes. In the case of rolled and pressed pipes, the values specified refer to a range of the quenched and tempered wall thickness between > 15 up to ≤ 100 mm or > 100 mm up to ≤ 200 mm, respectively.

5) The specified values for the 0.2%-proof stress, the tensile strength and the elongation at fracture shall also apply to the perpendicular test specimen orientation in the case of product forms under Sec. 8 with a quenched and tempered wall thickness exceeding 120 mm.

Table A 1-2: Mechanical-technological properties in the tensile test at room temperature for various product forms from the steel 20 MnMoNi 5 5

Product form under the following Sections	Test specimen orientation [1]	Temperature °C	0.2%-proof stress $R_{p0.2}$ N/mm² min.			Tensile strength R_m N/mm² min.			Elongation at fracture A % min.	
			Quenched and tempered wall thickness ≤ 400 mm							
5	longitudinal, transverse, perpendicular [2]	100	370			520			16	
		200	360			505			16	
		300	350			505			15	
		350	343			505			14	
		375	330			505			14	
		400 [3]	320			490			14	
			Quenched and tempered wall thickness in mm							
			≤ 320	> 320 to ≤ 650 [4]		≤ 650 [4]			≤ 320	> 320 to ≤ 650 [4]
4, 6 and 10 to 14	longitudinal, transverse, perpendicular [2]	100	370	370		520			17	16
		200	360	350		505			16	16
		300	350	330		505			16	15
		350	343	314		505			16	14
		375	330	300		505			16	14
		400 [3]	320	290		490			16	14
			Quenched and tempered wall thickness in mm							
			> 15 to ≤ 150	> 150 to ≤ 200		≥ 15 to ≤ 150	> 150 to ≤ 200		> 15 to ≤ 200	
9 [5], 15, 16 [6] and 17 [6]	longitudinal, transverse, perpendicular [2]	100	412	370		530	530		16	
		200	392	360		513	510		16	
		300	371	350		513	510		16	
		350	363	343		513	510		16	
		375	358	330		505	505		16	
		400 [3]	(353) [7]	(320) [7]		(500) [7]	(500) [7]		16	
			Quenched and tempered wall thickness in mm							
			≥ 30 to ≤ 70	> 70 to ≤ 150	> 150 to ≤ 200	≥ 30 to ≤ 70	> 70 to ≤ 150	>150 to ≤ 200	≥ 30 to ≤ 200	
7, 8	longitudinal, transverse	100	431	412	382	550	530	520	17	
		200	412	392	371	530	510	505	16	
		300	392	371	353	530	510	505	16	
		350	382	363	343	530	510	505	16	
		375	377	358	338	530	505	505	16	
		400 [3]	371	353	333	530	500	490	16	

[1] The definitions under Sec. 3.3.2 apply.
[2] In case of the perpendicular test specimens, only the values specified for $R_{p0.2}$ and R_m apply.
[3] When employing the steel at temperatures exceeding 375 °C, additional tests are required to determine the creep rupture strength.
[4] In the case of product forms under Sec. 6 and 10, the specified values apply only to a quenched and tempered wall thickness ≤ 1000 mm.
[5] Independently of the quenched and tempered wall thickness of the nozzle region, the same requirements apply as for the pipe section.
[6] The specified range of dimensions apply to forged pipes. In the case of rolled and pressed pipes, the values specified refer to a range of the quenched and tempered wall thickness between > 15 up to ≤ 100 mm or > 100 up to ≤ 200 mm, respectively..
[7] The values in parantheses still need to be ensured statistically.

Table A 1-3: Mechanical-technological properties in the tensile test at elevated temperatures for various product forms from the steel 20 MnMoNi 5 5

Test specimen orientation	Impact energy KV_2 J	
	Individual value	Mean value of 3 specimens
quer	34 1)	41 1)

1) If, on account of the dimensions in the case of pipes, longitudinal instead of transverse test specimens have to be taken, then the individual value of the absorbed impact energy shall not be less than 45 J and the mean value of three test specimens not less than 55 J.

Tabelle A 1-4: Minimum values of the absorbed impact energy at 0 °C for various product forms from the steel 20 MnMoNi 5 5

A 2 Austenitic steel X 2 NiCrAlTi 32 20

A 2.1 Scope

(1) Section A 2 specifies the details with regard to chemical composition, characteristic mechanical-technological and physical properties of the austenitic steel X 2 NiCrAlTi 32 20 with low strain hardening as well as with regard to further fabrication for the product forms within the scope of Sec. 18:

steam generator heat exchanger tubes (Section 18)

(2) Deviations from these requirements are permitted provided they are certified in the initial material appraisal of the authorized inspector.

A 2.2 Manufacturing of the material

(1) The material shall normally be molten in the electric arc furnace and, where required be treated by the argon-oxygen decarburization (AOD) process or the electro-slag remelt process. If other processes are used, a proof of equivalency is required.

(2) The tubes shall be delivered in the solution annealed and low-strain-hardened condition.

A 2.3 Requirements

A 2.3.1 Chemical analysis

The required chemical composition for the material to be determined by the ladle and the product analysis is specified in **Table A 2-1**.

A 2.3.2 Mechanical-technological properties

A 2.3.2.1 General requirements

The requirements regarding mechanical properties of the material apply to the condition of delivery.

A 2.3.2.2 Tensile test at room temperature and elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at room temperature and at elevated temperatures are specified in **Table A 2-2**.

A 2.3.2.3 Drift test

The tubes shall meet the requirements of the drift test in accordance with Sec. 18.

A 2.3.3 Grain size

The characteristic value of the grain size shall be at least 7 in accordance with DIN EN ISO 643.

A 2.3.4 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 2.3.5 Resistance to intergranular corrosion

(1) The steel, in the sensitisation-annealed condition, shall be resistant to intergranular corrosion under the testing conditions in accordance with DIN EN ISO 3651-2.

(2) The sensitisation annealing shall be performed as follows: heating-up to 650 °C in less than 1.5 minutes, time at temperature 5 minutes at 650 °C, quenching in water.

A 2.4 Heat treatment

The solution annealing shall be performed at temperatures between 980 °C and 1050 °C and in a protective atmosphere (even during cooling down).

A 2.5 Further fabrication

A 2.5.1 Welding-in of the tubes

Welding-in shall be performed with the tungsten-inert-gas (TIG) procedure with or without welding consumables and without any preheating.

A 2.5.2 Bending

The pipes shall be cold bent. The bending radius shall be at least 4.5 times the outer diameter of the pipe.

A 2.5.3 Heat treatment

(1) No heat treatment is neither allowed after bending nor after welding-in of the tubes.

(2) In the course of vessel annealing, the temperature shall not exceed 400 °C.

A 2.6 Material appraisal

Material manufacturers have to demonstrate a material appraisal in accordance with Sec. 2.2.2 which specifies the manufacturing procedures, the delivery conditions and range of dimensions.

	Content by mass, %												
	C	Si	Mn	P 1)	S	Al_{total}	Co	Cr	Cu	N 1)	Ni	Ti 2)	Fe
min.	—	0.3	0.4	—	—	0.15	—	20.0	—	—	32.0	—	—
max.	0.03	0.7	1.0	0.020	0.015	0.45	0.06	23.0	0.75	0.030	35.0	0.60	rest

1) If one of the two values is slightly exceeded, the sum of the mass content of phosphorus and nitrogen shall be the determining factor. The sum shall be smaller than 0.050 %..

2) Stabilizing ratio: Ti ≥ 12 • %C and Ti ≥ 8 • (%C + %N).

Table A 2-1: Chemical composition of the steel X 2 NiCrAlTi 32 20 determined by ladle and product analysis

Temperature °C	0.2%-proof stress $R_{p0.2}$ N/mm²	Tensile strength R_m N/mm²	Elongation at fracture A % min.
Room temperature	335 to 470	570 to 700	30
100	325	550	25
200	315	525	20
300	305	505	20
350	295	495	20
400	285	485	20

Table A 2-2: Mechanical-technological properties of the steel X 2 NiCrAlTi 32 20 in the tensile test at room temperature and elevated temperatures

A 3 Stainless austenitic rolled and forged steels X 6 CrNiTi 18 10 S, X 6 CrNiNb 18 10 S and X 6 CrNiMoTi 17 12 2 S

A 3.1 Scope

(1) Section A 3 specifies the details regarding chemical composition, characteristic mechanical and physical properties of the stainless austenitic rolled and forged steels X 6 CrNiTi 18 10 S, X 6 CrNiNb 18 10 S and X 6 CrNiMoTi 17 12 2 S as well as regarding further fabrication for the product forms within the scopes of Secs. 22 through 24 and 30:

a) sheets, plates, bars and forgings (Section 22)

b) seamless pipes (Section 23)

c) seamless elbows (Section 24)

d) product forms made of austenitic steels for integral connections to the reactor coolant pressure boundary (Section 30)

(2) Deviations from these requirements are permitted provided they are certified in the initial material appraisal of the authorized inspector.

A 3.2 Manufacturing of the materials

The steels shall normally be molten in the electric-arc furnace and, where required be treated by the argon-oxygen decarburisation (AOD) or vacuum-oxygen decarburisation (VOD) process or be remolten under vacuum or by the electro-slag remelt process. If other processes are used, a proof of equivalency is required.

A 3.3 Requirements

A 3.3.1 Chemical analysis

(1) The required chemical compositions for the steels to be determined by the ladle and the product analysis are specified in **Tables A 3-1** and **A 3-2**. In addition, the nitrogen content shall be disclosed in the product analysis.

(2) For those parts that are welded in the course of further fabrication, no credit shall be taken simultaneously from the eased restrictions regarding grain size and upper limit of the allowable content of niobium and sulphur.

A 3.3.2 Mechanical-technological properties

A 3.3.2.1 General requirements

(1) The requirements regarding mechanical properties of the material apply to the final heat treatment condition.

(2) The required values given below are valid for the specimen-taking locations, test specimen depths and orientations as specified under Secs. 22 through 24.

(3) The characteristic values of the mechanical-technological properties given below apply to the range of dimensions as specified with respect to the steel type and product form in **Tables A 3-3** and **A 3-4**.

A 3.3.2.2 Tensile test at room temperature

The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Tables A 3-3** and **A 3-4**.

A 3.3.2.3 Tensile tests at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at elevated temperatures are specified in **Tables A 3-5** to **A 3-7**.

A 3.3.2.4 Impact test

The values of the impact energy at room temperature are specified in **Table A 3-8**.

A 3.3.3 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 3.4 Heat treatment

The product forms shall be solution annealed at temperatures between 1020 °C and 1100 °C and be quenched in water or as quickly as possible in air. Sec. A 3.5 applies to heat treatments after further fabrication.

A 3.5 Further fabrication

A 3.5.1 Welding

(1) These steels are weldable by the following procedures:

a) metal-arc welding with coated electrodes,

b) submerged-arc welding,

c) tungsten-inert gas (TIG) are welding with or without welding filler metal,

d) plasma welding,

e) electron beam welding.

(2) No preheating is required.

(3) The intermediate layer and working temperature shall not exceed 200 °C.

(4) The product forms are usually not stress-relief heat treated after welding. If in special cases annealing is required, it shall be performed in such a way that, in the annealed condition, the values of the absorbed impact energy specified under **Table A 3-8** are met and that the resistance against intergranular corrosion is not detrimentally affected.

A 3.5.2 Flame cutting

Flame cutting is permitted provided adequate working conditions exist, e.g. by utilising flux, protective gas or plasma. Border regions that are detrimentally affected by flame cutting shall be mechanically removed.

A 3.5.3 Hot forming

(1) Bars and forgings under Sec. 22 shall normally be hot formed in the temperature range between 850 °C and 1100 °C, all other product forms in the temperature range between 750 °C and 1150 °C. After hot forming, the products shall basically be solution annealed in the lower temperature range specified under Sec. A 3.4 and shall be quenched in water or as quickly as possible in air. In those cases where the products have been already been solution annealed before, the lower value of the solution annealing temperature range specified under Sec. A 3.4 shall be reduced to 980 °C for products from steels that are not alloyed with molybdenum, and to 1000 °C for products from steels that are alloyed with 2.0 to 2.5 % molybdenum.

(2) Solution annealing after hot forming may be waived provided other measures are taken to ensure that the condition of the finished product is similar to the solution annealed and quenched condition in accordance with Sec. A 3.4, that is with respect to the usability of the product, e.g. the mechanical properties and corrosion resistance. Solution annealing may be waived in the following cases provided the authorized inspector has certified the procedure:

a) In the case of products which prior to hot forming are not in the delivery condition specified under Sec. A 3.4, solution annealing may be waived provided all of the following four conditions are met:
   aa) The products shall be entirely warmed up to the specified hot forming temperatures.
   ab) The initial hot forming temperature shall be greater than 1020 °C.
   ac) The final hot forming temperature shall be greater than 850 °C.
   ad) After hot forming the products shall be quenched in accordance with Sec. A 3.4.
b) In the case of products which prior to hot forming are in the delivery condition specified under Sec. A 3.4, solution annealing after hot forming may be waived provided the following two conditions are met:
   ba) The final hot forming temperature shall be greater than 850 °C.
   bb) After hot forming, the products shall be quenched in accordance with Sec. A 3.4.

   Note:
   Contrary to the procedure under a), the initial hot forming temperature may be freely chosen for products which prior to hot forming are in the delivery condition in accordance with Sec. A 3.4.
c) In the case of products from steels not alloyed with molybdenum which prior to hot forming are in the delivery condition specified under Sec. A 3.4, the solution annealing after hot forming may be replaced by a stabilisation annealing at a temperature of 900 °C ± 20 K provided the subsequent cooling-down is carried out in air.

(3) Locally hot formed products shall be entirely solution annealed and quenched. In the case of local hot-forming procedures with reproducible results, the authorized inspector may specify different requirements during procedure appraisal provided

a) the products, prior to hot forming, are either in the delivery condition as specified under Sec. A 3.4 or in the additionally stabilisation annealed condition, and
b) the products, after hot forming, are quenched in accordance with Sec. A 3.4.

Hereby, the final hot forming temperature shall normally be greater than 850 °C.

A 3.5.4 Cold forming

(1) The steels are suited for cold forming. It shall, however, be considered that cold forming affects the material properties. Therefore, a heat treatment in accordance with Sec. A 3.4 is basically required after cold forming.

(2) In the case of cold forming less than 5 % or of straightening with a similar degree of forming, the subsequent heat treatment may be omitted provided the products, prior to hot forming, are either in the heat treated condition as specified under A 3.4 or in a similar condition (cf. Sec. A 3.5.3 (2) and (3)), and no requirements to the contrary were specified.

(3) Cold forming of a degree greater than 5 % and equal to or less than 10 % without subsequent heat treatment in accordance with Sec. A 3.4 are allowed provided the authorized inspector has certified during procedure appraisal and the customer has agreed to the procedure.

(4) In the case of cold bending of pipes greater than DN 50 but equal to or less than DN 150 without deforming the ends, subsequent heat treatment may be omitted if it can be demonstrated during the procedure appraisal that after bending the minimum values of elongation at fracture A and of elongation before reduction of area are not less than 15 % and about 5 %, respectively. The minimum values required for the initial pipe apply to the other mechanical properties, i.e. 0.2 % proof stress, 1.0 % proof stress, tensile strength and absorbed impact energy.

(5) In the regions of cold bending, no hot tasks like hot straightening or welding are allowed. When performing other tasks on these areas, attention shall be paid to their cold forming condition.

A 3.6 Material appraisal

Material manufacturers of product forms bars and forgings possessing a completed material appraisal in accordance with Sec. 2.2.2 are listed in VdTÜV Material Specification Sheet 451 which specifies the manufacturing procedures, the delivery conditions and range of dimensions.

Steel grade		Content by mass, %										
		C	Si	Mn	P	S [1]	Co	Cr	Mo	Nb [1] [2]	Ni	Ti [3]
X 6 CrNiTi 18 10 S	min.	—	—	—	—	—	—	17.0	—	—	9.0	5 • C
	max.	0.06	1.0	2.0	0.035	0.015	0.2	19.0	—	—	12.0	0.5
X 6 CrNiNb 18 10 S [4]	min.	—	—	—	—	—	—	17.0 [4]	—	10 • C	9.0	—
	max.	0.04 [4]	1.0 [4]	2.0	0.035 [4]	0.015 [4]	0.2	19.0	—	0.65 [4]	12.0	—
X 6 CrNiMoTi 17 12 2 S	min.	—	—	—	—	—	—	16.5	2.0	—	10.5	5 • C
	max.	0.06	1.0	2.0	0.035	0.015	0.2	18.5	2.5	—	13.5	0.5

1) See also Sec. A 3.3.1.

2) For parts that are annealed after welding (cf. Sec. A 3.5): $13 \cdot C \leq Nb \leq 0.65$ %.

3) For parts that are annealed after welding (cf. Sec. A 3.5): $8 \cdot C \leq Ti \leq 0.7$ %.

4) When used for hot (operating temperature $T \geq 200$ °C during continuous operation) reactor water containing product forms and components in BWR plants the following limit values apply:

$C \leq 0.03$ %
$Si \leq 0.5$ %
$P \leq 0.025$ %
$S \leq 0.010$ %
$18.0\ \% \leq Cr \leq 19.0\ \%$
$13 \cdot C \leq Nb \leq 0.65$ %

Table A 3-1: Chemical composition determined by ladle analysis for stainless austenitic rolled and forged steel

Chemical element	Allowable deviation [1] (content by mass), %
Carbon	+ 0.01
Phosphorus	+ 0.005
Sulphur	+ 0.005
Silicon	+ 0.05
Manganese	+ 0.04
Chrome	± 0.20
Molybdenum	± 0.10
Nickel	± 0.15
Cobalt	+ 0.05
Titanium	± 0.05
Niobium	± 0.05

1) If more than one product analysis is performed for one melt and the results show deviations of the chemical composition determined by the product analysis from the range limit of the composition determined by the ladle analysis, then a particular element may either be above the maximum or below the minimum limit value specified in **Table A 3-1**, but no simultaneous deviation of a melt from both limit values is permitted.

Table A 3-2: Allowable deviations of the chemical composition determined by the product analysis from the range limit of the composition determined by the ladle analysis for stainless austenitic rolled and forged steels

Steel grade	Product form [2]			0.2%-proof stress $R_{p0.2}$ N/mm² min.	1%-proof stress $R_{p1.0}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.	
	Sheets [1]	Bars	Forgings and plates				Test specimen orientation	
	Determining dimensions						longitudinal	transverse or tangential
	Thickness mm	Diameter mm	Wall thickness mm					
X 6 CrNiTi 18 10 S	≤ 75	—	—	200	235	500 to 730	—	35
	—	≤ 400	≤ 275	190	225		40	
X 6 CrNiNb 18 10 S	≤ 75	—	—	205	240	510 to 740	—	
	—	≤ 900	≤ 600				40	
X 6 CrNiMoTi 17 12 2 S	≤ 75	—	—	210	245	500 to 730	—	
	—	≤ 400	≤ 275				40	

1) The values for sheets with a thickness between > 50 and ≤ 75 mm still have to be verified.

2) Solution annealed and quenched condition.

Table A 3-3: Mechanical-technological properties in the tensile test at room temperature of stainless austenitic rolled and forged steel for the product forms sheet, bar, forging and plate

Steel grade	Wall thickness mm	Fabrication process and heat treatment condition	0.2%-proof stress $R_{p0.2}$ N/mm² min.	1%-proof stress $R_{p1.0}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.	
						Test specimen orientation	
						longi-tudinal	transverse or tangential
X 6 CrNiTi 18 10 S	≤ 50	hot formed, solution annealed and quenched	180	215	460 to 680	35	30
		cold formed, solution annealed and quenched 1)	200	235	500 to 730	30	
X 6 CrNiNb 18 10 S	≤ 50	hot or cold formed, solution annealed and quenched	205	240	510 to 740	30	
X 6 CrNiMoTi 17 12 2 S	≤ 50	hot formed, solution annealed and quenched	190	225	490 to 690	35	
		cold formed, solution annealed and quenched 1)	210	245	500 to 730	30	

1) For calculation purposes, the material properties of the hot formed condition shall basically be used. The material properties of the cold formed condition may be used only if it is ensured that cold formed pipes are actually delivered. Pipes ≥ DN 200 are generally only available in the hot formed condition. In the case of cold formed elbows the cold formed properties may be used only, if the initial pipes have also been cold formed.

Table A 3-4: Mechanical-technological properties in the tensile test at room temperature of stainless austenitic rolled and forged steel for the product forms pipe and pipe elbow

Steel grade 1)	0.2%-proof stress $R_{p0.2}$ N/mm² min.								1%-proof stress $R_{p1.0}$ N/mm² min.							
	at temperature, °C															
	50	100	150	200	250	300	350	400	50	100	150	200	250	300	350	400
X 6 CrNiTi 18 10 S	180	166	157	147	137	126	120	115	212	198	185	175	165	157	151	146
X 6 CrNiNb 18 10 S	191	177	167	157	147	136	130	125	226	211	196	186	177	167	161	156
X 6 CrNiMoTi 17 12 2 S	202	185	177	167	157	145	140	135	234	218	206	196	186	175	169	164

1) Solution annealed and quenched condition. Dimensional range in accordance with **Table A 3-3**.

Table A 3-5: Mechanical-technological properties in the tensile test at elevated temperatures (0.2%- and 1%-proof stress) of stainless austenitic rolled and forged steel for the product forms sheet, bar, forging and plate

Steel grade 1)	Fabrication process and heat treatment condition 2)	0.2%-proof stress $R_{p0.2}$ N/mm² min.								1%-proof stress $R_{p1.0}$ N/mm² min.							
		at temperature, °C															
		50	100	150	200	250	300	350	400	50	100	150	200	250	300	350	400
X 6 CrNiTi 18 10 S	HSQ	162	147	132	118	108	100	94	89	201	181	162	147	137	127	121	116
	CSQ 3)	190	176	167	157	147	136	130	125	222	208	195	185	175	167	161	156
X 6 CrNiNb 18 10 S	HSQ or CSQ	191	177	167	157	147	136	130	125	226	211	196	186	177	167	161	156
X 6 CrNiMoTi 17 12 2 S	HSQ	182	166	152	137	127	118	113	108	217	199	181	167	157	145	139	135
	CSQ 3)	202	185	177	167	157	145	140	135	234	218	206	196	186	175	169	164

1) Wall thickness equal to or less than 50 mm.

2) HSQ: hot formed, solution annealed and quenched
CSQ: cold formed, solution annealed and quenched

3) For calculation purposes, the material properties of the hot formed condition shall basically be used. The material properties of the cold formed condition may be used only if it is ensured that cold formed pipes are actually delivered. Pipes ≥ DN 200 are generally only available in the hot formed condition.
In the case of cold formed elbows the cold formed properties may be used only, if the initial pipes have also been cold formed.

Table A 3-6: Mechanical-technological properties in the tensile test at elevated temperatures (0.2%- and 1%-proof stress) of stainless austenitic rolled and forged steel for the product forms pipe and pipe elbow

Steel grade [1]	Tensile strength R_m, N/mm² min.				
	at temperature, °C				
	200	250	300	350	400
X 6 CrNiTi 18 10 S	370	360	350	335	320
X 6 CrNiNb 18 10 S	370	360	350	335	320
X 6 CrNiMoTi 17 12 2 S	390	380	370	355	340

[1] Solution annealed and quenched condition.

Table A 3-7: Mechanical-technological properties in the tensile test at elevated temperatures (tensile strength) of stainless austenitic rolled and forged steel for various product forms

Heat treatment condition	Test specimen orientation	Impact energy KV_2, J	
		Mean value of 3 specimens min.	Smallest individual value min.
Solution annealed and quenched	longitudinal	100	90
	transverse or tangential	70	60
Annealed (cf. Sec. A 3.5)	longitudinal	85	60
	transverse or tangential	55	40

Table A 3-8: Absorbed impact energy at room temperature of stainless austenitic rolled and forged steel for various product forms

A 4 Cast steel GS-18 NiMoCr 3 7

A 4.1 Scope

(1) Section A 4 specifies the details regarding chemical composition, characteristic mechanical and physical properties of the cast steel GS-18 NiMoCr 3 7 as well as regarding further fabrication for the product forms within the scopes of Secs. 25 and 26:

a) primary coolant pump casings from ferritic cast steel (Section 25)
b) valve bodies from ferritic cast steel (Section 26)

(2) Deviations from these requirements are permitted provided they are certified in the initial material appraisal of the authorized inspector (cf. clause 2.2.2 (4)).

A 4.2 Manufacturing of the material

(1) The cast steel GS-18 NiMoCr 3 7 is a quenched and tempered alloy steel and is characterised by high strength at elevated temperatures.

(2) The material shall normally be molten in the electric-arc furnace, the electric induction oven or by the argon-oxygen decarburisation (AOD) process. If other processes are used, a proof of equivalency is required.

A 4.3 Requirements

A 4.3.1 Chemical analysis

The required chemical composition for the cast steel GS-18 NiMoCr 3 7 is specified in **Table A 4-1** and shall be determined by the ladle and the product analysis.

Note:
Some of the differences in the chemical compositions between the ladle analysis and the product analysis are smaller than is to be expected on the basis of metallurgical considerations. This is due to the fact that the limit values of the chemical composition for the product analysis are based only on the melts covered in the initial material appraisal. These values will, therefore, be reviewed when further information is available.

A 4.3.2 Mechanical-technological properties

A 4.3.2.1 General requirements

(1) The requirements regarding mechanical properties of the material apply to the final condition of the component after heat treatment.

(2) The properties in accordance with Secs. 25 and 26 shall be demonstrated in the acceptance test on quenched and tempered and simulation stress-relief heat treated and on accompanying test coupons. The required values given below are valid for the specimen-taking locations and orientations as specified under Secs. 25 and 26.

(3) In the case of a quenched and tempered wall thickness equal to or less than 300 mm, the specified mechanical properties can be maintained over the entire wall thickness. In the case of a quenched and tempered wall thickness exceeding 300 mm, 20 % lower values of the minimum specified $R_{p0.2}$ and R_m are permitted for mid-wall than specified for the specimen-taking locations provided the impact energy and lateral expansion determined for 80 °C at mid-wall are equal to or greater than 68 J and 0.9 mm, respectively. However, testing at mid-wall shall only be considered if cast-integral coupons are available in accordance with the definition under Secs. 25 and 26, i.e. in accordance with the determining wall thickness, with a thickness exceeding 300 mm.

A 4.3.2.2 Tensile test at room temperature

(1) The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Table A 4-2**.

(2) The values for the reduction of area shall be documented for informative purposes only. The elastic ratio shall normally not exceed 0.80.

A 4.3.2.3 Tensile test at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at elevated temperatures are specified in **Table A 4-3**.

A 4.3.2.4 Impact test

The values of the minimum impact energy are specified in **Table A 4-4** and apply to the base metal and, also, under consideration of Sec. A 4.4.1 and A 4.5.1, to the heat affected zone of welded joints on the component.

A 4.3.2.5 Nil-ductility transition temperature

In the Pellini drop-weight test the test specimen shape shall be P2 in accordance with SEP 1325.

A 4.3.3 Grain size

After quenching and tempering, the characteristic grain size value shall be at least 5 in accordance with DIN EN ISO 643.

A 4.3.4 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 4.4 Heat treatment

Note:
The temperature values specified are individual piece temperatures.

A 4.4.1 Quenching and tempering

(1) The cast steel GS-18 NiMoCr 3 7 shall be subjected to a double water quenching and tempering.

Quenching and tempering	
Quenching	Tempering
800 °C to 950 °C	650 °C to 700 °C

(2) The material manufacturer together with the component manufacturer shall specify the heating and cooling rates, the temperatures as well as the holding duration times at temperature depending on component dimensions and chemical composition such that, under consideration of all subsequent heat treatments, the mechanical properties in accordance with Sec. A 4.3.2 are obtained in the final condition of the finished component.

A 4.4.2 Heat treatment after welding

A 4.4.2.1 Quenched and tempered weldings

Production and construction weldings shall be performed after the first quenching and tempering in accordance with Sec. A 4.4.1. After the welding, a renewed quenching and tempering is required, except where Sec. A 4.4.2.2 applies.

A 4.4.2.2 Stress-relief heat treated weldings

(1) Small production weldings that are carried out after the double quenching and tempering procedure shall subsequently be stress-relief heat treated (cf. Sec. A 4.4.2.3).

(2) Weldings that can only be performed after the double quenching and tempering of the castings shall be welded higher by two layers. They shall subsequently be stress-relief heat treated in accordance with Sec. A 4.4.2.3.

(3) Connection weldings between castings and rolled or forged product forms may be performed after the double quenching and tempering of the castings. After welding, they shall be stress-relief heat treated in accordance with Sec. A 4.4.2.3.

(4) Connection weldings that are performed at the assembly site shall be subjected to stress-relief heat treatment. In this regard, the requirements laid down in KTA 3201.3 shall be observed.

(5) In those cases where in the post-welding phase no quenching and tempering but rather only a stress-relief heat treatment is performed, special attention shall be paid to the possibility for performing non-destructive test and inspections as in-service inspections.

A 4.4.2.3 Stress-relief heat treatment

(1) The final stress-relief heat treatment shall be performed between 580 °C and 620 °C with a subsequent cooling down period spent in the oven or in still air.

(2) Any required intermediate annealing may be performed at 550 °C.

Note:
*Observe footnote 1 under **Table A 4-1**.*

(3) When specifying the annealing temperature rates, the heating-up and cooling rates and times at temperature, consideration shall be given to changes in material characteristics that may possibly occur during annealing, with special attention also to be paid to the cladding (corrosion resistance, ductility).

A 4.5 Further fabrication

A 4.5.1 Welding

(1) Castings in the appraised range of dimensions are fusion-weldable by the following procedures:

a) Production and construction weldings:
   aa) metal-arc welding with basic coated electrodes,
   ab) submerged-arc welding with basic flux.
b) Clad weldings:
   ba) metal-arc welding with basic coated electrodes or mixed types,
   bb) submerged-arc welding with strip electrodes and basic flux or flux mixtures.

(2) The pre-heating, intermediate layer or working temperature depends on the thickness of the welded piece and shall be between 150 °C and 250 °C, clad weldings shall be performed at a recommended maximum temperature of 180 °C. The welding conditions apply to connection weldings in the filler layer region for cooling-down times $t_{8/5}$ between 7 and 25 sec.

Note:
The correlation between welding parameters and $t_{8/5}$ is shown in Stahl-Eisen-Werkstoffblatt SEW 088.

(3) When using basic coated rod electrodes or fluxes of basic characteristics the following diffusible hydrogen content shall be provided:

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) The component shall be saddened for two hours or more at about 280 °C directly from the welding heat (hydrogen reduction heat treatment), unless a stress-relief heat treatment is performed directly from the welding heat.

(5) A hydrogen reduction heat treatment (soaking) subsequent to weld cladding may be waived provided it is shown (e.g. by a sulphur print) that the region to be clad is free of segregations. In

this case, a slow cooling-down shall be performed directly from the welding heat, unless a stress-relief heat treatment in accordance with Sec. A 4.4.2.3 is performed directly from the welding heat.

(6) Any deviation from the requirements above, e.g., shorter duration of saddening or reduction of the saddening temperature, are permitted, if this was demonstrated by a welding procedure qualification or production control test in accordance with the KTA 3201.3.

A 4.5.2 Flame cutting and gouging

(1) A pre-heating at between 150 °C and 300 °C is required before any flame cutting or gouging. It is recommended to perform the pre-heating in a furnace in order to achieve a uniform temperature distribution (soaking).

(2) If pre-heating is carried out locally, the heated region must be large enough to ensure thorough heating. The preheating temperature shall be maintained during the entire flame cutting and gouging process.

A 4.6 Material appraisal

Material manufacturers possessing a completed material appraisal in accordance with Sec. 2.2.2 are listed in VdTÜV Material Specification Sheet 381 which specifies the manufacturing procedures, the delivery conditions and range of dimensions.

Verification by		Content by mass, %													
		C	Si	Mn	P	S	Cr	Mo	Ni	Al_{total}	Cu	V	Sn	N_{total}	As
Ladle analysis	min.	0.17	0.30	0.70	—	—	0.30	0.40	0.60	0.020	—	—	—	—	—
	max.	0.23	0.50	1.10	0.012	0.010	0.50	0.60	1.10	0.050	0.12	0.02	0.011	0.015	0.025
Product analysis [1]	min.	0.16	0.25	0.70	—	—	0.30	0.40	0.60	0.020	—	—	—	—	—
	max.	0.23	0.50	1.20	0.012 [2]	0.012 [2]	0.50	0.60 [2]	1.10	0.050	0.12 [2]	0.02	0.011 [2]	0.015 [2]	0.025

[1] See Note under Sec. A 4.3.1.

[2] If these values are exceeded and the limits for the content determined in the product analysis are claimed as P ≤ 0.015 %, S ≤ 0.015 %, Mo ≤ 0.63 %, Cu ≤ 0.18 %, Sn ≤ 0.016 % and N_{total} ≤ 0.015 %, examinations of the heat affected zone and possibly tangential cross sections shall be performed until further notice. If further fabrication calls for intermediate tempering at 550 °C, the acceptability of this temperature shall be shown in these tests or examinations. The extent and procedure of testing shall be fixed jointly with the authorized inspector.

Table A 4-1: Chemical composition determined by ladle and product analysis for various product forms made from the cast steel GS-18 NiMoCr 3 7

Determining wall thickness mm	0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.
≤ 300	390	570 to 735	16

Table A 4-2: Mechanical-technological properties in the tensile test at room temperature for various product forms made from the cast steel GS-18 NiMoCr 3 7

Temperature °C	0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm² min.	Elongation at fracture A % min.
100	370	570	16
200	360	550	15
250	350	535	14
300	345	520	13
350	343	490	12
375	338	475	11
400 [1]	333	455	11

[1] If the materials are to be used at temperatures exceeding 375 °C, supplementary tests shall be performed to determine the creep rupture strength.

Table A 4-3: Mechanical-technological properties in the tensile test at elevated temperatures for various product forms made from the cast steel GS-18 NiMoCr 3 7

	Impact energy KV_2 J		Upper shelf [2] of the absorbed impact energy KV_2 J
	at 0 °C min.	at 33 °C [1] min.	min.
Mean value of 3 specimens	41	—	—
Individual value	34	68	100

[1] If agreed upon when placing the order, this requirement also applies to lower temperatures, however, not below 10 °C.
[2] The test is generally performed at 80 °C.

Table A 4-4: Absorbed impact energy for various product forms made from the cast steel GS-18 NiMoCr 3 7

A 5 Heat-resistant cast steel GS-C 25 S

Note:
The following specifications are temporary in nature since the supplementary appraisal with respect to the requirements going beyond those for the cast steel GS-C 25 in accordance with DIN 17245 has not been completed.

A 5.1 Scope

(1) Section A 5 specifies the details regarding chemical composition, characteristic mechanical and physical properties of the cast steel GS-C 25 S as well as regarding further fabrication from castings with a wall thickness up to 100 mm within the scope of Sec. 26:

valve bodies from ferritic cast steel
(Section 26)

(2) Deviations from these requirements are permitted provided they are certified in the initial material appraisal of the authorized inspector.

A 5.2 Manufacturing of the material

(1) The cast steel GS-C 25 S is a quenched and tempered alloy steel with high strength at elevated temperatures.

(2) The cast steel GS-C 25 S shall normally be molten in the electric arc furnace, the electric induction furnace or by the argon- oxygen decarburisation (AOD) process. If other processes are used, a proof of equivalency is required.

A 5.3 Requirements

A 5.3.1 Chemical analysis

The required chemical composition for the cast steel GS-C 25 S is specified in **Table A 5-1** and shall be determined by the ladle and the product analysis.

Note:
Some of the differences in the chemical compositions between the ladle analysis and the product analysis are smaller than may be expected on the basis of metallurgical considerations. This is due to the fact that the limit values of the chemical composition for the product analysis are based only on the melts covered in the initial material appraisal.

A 5.3.2 Mechanical-technological properties

A 5.3.2.1 General requirements

(1) The requirements regarding mechanical properties of the material apply to the final condition of the component after heat treatment.

(2) The properties in accordance with Sec. 26 shall be demonstrated in the acceptance test on simulation stress-relief heat treated test coupons. The required values given below are valid for the specimen-taking locations and specimen orientations as specified under Sec. 26.

(3) In the case of a quenched and tempered wall thickness exceeding 100 mm, 10 % lower values of the minimum specified $R_{p0.2}$ and $R_m$are allowed for mid-wall than specified for the specimen-taking locations provided the impact energy and lateral expansion determined for 80 °C at mid-wall are equal to or greater than 68 J and 0.9 mm, respectively. However, testing at mid-wall shall only be considered if cast-integral test coupons are available in accordance with the definition under Sec. 26, i.e., with a thickness exceeding 100 mm in accordance with the determining wall thickness.

A 5.3.2.2 Tensile test at room temperature

(1) The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Table A 5-2**.

(2) The values for the reduction of area shall be documented for informative purposes only.

A 5.3.2.3 Tensile test at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at elevated temperatures are specified in **Table A 5-3**.

A 5.3.2.4 Impact test

The values of the minimum impact energy are specified in **Table A 5-4** and apply to the base metal and, under consideration of Sec. A 5.4.1 and A 5.5.1, also to the heat affected zone of welded joints on the component.

A 5.3.2.5 Nil-ductility transition temperature

In the Pellini drop-weight test the test specimen shape shall be P2 in accordance with SEP 1325.

A 5.3.3 Grain size

After quenching and tempering the characteristic value of the grain size shall be at least 5 in accordance with DIN EN ISO 643.

A 5.3.4 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 5.4 Heat treatment

Note:

The temperature values specified are individual piece temperatures.

A 5.4.1 Quenching and tempering

(1) The cast steel GS-C 25 S shall be subjected to a double water quenching and tempering.

Quenching and tempering	
Quenching	Tempering
900 °C to 940 °C	650 °C to 700 °C

(2) The material manufacturer together with the component manufacturer shall specify the heating and cooling rates, the temperatures as well as the times at temperature depending on component dimensions and chemical composition such that, under consideration of all subsequent heat treatments, the mechanical properties in accordance with Sec. A 5.3.2 are obtained in the final condition of the finished component.

A 5.4.2 Heat treatment during and after further fabrication

A 5.4.2.1 Quenched and tempered weldings

Production and construction weldings shall be performed after the first quenching and tempering in accordance with Sec. A 5.4.1. After the welding, a renewed quenching and tempering is required, except where Sec. A 5.4.2.2 applies.

A 5.4.2.2 Stress-relief heat treated weldings

(1) Small production weldings carried out after the double quenching and tempering procedure shall subsequently be stress-relief heat treated (cf. A 5.4.2.3).

(2) Connection weldings between castings and rolled or forged product forms may be performed after the double quenching and tempering of the castings. After welding, they shall be stress-relief heat treated in accordance with Sec. A 5.4.2.3.

(3) Connection weldings performed at the assembly site shall be subjected to stress-relief heat treatment. In this regard, the requirements laid down in KTA 3201.3 shall be observed.

(4) Weldings that can only be performed after the double quenching and tempering of the castings shall be welded higher by two layers. They shall subsequently be stress-relief heat treated in accordance with Sec. A 5.4.2.3.

(5) In those cases where in the post-welding phase no quenching and tempering but rather a stress-relief heat treatment is performed, special attention shall be paid to the possibility of performing non-destructive tests and inspections as in-service inspections.

A 5.4.2.3 Stress-relief heat treatment

(1) The final stress-relief heat treatment shall be performed between 580 °C and 620 °C.

(2) When specifying the annealing temperature, the heating and cooling rates and times at temperature, consideration shall be given to changes in material characteristics that may occur during annealing.

A 5.5 Further fabrication

A 5.5.1 Welding

(1) Castings are fusion-weldable (production and construction weldings) by the following procedures:

a) metal-arc welding with basic coated electrodes,

b) submerged-arc welding with basic flux.

(2) The pre-heating, intermediate layer or working temperature depends on the thickness of the welded piece and shall be between 100 °C and 250 °C; in the case of sufficient experience, the preheating may be omitted.

(3) The weld consumables and filler materials allowed for submerged arc welding shall basically be basic-coated rod electrodes with controlled content of hydrogen or similar basic fluxes that must be dried, if necessary, in accordance with the requirements of the manufacturer of the weld filler material. The component shall be saddened for not less than 2 hours at about 280 °C directly from the welding heat, unless a stress-relief heat treatment is performed directly from the welding-heat. A heat treatment for low hydrogen content is not required provided the component was preheated prior to welding.

(4) Any deviation from the requirements above, e.g., application of different welding procedures, shall be agreed upon with the material manufacturer and fixed jointly with the authorized inspector. Here, the wall thickness and the type of weld consumables, the component type and experience gained up to now shall all be taken into account. It shall be shown that no damaging effects, e.g. of the weld connection, result from these deviations.

A 5.5.2 Flame cutting and gouging

(1) A pre-heating at between 100 °C and 300 °C is required before any flame cutting or gouging. It is recommended to perform the pre-heating in a furnace in order to achieve a uniform temperature distribution (soaking).

(2) If the pre-heating is carried out locally, the heated region must be large enough to ensure thorough heating. The preheating temperature shall be maintained during the entire flame cutting and gouging process.

A 5.6 Material appraisal

Material manufacturers have to demonstrate a material appraisal in accordance with Sec. 2.2.2 which specifies the manufacturing procedures, the delivery conditions and range of dimensions.

Verification by		Content by mass, %									
		C	Si	Mn	P	S	Cr	Al_{total}	Cu	V	N_{total}
Ladle analysis	min.	0.18	0.30	0.50	—	—	—	0.020	—	—	—
	max.	0.22	0.60	1.10	0.015	0.010	0.30	0.070	0.18	0.02	0.015
Product analysis [1)]	min.	0.18	0.30	0.50	—	—	—	0.020	—	—	—
	max.	0.22	0.60	1.10	0.015	0.012	0.30	0.070	0.18	0.02	0.015

[1)] See Note under Sec. A 5.3.1.

Table A 5-1: Chemical composition of the cast steel GS-C 25 S determined by ladle and product analysis

Determining wall thickness mm	0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm² min.	Elongation at fracture A % min.
≤ 100	245	440 to 590	22

Table A 5-2: Mechanical-technological properties of the cast steel GS-C 25 S in the tensile test at room temperature

Temperature °C	0.2%-proof stress [1)] $R_{p0.2}$ N/mm² min.	Tensile strength [1)] R_m N/mm² min.	Elongation at fracture [1)] A % min.
100	(205)	(410)	(21)
200	175	(400)	(20)
250	(160)	(400)	(19)
300	145	(390)	(18)
350	135	(375)	(20)
400	(130)	(355)	(25)

1) The values in parantheses still need to be ensured statistically.

Table A 5-3: Mechanical-technological properties of the cast steel GS-C 25 S in the tensile test at elevated temperatures

	Impact energy KV_2 J		Upper shelf [2)] of the absorbed impact energy KV_2 J min.
	at 0 °C min.	at 33 °C [1)] min.	
Mean value of 3 specimens	41	—	—
Individual value	34	68	100

1) If agreed upon when placing the order, this requirement also applies to lower temperatures, however, not below +5 °C.
2) The test is generally performed at 80 °C.

Table A 5-4: Absorbed impact energy of the cast steel GS-C 25 S

A 6 Austenitic cast steel G-X 5 CrNiNb 18 9 S

A 6.1 Scope

(1) Section A6 specifies the details regarding chemical composition, characteristic mechanical and physical properties of the cast steel G-X 5 CrNiNb 18 9 S as well as regarding further fabrication for the product forms within the scopes of Sec. 27:

valve bodies from austenitic cast steel
(Section 27)

(2) Deviations from these requirements are permitted provided they are certified in the initial material appraisal of the authorized inspector.

A 6.2 Manufacturing of the material

The cast steel G-X 5 CrNiNb 18 9 S shall normally be molten in the electric-arc furnace, the electric induction furnace or by the argon-oxygen decarburization (AOD) process. If other processes are used, a proof of equivalency is required.

A 6.3 Requirements

A 6.3.1 Chemical analysis

The required chemical composition for the cast steel G-X 5 CrNiNb 18 9 S is specified in **Table A 6-1** and shall be determined by the ladle and the product analysis.

A 6.3.2 Mechanical-technological properties

A 6.3.2.1 General requirements

(1) The requirements regarding mechanical properties of the material apply to the final condition of the component after heat treatment.

(2) The required values given below are valid for the specimen- taking locations and specimen orientations as specified under Sec. 27.

A 6.3.2.2 Tensile test at room temperature

The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Table A 6-2**.

Note:

The strength characteristics are achievable over the entire cross section due to the regular wall thickness of about 150 mm within the scope of Sec. 27.

A 6.3.2.3 Tensile at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at elevated temperatures are specified in **Table A 6-3**.

A 6.3.2.4 Impact test

The values of the minimum impact energy are specified in **Table A 6-4** and apply to the base metal and, also, under consideration of Sec. A 6.4.1 and A 6.4.2, to the heat affected zone of weldings in the component.

A 6.3.3 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 6.3.4 Corrosion resistance

The cast steel G-X 5 CrNiNb 18 9 S, in the sensitisation annealed condition (650 °C, 30 minutes), shall be resistant to intergranular corrosion under the testing conditions in accordance with DIN EN ISO 3651-2.

A 6.4 Heat treatment

Note:

The temperature values specified are individual piece temperatures.

A 6.4.1 Solution annealing

The cast steel G-X 5 CrNiNb 18 9 S shall be solution annealed between 1050 °C and 1100 °C and subsequently be quenched in water.

A 6.4.2 Heat treatment during and after processing

(1) Production and construction weldings shall be performed on the casting after solution annealing and quenching. After the welding, a renewed solution annealing and quenching shall normally be performed.

(2) Connection weldings between castings and rolled or forged product forms may be performed after the last solution annealing of the castings; after welding, no renewed heat treatment is required.

(3) In the case of smaller production weldings, the renewed solution annealing and quenching may be omitted (cf. Sec. 27).

(4) The material does not required stress-relief heat treatment after weldings.

A 6.5 Further fabrication

A 6.5.1 Welding

(1) The cast steel G-X 5 CrNiNb 18 9 S in the certified range of dimensions is fusion-weldable by the following procedures:

a) metal-arc welding with basic coated electrodes,

b) submerged-arc welding with basic flux,

c) inert gas welding with or without weld additives (TIG, MIG).

(2) The material is welded without any preheating.

(3) The intermediate layer and working temperatures shall not exceed 200 °C.

A 6.5.2 Flame cutting and gouging

The material is flame-cut and gouged without requiring any preheating.

A 6.6 Material appraisal

Material manufacturers have to demonstrate a material appraisal in accordance with Sec. 2.2.2 which specifies the manufacturing procedures, the delivery conditions and range of dimensions.

Verification by		Content by mass, %									
		C	Si	Mn	P	S	Cr	Ni	Mo	Nb	Co
Ladle analysis	min.	—	—	—	—	—	18.0	9.0	—	8 • C	—
	max.	0.06	1.50	1.50	0.020	0.010	20.0	11.0	0.50	0.65	0.2
Product analysis [1)]	min.	—	—	—	—	—	18.0	9.0	—	8 • C	—
	max.	0.06	1.50	1.50	0.020	0.010	20.0	11.0	0.50	0.65	0.2

[1)] See Note under Sec. A 4.3.1.

Table A 6-1: Chemical composition of the cast steel G-X 5 CrNiNb 18 9 S determined by ladle and product analysis

Determining wall thickness mm	0.2%-proof stress $R_{p0.2}$ N/mm² min.	1%-proof stress $R_{p1.0}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.
≤ 150	175	200	440 to 640	20

Table A 6-2: Mechanical properties of the cast steel G-X 5 CrNiNb 18 9 S in the tensile test at room temperature

Temperature °C	0.2%-proof stress $R_{p0.2}$ N/mm² min.	1%-proof stress [1] $R_{p1.0}$ N/mm² min.	Tensile strength R_m N/mm² min.	Elongation at fracture A % min.
100	150	175	400	20
200	130	155	360	21
250	125	150	345	21
300	120	145	330	22
350	115	140	325	22
400	110	130	300	25

[1] Regarding the utilisation of the minimum 1.0%-proof stress in strength calculations, see KTA 3201.2.

Table A 6-3: Mechanical properties of the cast steel G-X 5 CrNiNb 18 9 S in the tensile test at elevated temperatures

	Impact energy KV_2 J min.
Mean value of 3 specimens	80
Individual value	70

Table A 6-4: Absorbed impact energy of the cast steel G-X 5 CrNiNb 18 9 S at 20 °C

A 7 Quenched and tempered fine-grained structural steel as base material and stainless austenitic steel as cladding material for seamless, extrusion-clad composite tubes

A 7.1 Scope

(1) Section A 7 specifies the details with regard to chemical composition, characteristic mechanical and physical properties of the aluminium-killed fine-grained structural steel as base material and stainless austenitic steel as cladding material as well as with regard to further fabrication for the product forms within the scopes of Sec. 19:

seamless, extrusion-clad composite pipes (Section 19).

(2) Deviations from these requirements are permitted provided they are certified in the initial material appraisal of the authorized inspector.

A 7.2 Manufacturing of the material

(1) The base material is an aluminium-killed fine-grained structural steel. The wall thickness of the base material lies between 10 and 30 mm. The cladding material is a stainless austenitic steel.

(2) The steels shall normally be molten in the electric-arc furnace and may be treated further by the argon-oxygen decarburization (AOD) or the vacuum-oxygen decarburization (VOD) process. If other processes are used, a proof of equivalency is required.

(3) The composite pipes shall be delivered in the quenched and tempered and stress-relief heat treated condition.

A 7.3 Requirements

A 7.3.1 Chemical analysis

The required chemical compositions for the base material and cladding material are specified in **Tables A 7-1** and **A 7-2** and shall be determined by the ladle and the product analysis.

A 7.3.2 Mechanical-technological properties

A 7.3.2.1 General requirements

(1) The requirements regarding mechanical properties of the material apply to the final condition of the component after the final heat treatment.

(2) The properties shall be demonstrated in the acceptance test on simulation stress-relief heat treated test coupons (cf. Sec. A 7.4.3). The required values given below are valid for the specimen-taking locations and specimen orientations as specified under Sec. 19.

A 7.3.2.2 Tensile test at room temperature

The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Table A 7-3**.

A 7.3.2.3 Tensile test at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at elevated temperatures are specified in **Table A 7-4**.

A 7.3.2.4 Impact test

The values of the minimum impact energy are specified in **Table A 7-5**.

A 7.3.2.5 Ring flattening test

(1) In the ring flattening test in accordance with DIN EN ISO 8492, the test specimens or pipes shall be flattened to such a degree that a defined distance H between the two pressure plates is achieved. This distance H in mm is defined by the following equation with s being the wall thickness and d_a the outer diameter, both in mm:

$$H = \frac{(1+0.07)\cdot s}{0.07+\frac{s}{d_a}},$$

(2) The ring flattening test may be continued until the pipe breaks or cracks in order to be able to evaluate the fracture cross section. However, the deciding factor is that flattening can be performed down to the specified distance of the plate without any cracks appearing in the pipe.

A 7.3.2.6 Disbonding test of cladding

The side-bend test to DIN EN ISO 5173 shall be performed on cladded axial test specimens and with a bending mandrel of diameter D = 4 · a (a : specimen thickness) ; a bending angle of 180 degrees shall be obtained.

A 7.3.3 Grain size

In the delivery condition, the characteristic value of the ferrite grain size for the base material shall be equal or greater than 5 in accordance with DIN EN ISO 643.

A 7.3.4 Resistance to intergranular corrosion

(1) Under given conditions of fabrication, especially after welding and after heat treatment, the surface of the cladding material shall be resistant to intergranular corrosion down to a depth of 1.5 mm when tested in accordance with DIN EN ISO 3651-2.

(2) The sensitisation shall be carried out in accordance with Sec. A 7.4.3, unless other requirements are specified when placing the order.

A 7.4 Heat treatment

Note:
The temperature values specified are individual piece temperatures.

A 7.4.1 Quenching and tempering, and stress-relief heat treatment (delivery condition)

Quenching and tempering		Stress-relief heat treatment [1]
Quenching	Tempering	
900 °C to 950 °C quenching in water	640 °C to 690 °C cooling in air	565 °C to 595 °C

[1] After straightening the pipes.

A 7.4.2 Stress-relief heat treatment after welding

If, on account of the design, a stress-relief heat treatment is required after welding, it shall be performed within the temperature range of 550 °C and 600 °C.

A 7.4.3 Simulation heat treatment

(1) Unless other values are specified by the purchaser, the test coupons for the acceptance test shall be subjected to the following simulation heat treatment:

a) heating-up to 590 °C ± 10 K, holding time 5 h,

b) cooling-down to 500 °C ± 10 K,

c) heating-up to 590 °C ± 10 K, holding time 5 h,

d) cooling down.

(2) Above 300 °C, the heating and cooling rates shall normally be about 50 K/h.

A 7.5 Further fabrication

A 7.5.1 Welding

(1) The application of the following welding procedures are considered to be appraised for the base material and the cladding material:

a) metal-arc welding,

b) inert gas welding with weld consumables.

(2) The pre-heating and working temperature shall normally be at least 120 °C, the intermediate layer temperature shall normally not be higher than 200 °C.

(3) When welding the weld root within the cladding layer, no pre-heating is required.

A 7.5.2 Flame cutting

Flame cutting is not intended to be performed.

A 7.5.3 Forming

It is not intended that any forming be performed during further fabrication.

A 7.6 Material appraisal

Material manufacturers possessing a completed material appraisal in accordance with Sec. 2.2.2 are listed in VdTÜV Material Specification Sheet 439 which specifies the manufacturing procedures, the delivery conditions and range of dimensions.

Verification by		Content by mass, % [1]					
		C	Si	Mn	P	S	Al
Ladle analysis	min.	0.15	0.20	1.25	—	—	0.010
	max.	0.20	0.40	1.60	0.020	0.015	0.030
Product analysis	min.	0.13	0.18	1.20	—	—	0.005
	max.	0.22	0.42	1.65	0.020	0.015	0.040

[1] The elements N, Cr, Cu, Mo, Nb, Ni, Ti and V shall not be added as alloying elements. In the inspection certificate, the content of these elements shall be specified as determined in the ladle analysis.

Table A 7-1: Chemical composition of the base material determined by ladle and product analysis for seamless, extrusion clad composite pipes

Verification by		Content by mass, %									
		C	Si	Mn	P	S	N [1]	Cr	Mo [1]	Ni	Nb
Ladle analysis	min.	—	—	—	—	—	—	17.0	—	9.0	13 • C
	max.	0.040	1.00	2.00	0.030	0.030	—	19.0	—	12.0	0.65
Product analysis	min.	—	—	—	—	—	—	16.8	—	8.85	13 • C
	max.	0.050	1.05	2.04	0.035	0.035	—	19.2	—	12.15	0.70

[1] The elements N and Mo shall not be added as alloying elements. In the inspection certificate, the content of these elements shall be specified as determined in the ladle analysis.

Table A 7-2: Chemical composition of the cladding material determined by ladle and product analysis for seamless, extrusion clad composite pipes

0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.
345	500 bis 650	25

Table A 7-3: Mechanical properties of the base material in the tensile test of longitudinal test specimens at room temperature for seamless, extrusion clad composite pipes

	Temperature T						
	100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C
0.2%-proof stress $R_{p0.2}$ N/mm² min.	310	305	295	295	295	295	295
Tensile strength R_m N/mm² min.	—	—	—	—	—	470	—

Table A 7-4: Mechanical properties of the base material in the tensile test of longitudinal test specimens at elevated temperatures for seamless, extrusion clad composite pipes

Test specimen shape	Test specimen orientation	Impact energy KV_2 (smallest individual value) J min.	Lateral expansion (smallest individual value) mm min.
Charpy-V	transverse	41	0.6
	longitudinal	160	1.5

Table A 7-5: Absorbed impact energy and lateral expansion of the base material at 20°C for seamless, extrusion clad composite pipes

A 8 Martensitic steel X 5 CrNi 13 4

A 8.1 Scope

(1) Section A 8 specifies the details with regard to the chemical composition, characteristic mechanical and physical properties of the martensitic steel X 5 CrNi 13 4 as well as with regard to further fabrication for the product forms within the scopes of Sec. 28:

bars and forgings
(Section 28)

(2) The maximum allowed design temperature is 350 °C and the maximum allowed continuous operating temperature is 300 °C.

(3) Deviations from these requirements are permitted provided they are certified in the initial material appraisal of the authorized inspector.

A 8.2 Manufacturing of the material

The material shall normally be molten in the electric-arc furnace and may be treated further by the argon-oxygen decarburisation (AOD), the vacuum-oxygen decarburisation (VOD) or the electro-slag remelt process. If other processes are used, a proof of equivalency is required.

A 8.3 Requirements

A 8.3.1 Chemical analysis

The chemical composition of the material is specified in **Table A 8-1** and shall be determined by the ladle and the product analysis.

A 8.3.2 Mechanical-technological properties

A 8.3.2.1 General requirements

(1) The requirements regarding material characteristics apply to the quenched and tempered or quenched and tempered and stress-relief heat treated condition.

(2) The required values given below are valid for the specimen-taking locations and specimen orientations as specified under Sec. 28.

(3) The characteristic values of the mechanical properties given below are valid for the range of dimensions specified in **Table A 8-2**.

A 8.3.2.2 Tensile test at room temperature

(1) The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Table A 8-2**.

(2) The elastic ratio shall normally not exceed a value of 0.90.

A 8.3.2.3 Tensile test at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at elevated temperatures are specified in **Table A 8-3**.

A 8.3.2.4 Impact test

The values of the minimum impact energy at room temperature are specified in **Table A 8-4**.

A 8.3.3 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 8.4 Heat treatment

Note:
The temperature values specified are individual piece temperatures.

Quenching and tempering	
Quenching	Tempering
950 °C to 1050 °C Holding time at least 1 h after soaking of the product. Cooling in air or oil.	560 °C to 600 °C Holding time at least 8 h after soaking of the product; in the case of multiple annealing, this applies to the overall holding time. Cooling in furnace or in air.

A 8.5 Further fabrication

A 8.5.1 Welding

(1) The application of the following welding procedures are considered as certified:

a) metal-arc welding with basic coated electrodes,

b) submerged arc welding with basic flux,

c) tungsten-inert-gas welding with or without weld additives,

d) tungsten-inert-gas welding with or without weld additives,.

(2) A pre-heating to a temperature between 150 °C and 200 °C is required. The intermediate layer temperature shall not exceed 350 °C.

(3) After welding, a heat treatment is required.

(4) The heat treatment may be performed as follows

a) tempering in accordance with Sec. A 8.4 or

b) stress-relief heat treatment in the temperature range between 530 °C and 570 °C, however, not above the actually used tempering temperature. The heating time shall be at least 4 hours. The cooling shall subsequently be performed in the furnace.

A 8.5.2 Forming

It is not intended that any forming be performed during further fabrication.

A 8.6 Material appraisal

Material manufacturers possessing a material appraisal in accordance with Sec. 2.2.2 are listed in VdTÜV Material Specification Sheet 395/3 which specifies the manufacturing procedures, the delivery condition and range of dimensions.

Verification by		Content by mass, %									
		C	Si	Mn	P	S	N	Co	Cr	Mo	Ni
Ladle analysis	min.	—	—	—	—	—	0.020	—	12.6	0.30	3.50
	max.	0.050	0.60	1.00	0.030	0.015	—	0.20	13.9	0.70	4.50
Product analysis	min.	—	—	—	—	—	0.015	—	12.5	0.25	3.45
	max.	0.060	0.65	1.05	0.035	0.018	—	0.23	14.0	0.75	4.60

Table A 8-1: Chemical composition of the steel X 5 CrNi 13 4 determined by ladle and product analysis

Product form	Dimension		Test specimen orientation	0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.	Reduction of area at fracture Z % min.
	Diameter mm	Wall thickness mm					
Bars	≤ 160	—	transverse	685	780 to 980	15	40
			longitudinal		780 to 980	17	
	> 160 to ≤ 400	—	transverse	635	780 to 980	15	
Forgings	—	≤ 750	transverse/ tangential		780 to 980	15	
The ratio $\frac{R_{p0.2}}{R_m}$ shall normally not exceed 0.90.							

Table A 8-2: Mechanical-technological properties of the steel X 5 CrNi 13 4 in the tensile test at room temperature

Product form	Dimension		Test specimen orientation	Test temperature °C	0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm² min.
	Diameter mm	Wall thickness mm				
Bars	≤ 160	—	transverse and longitudinal	100	650	745
				150	635	730
				200	620	715
				250	605	700
				300	590	685
				350	575	670
Bars	> 160 to ≤ 400	—	transverse	100	600	695
				150	585	680
				200	570	665
Forgings	—	≤ 750	transverse/ tangential	250	555	650
				300	540	635
				350	525	620

Table A 8-3: Mechanical-technological properties of the steel X 5 CrNi 13 4 in the tensile test at elevated temperatures

Product form	Dimension		Test specimen orientation	Impact energy KV_2 in J	
	Dimension mm	Wall thickness mm		Mean value of 3 test specimens min.	Individual value min.
Bars	≤ 160	—	transverse	70	50
			longitudinal	90	70
	> 160 to ≤ 400	—	transverse	70	50
Forgings	—	≤ 750	transverse/ tangential	70	50

Table A 8-4: Absorbed impact energy of the steel X 5 CrNi 13 4 at room temperature

A 9 Nickel Alloy 29 Fe

A 9.1 Scope

Section A 9 specifies the details with regard to the chemical composition, characteristic mechanical and physical properties of the nickel alloy NiCr 29 Fe as well as with regard to further fabrication for the product forms within the scopes of Secs. 18 and 22:

a) steam generator heat exchanger tubes (Section 18),

b) bars (Section 22).

A 9.2 Manufacturing of the material

(1) The material shall normally be molten in the electric-arc furnace and may be treated further in the argon-oxygen decarburisation (AOD) converter or by the electro-slag remelt process. If other processes are used, a proof of equivalency is required.

(2) The tubes and bars shall be delivered in a stabilization annealed condition.

A 9.3 Requirements

A 9.3.1 Chemical analysis

The chemical composition of the nickel alloy NiCr 29 Fe is specified in **Tables A 9-1** and **A 9-2** and shall be determined by the ladle and the product analysis.

A 9.3.2 Mechanical-technological properties

A 9.3.2.1 General requirements

The requirements regarding material characteristics apply to the delivery condition.

A 9.3.2.2 Tensile test at room temperature and at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at room temperature and elevated temperatures are specified in **Table A 9-3**.

A 9.3.2.3 Impact test on bars

For each specimen-taking location one set of impact test specimens shall be tested in accordance with Sec. 3.3.7.3 (3) at 20 °C. The values of the minimum impact energy are specified in **Table A 9-4**.

A 9.3.2.4 Drift test on tubes

The tubes shall meet the requirements of the drift test in accordance with Sec. 18.

A 9.3.3 Metallographic examinations

(1) The characteristic value of the grain size of bars shall be equal to or greater than 4 and of tubes equal to or greater than 7 in accordance with DIN EN ISO 643.

(2) The grain boundaries must be filled entirely with carbides.

A 9.3.4 Corrosion resistance

The corrosion resistance shall be demonstrated in accordance with ASTM A262 practice B on one test specimen of each melt and heat treatment lot.

The maximum acceptable weight loss is 0.4 mm/a.

A 9.3.5 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 9.4 Heat treatment

(1) The solution annealing shall be performed at temperatures between 1070 °C and 1120 °C. The annealing and cooling of tubes shall be performed in protective gas. The cooling of bars shall be performed in air or faster.

(2) The subsequent stabilizing annealing shall be performed at temperatures between 700 °C and 730 °C complying with a tolerance of ± 10 K at the temperature used. The duration of stabilizing annealing shall not be less than 10 h. The annealing and cooling of tubes shall be performed in protective gas.

(3) Sec. A 9.5.3 shall be taken into account when performing heat treatments.

Note:
In international practice the term "Thermal Treatment (TT)" is used for this heat treatment condition.

A 9.5 Further fabrication

A 9.5.1 Welding in the tubes

The tubes-to-tubesheet welding shall be performed with the tungsten-inert-gas welding with or without weld filler metals. No preheating is required. Sec. A 9.5.3 shall be taken into consideration.

A 9.5.2 Bending of the tubes

(1) Cold bending of the tubes is allowed.

(2) After cold bending with bending radii of 300 mm or smaller, another stabilizing heat treatment with a duration of at least 2 h shall be performed.

A 9.5.3 Special fabrication measures

(1) At temperatures above 400 °C the material is sensitive to sulphur. Therefore, the surface shall be carefully cleaned before welding and after each heat treatment (e.g., oil and grease residues, finger prints, paints and other markings, atmospheric pollution).

(2) The furnace atmosphere shall be free of sulphur and may then be adjusted to a slightly reducing or neutral atmosphere.

(3) If freedom from sulphur cannot be ensured, the annealing shall be performed in a slightly oxidising atmosphere. Fluctuations between oxidising and reducing conditions shall be avoided.

A 9.6 Material appraisal

Material manufacturers have to demonstrate a material appraisal in accordance with Sec. 2.2.2 which specifies the manufacturing procedures, the delivery conditions and range of dimensions.

Verification by		Content by mass, %							
		C	Si	Mn	P	S	Cr	Ni	Fe
Ladle analysis	min.	0.015	—	—	—	—	28.5	58.0	9.0
	max.	0.025	0.50	0.50	0.015	0.010	31.0	62.0	11.0
Product analysis	min.	0.010	—	—	—	—	28.2	57.65	8.9
	max.	0.035	0.53	0.53	0.020	0.013	31.3	62.45	11.15
Verification by		Content by mass, %							
		Nb [1]	Ti	Cu	Co	Al	B	Mo	N
Ladle analysis	min.	—	—	—	—	—	—	—	—
	max.	0.10	0.40	0.10	0.06	0.40	0.005	0.20	0.050
Product analysis	min.	—	—	—	—	—	—	—	—
	max.	0.15	0.43	0.12	0.07	0.45	0.007	0.23	0.060
[1] Including Ta									

Table A 9-1: Chemical composition of steam generator heat exchanger tubes made of the nickel alloy NiCr 29 Fe determined by ladle and product analysis

Verification by		Content by mass, %							
		C	Si	Mn	P	S	Cr	Ni	Fe
Ladle analysis	min.	0.015	—	—	—	—	28.0	58.0	8.0
	max.	0.040	0.50	0.50	0.015	0.010	31.0	62.0	11.0
Product analysis	min.	0.010	—	—	—	—	27.7	57.65	7.9
	max.	0.050	0.53	0.53	0.020	0.013	31.3	62.45	11.15
Verification by		Content by mass, %							
		Nb [1]	Ti	Cu	Co	Al	B	Mo	N
Ladle analysis	min.	—	—	—	—	—	—	—	—
	max.	0.10	0.50	0.50	0.20	0.50	0.007	0.20	0.050
Product analysis	min.	—	—	—	—	—	—	—	—
	max.	0.15	0.53	0.53	0.22	0.55	0.009	0.23	0.060
[1] Including Ta									

Table A 9-2: Chemical composition of bars made of the nickel alloy NiCr 29 Fe determined by ladle and product analysis

Temperature	0.2%-proof stress $R_{p0.2}$ N/mm²			Tensile strength R_m N/mm²		Elongation at fracture A %	
	Tubes		Bars	Tubes	Bars	Tubes	Bars
	min.	max.	min.	min.	min.	min.	min.
Room temperature	276	379	220	586	586	30	30
350 °C	217	—	160	551	480	—	—

Table A 9-3: Mechanical-technological properties of the nickel alloy NiCr 29 Fe in the tensile test at room temperature and elevated temperatures

Impact energy KV_2 J Mean value of 3 specimens min.	Impact energy KV_2 J Individual value min.
125	90

Table A 9-4: Absorbed impact energy of bars made of the nickel alloy NiCr 29 Fe at room temperature

A 10 Quenched and tempered steels for bars and rings for bolts and nuts as well as extension sleeves

A 10.1 Scope

(1) Section A 10 specifies the details regarding the chemical composition, characteristic mechanical and physical properties of the steels as well as regarding further fabrication of the product forms within the scopes of Secs. 20 and 21:

a) bars and rings for bolts, nuts and washers as well as bolts, nuts and washers as well as bolts, nuts and washers (dimensions exceeding M 130),
(Section 20),

b) bars for bolts, nuts and washers as well as extension sleeves (dimensions equal to or less than M 130)
(Section 21).

(2) These requirements apply to forged bars and rings as well as to the bolts, nuts and washers as well as extension sleeves machined from these product forms.

A 10.2 Manufacturing of the steels

(1) The steels are quenched and tempered steels characterised by specified minimum values of high strength at elevated temperatures.

(2) The steels shall be molten in the electric-arc furnace or by the basic-oxygen process and the ladle then be metallurgically treated or remolten under vacuum or by the electro-slag remelt process. If other processes are used, a proof of equivalency is required.

(3) The steels are delivered in the quenched and tempered condition or in the annealed and stress-relief heat treated condition.

A 10.3 Requirements

A 10.3.1 Chemical analysis

(1) The chemical compositions specified in **Table A 10-1** apply to these steels and shall be determined by the ladle analysis.

(2) The allowable deviations of the chemical compositions determined in the product analysis from the limit values of the ladle analysis are specified in **Table A 10-2**.

A 10.3.2 Mechanical-technological properties

A 10.3.2.1 General requirements

The requirements regarding mechanical properties apply to the delivery condition as specified under Sec. A 10.2 (3). The specified values apply to the specimen shape, specimen-taking locations and specimen orientation as specified under Secs. 20 and 21 for bars and rings.

A 10.3.2.2 Tensile test at room temperature

The characteristic values for the mechanical properties determined by the tensile test at room temperature are specified in **Table A 10-3**.

A 10.3.2.3 Tensile test at elevated temperatures

The characteristic values for the mechanical properties determined by the tensile test at elevated temperatures are specified in **Table A 10-4**.

A 10.3.2.4 Impact test

The values of the minimum impact energy are specified in **Table A 10-5**.

A 10.3.3 Physical characteristics

Typical values for the physical characteristics are specified in **Annex AP**.

A 10.4 Heat treatment

The details regarding heat treatment are specified in **Table A 10-6.**

A 10.5 Further fabrication

Only machining procedures are allowed for further fabrication.

Note:
It is not intended that any hot or cold forming be performed during further fabrication (thread rolling is not considered to be a cold forming procedure).

A 10.6 Material appraisal

Material manufacturers of the steels 20 NiCrMo 14 5 and 26 NiCrMo 14 6 possessing a material appraisal in accordance with Sec. 2.2.2 are listed in VdTÜV Material Specification Sheets 337 and 390 which specify the manufacturing procedures, the delivery conditions and range of dimensions.

Material		Content by mass, %									
		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	0.15	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	—	[2]
	max.	0.38	0.40	0.70	0.020	0.010	1.70	0.35	1.70	—	

[1] Values > 0.08 up to ≤ 0.12 % may be specified in the individual material appraisal.

[2] An aluminium content is not specified.

Table A 10-1: Chemical composition of the quenched and tempered steels for bars and rings for bolts, nuts, washers as well as extension sleeves determined by ladle analysis

Chemical element	Allowable deviation [1] of values determined by 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 more than one product analysis is performed for one melt and the results show deviations of the chemical composition determined by the product analysis from the range limit of the composition determined by the ladle analysis, then a particular element may either be above the maximum or below the minimum limit value specified in **Table A 10-1**, but no simultaneous deviation of a melt from both limit values is permitted.

[2] If the nickel content determined by the ladle analysis lies between 2.00 and 4.00 %, the deviation as determined by the product analysis is allowed to be ± 0.07 %.

Table A 10-2: Allowable deviations of the chemical composition by the product analysis from the range limit of the composition by the ladle analysis

Steel grade	Diameter (bars) mm	Test specimen orientation	0.2%-proof stress $R_{p0.2}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation at fracture A % min.	Reduction of area at fracture Z % min.
20 NiCrMo 14 5 (I)	≤ 130	longitudinal	940	1040 to 1240	14	55
20 NiCrMo 14 5 (II)	≤ 130	longitudinal	980	1080 to 1280	14	55
26 NiCrMo 14 6	≤ 130	longitudinal	940	1040 to 1240	14	50
	> 130 to ≤ 380	longitudinal or tangential	885	1030 to 1230	14	45
34 CrNiMo 6 S	≤ 130	longitudinal	830	930 to 1130	16	45
	> 130 to ≤ 380	longitudinal or tangential	735	835 to 980	16	45

Table A 10-3: Mechanical properties of the quenched and tempered steels for bars and rings for bolts, nuts, washers as well as extension sleeves in the tensile test at room temperature

Steel grade	Diameter (bars) mm	Test specimen orientation	0.2%-proof stress $R_{p0.2}$ N/mm² min.		Tensile strength R_m N/mm² min.		Elongation at fracture A % min.		Reduction of area at fracture Z % min.	
			at temperature, °C							
			300	350	300	350	300	350	300	350
20 NiCrMo 14 5 (I)	≤ 130	longitudinal	785	735	860	840	14	14	55	55
20 NiCrMo 14 5 (II)	≤ 130	longitudinal	830	785	900	880	14	14	55	55
26 NiCrMo 14 6	≤ 380	longitudinal or tangential [1)]	790	785	860	820	14	14	45	45
34 CrNiMo 6 S	≤ 380	longitudinal or tangential [1)]	630	560	760	735	16	16	45	45

[1)] In the case of diameters less than 130 mm the values apply only to the longitudinal test specimen orientation.

Table A 10-4: Mechanical-technological properties of the quenched and tempered steels for bars and rings for bolts, nuts, washers as well as extension sleeves in the tensile test at elevated temperatures

Steel grade	Diameter (bars) mm	Test specimen orientation	Impact energy KV_2 J		Lateral expansion mm
			Mean value of 3 test specimens min.	Individual value min.	Individual value min.
20 NiCrMo 14 5 (I)	≤ 130	longitudinal	76	61	0.65
20 NiCrMo 14 5 (II)	≤ 130	longitudinal	76	61	0.65
26 NiCrMo 14 6	≤ 380	longitudinal or tangential [1)]	72	61	0.65
34 CrNiMo 6 S	≤ 380	longitudinal or tangential [1)]	76	61	0.65

[1)] In the case of diameters ≤ 130 mm the values apply only to the longitudinal test specimen orientation.

Table A 10-5: Absorbed impact energy of the quenched and tempered steels for bars and rings for bolts, nuts, washers as well as extension sleeves at 20 °C

Steel grade	Temperature range for austenitising °C	Quenching medium	Temperature for tempering [1] °C	Temperature for stress-relief heat treatment °C
20 NiCrMo 14 5 (I)	840 to 900	water or oil	520 to 600	430 to 470
20 NiCrMo 14 5 (II)			500 to 580	
26 NiCrMo 14 6	840 to 870	water or oil	530 to 580	450 to 500
34 CrNiMo 6 S	820 to 870	water or oil	550 to 640	450 to 500

[1] The heating and cooling rates, the temperatures as well as the holding times shall be specified by the material manufacturer depending on the dimensions and chemical compositions such that the mechanical properties specified under Sec. A 10.3.2 are met.

Table A 10-6: Specifications for the heat treatment of the quenched and tempered steels for bars and rings for bolts, nuts, washers as well as extension sleeves

A 11 Quenched and tempered steels in accordance with DIN EN 10269 for bars and rings for bolts, nuts and washers as well as extension sleeves; supplementary requirements to DIN EN 10269

A 11.1 Scope

(1) Section A 11 supplements DIN EN 10269 with respect to the steel grades specified in **Table A 11-1** in as far as they are used for bolts, nut and washers as well as extension sleeves in accordance with Sec. 21.

(2) The requirements apply to rolled or forged bars and to the bolts, nuts and washers as well as extension sleeves fabricated from these product forms.

A 11.2 Limits of dimensions

The steel grades specified in **Table A 11-1** shall be applied only up to the dimensions specified in this table.

A 11.3 Impact test

The required values to be obtained for the absorbed impact energy and the lateral expansion in the impact test on longitudinal test specimens at 20 °C are specified in **Table A 11-1**.

A 11.4 Tensile test at elevated temperatures

The required values to be obtained for the tensile strength at 300 °C and 350 °C are specified in **Table A 11-1**.

A 11.5 Material appraisal

The material appraisal required in accordance with Sec. 2.2.2 is considered to be successfully performed for the steel grades to DIN EN 10269 as specified in **Table A 11-1** due to the proved experience with these materials under consideration of the additional requirements specified in **Table A 12-1** and of the scope specified under Sec. A 11.1.

Steel grade to DIN EN 10269	Limits of allowable dimensions	Impact energy KV_2 J		Lateral expansion mm	Tensile strength R_m N/mm²	
		at room temperature (longitudinal test specimens)			min.	
	diameter mm	Mean value min.	Individual value min.	Individual value min.	at temperature 300 °C	350 °C
C35E+QT	≤ 60	55	42	0.65	400	390
25CrMo4	≤ 100	60	42	0.65	460	440
21CrMoV5-7	≤ 100	63	52	0.65	590	560

Table A 11-1: Limit values for the dimensions and supplementary requirements for steels in accordance with DIN EN 10269 for bolts, nuts and washers as well as extension sleeves

Annex AP

Characteristic values of physical properties

AP 1 General

This Annex contains characteristic values for

a) the density,

b) the dynamic modulus of elasticity,

c) the average linear thermal expansion coefficient,

d) the average specific thermal capacity and

e) the thermal conductivity

of the steel types specified under Sec. A 1 through A 12.

AP 2 Characteristic values

AP 2.1 General

The characteristic values of physical properties specified in the following tables represent data collected on the basis of measurements on individual melts and of data from literature [3].

AP 2.2 Determination of the characteristic values

At this time, there are no standard procedures for the determination of the characteristic values for the physical properties as mentioned herein.

AP 2.3 Deviation of the characteristic values

(1) Any changes in the chemical composition and the heat treatment will cause certain deviations in the physical properties. E.g., a possible grain orientation has a particularly strong influence on the modulus of elasticity.

(2) Differences in the measurement procedures used can lead to additional deviations..

(3) The data available at this time do not suffice to allow a statistical evaluation of their reliability.

(4) The data regarding the scatter band width of the characteristic values given in footnotes 1 through 5 of **Tables AP-1** to **AP-10** are taken from literature [3]. They indicate the average scatter band width of the corresponding measurement values.

	Temperature T, °C					
	20	100	200	300	350	400
Density [1], 10^6 g/m^3	7.86	—	—	—	—	—
Dynamic modulus of elasticity [2], 10^3 N/mm^2	211	206	199	192	—	184
Average linear thermal expansion coefficient [3] between 20 °C and T, 10^{-6} K^{-1}	—	12.7	13.2	13.6	—	14.0
Thermal conductivity [5], Wm^{-1} K^{-1}	44	44	43	41	—	39
Average specific thermal capacity [4] between 20 °C and T, Jg^{-1} K^{-1}	—	0.46	0.49	0.51	0.52	0.53

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m^3.

[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm^2.

[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.

[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.

[5] Average scatter band width of the measured values ± 3.5 Wm^{-1} K^{-1}.

Table AP-1: Characteristic values of physical properties for various product forms for the steel 20 MnMoNi 5 5

	Temperature T, °C					
	20	100	200	300	350	400
Density [1], 10^6 g/m^3	7.94	—	—	—	—	—
Dynamic modulus of elasticity [2], 10^3 N/mm^2	197	191	184	177	—	170
Average linear thermal expansion coefficient [3] between 20 °C and T, 10^{-6} K^{-1}	—	15.4	16.0	16.5	—	16.8
Thermal conductivity [5], Wm^{-1} K^{-1}	11.8	13.0	14.5	16.1	—	17.6
Average specific thermal capacity [4] between 20 °C and T, Jg^{-1} K^{-1}	—	0.48	0.50	0.52	—	0.53

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m^3.

[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm^2.

[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.

[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.

[5] Average scatter band width of the measured values ± 1.5 Wm^{-1} K^{-1} for austenitic steels.

Table AP-2: Characteristic values of physical properties for the steel X 2 NiCrAlTi 32 20

Steel grade	Density [1] 10^6 g/m³ at 20 °C	Dynamic modulus of elasticity [2] 10^3 N/m² at temperature T, °C					Average linear thermal expansion coefficient [3], 10^{-6} K^{-1} between 20 °C and temperature T, °C				Thermal conductivity [5] W m^{-1} K^{-1} at temperature T, °C					Average specific thermal capacity [4] J g^{-1} K^{-1} between 20 °C and temperature T, °C				
		20	100	200	300	400	100	200	300	400	20	100	200	300	400	100	200	300	350	400
X 6 CrNiTi 18 10 S	7.9	200	194	186	179	172	16.0	16.5	17.0	17.5	15.0	16.0	17.0	19.0	20.0	0.47	0.49	0.50	0.51	0.52
X 6 CrNiNb 18 10 S	7.9						16.0	16.5	17.0	17.5										
X 6 CrNiMoTi 17 12 2 S	8.0						16.5	17.5	18.0	18.5										

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m³.
[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm².
[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.
[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.
[5] Average scatter band width of the measured values ± 1.5 Wm^{-1} K^{-1}.

Table AP-3: Characteristic values of physical properties for stainless austenitic rolled and forged steels

	Temperature T, °C					
	20	100	200	300	350	400
Density [1], 10^6 g/m³	7.86	—	—	—	—	—
Dynamic modulus of elasticity [2], 10^3 N/mm²	210	203	194	185	—	175
Average linear thermal expansion coefficient [3] between 20 °C and T, 10^{-6} K^{-1}	—	12.6	13.9	14.8	—	14.9
Average specific thermal capacity [4] between 20 °C and T, Jg^{-1} K^{-1}	—	0.46	0.49	0.51	0.52	0.53
Thermal conductivity [5], Wm^{-1} K^{-1}	38	37	34	32	—	—

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m³.
[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm².
[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.
[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.
[5] Average scatter band width of the measured values ± 3.5 Wm^{-1} K^{-1}.

Table AP-4: Characteristic values of physical properties for various product forms of the cast steel GS-18 NiMoCr 3 7

	Temperature T, °C					
	20	100	200	300	350	400
Density [1], 10^6 g/m³	7.83	—	—	—	—	—
Dynamic modulus of elasticity [2], 10^3 N/mm²	211	204	196	186	—	177
Average linear thermal expansion coefficient [3] between 20 °C and T, 10^{-6} K^{-1}	—	12.2	12.9	13.4	—	13.9
Thermal conductivity [5], Wm^{-1} K^{-1}	43	43	42	41	—	39
Average specific thermal capacity [4] between 20 °C and T, Jg^{-1} K^{-1}	—	0.46	0.49	0.51	0.52	0.53

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m³.
[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm².
[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.
[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.
[5] Average scatter band width of the measured values ± 3.5 Wm^{-1} K^{-1}.

Table AP-5: Characteristic values of physical properties for the cast steel GS-C 25 S

	Temperature T, °C					
	20	100	200	300	350	400
Density [1], 10^6 g/m^3	7.93	—	—	—	—	—
Dynamic modulus of elasticity [2], 10^3 N/mm^2	200	194	186	179	—	172
Average linear thermal expansion coefficient [3] between 20 °C and T, 10^{-6} K^{-1}	—	16.0	17.0	17.0	—	18.0
Thermal conductivity [5], Wm^{-1} K^{-1}	15	16	17	19	—	20
Average specific thermal capacity [4] between 20 °C and T, Jg^{-1} K^{-1}	—	0.47	0.49	0.50	0.51	0.52

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m^3.
[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm^2.
[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.
[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.
[5] Average scatter band width of the measured values ± 1.5 Wm^{-1} K^{-1}.

Table AP-6: Characteristic values of physical properties for the cast steel G-X 5 CrNiNb 18 9 S

	Temperature T, °C					
	20	100	200	300	350	400
Density [1], 10^6 g/m^3	7.70	—	—	—	—	—
Dynamic modulus of elasticity [2], 10^3 N/mm^2	200	195	185	175	172	170
Average linear thermal expansion coefficient [3] between 20 °C and T, 10^{-6} K^{-1}	—	10.5	11.0	12.0	—	12.5
Thermal conductivity [5], Wm^{-1} K^{-1}	25	—	—	—	—	—
Average specific thermal capacity [4] between 20 °C and T, Jg^{-1} K^{-1}	0.46	—	—	—	—	—

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m^3.
[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm^2.
[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.
[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.
[5] Average scatter band width of the measured values ± 3.5 Wm^{-1} K^{-1}.

Table AP-7: Characteristic values of physical properties for the steel X 5 CrNi 13 4

	Temperature T, °C					
	20	100	200	300	350	400
Density [1], 10^6 g/m^3	8.19	—	—	—	—	—
Dynamic modulus of elasticity [2], 10^3 N/mm^2	211	206	201	195	192	189
Average linear thermal expansion coefficient [3] between 20 °C and T, 10^{-6} K^{-1}	—	14.1	14.3	14.6	14.7	14.8
Thermal conductivity [5], Wm^{-1} K^{-1}	12.0	13.5	15.3	17.3	18.2	19.1
Average specific thermal capacity [4] between 20 °C and T, Jg^{-1} K^{-1}	0.45	0.47	0.49	0.51	0.52	0.53

[1] Average scatter band width of the measured values ± 0.05 · 10^6 g/m^3.
[2] Average scatter band width of the measured values ± 5 · 10^3 N/mm^2.
[3] Average scatter band width of the measured values ± 0.8 · 10^{-6} K^{-1}.
[4] Average scatter band width of the measured values ± 0.01 Jg^{-1} K^{-1}.
[5] Average scatter band width of the measured values ± 1.5 Wm^{-1} K^{-1}.

Table AP-8: Characteristic values of physical properties for the nickel alloy NiCr 29 Fe

Steel grade	Density [1] 10^6 g/m^3 at 20 °C	Dynamic modulus of elasticity [2] 10^3 N/m^2 at temperature T, °C						Average linear thermal expansion coefficient [3], 10^{-6} K^{-1} between 20 °C and temperature T, °C					Thermal conductivity [5] Wm^{-1} K^{-1} at temperature T, °C						Average specific thermal capacity [4], Jg^{-1} K^{-1} between 20 °C and temperature T, °C				
		20	100	200	300	350	400	100	200	300	350	400	20	100	200	300	350	400	100	200	300	350	400
20 NiCrMo 14 5	7,84	205	200	191	182	—	—	11,2	11,6	12,1	12,2	—	29	30	31	31	—	31	0,46	0,49	0,51	0,52	0,53
26 NiCrMo 14 6								11,2	11,6	12,1	12,2	—	29	30	31	31	—	31					
34 CrNiMo 6 S								12,5	13,2	13,7	—	14,2	34	36	37	37	—	36					

[1] Average scatter band width of the measured values $\pm 0{,}05 \cdot 10^6$ g/m^3.

[2] Average scatter band width of the measured values $\pm 5 \cdot 10^3$ N/mm^2.

[3] Average scatter band width of the measured values $\pm 0{,}8 \cdot 10^{-6}$ K^{-1}.

[4] Average scatter band width of the measured values $\pm 0{,}01$ Jg^{-1} K^{-1}.

[5] Average scatter band width of the measured values $\pm 3{,}5$ Wm^{-1} K^{-1}.

Table AP-9: Characteristic values of physical properties for the quenched and tempered steels for bars and rings for bolts, nuts and washers as well as extension sleeves

Annex B

Performance of manual ultrasonic testing

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B 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.

B 2 Definitions, symbols, formulae

B 2.1 Definitions

The definitions of DIN EN ISO 5577 apply.

B 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	—
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

B 2.3 Formulae

The variables to be calculated shall be determined by means of the following equations:

a) Required width of the reference block

$$C \geq D_{S\text{-}20dB} \qquad \text{(B-1)}$$

b) The beam width $D_{S\text{-}20dB}$ referred to a 20 dB echo amplitude decrease:

$$D_{S-20dB} = 2 \cdot \lambda \cdot \frac{S}{D_Q} \qquad \text{(B-2)}$$

c) Conversion of side-drilled hole echo amplitudes to disc shaped reflector echo amplitudes:

$$D_{KSR} = \sqrt{\frac{\sqrt{2}}{\pi} \cdot \lambda \cdot \sqrt{D_Z \cdot S}}\ , \qquad \text{(B-3)}$$

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:

$$D_{S\text{-}6dB} = 2 \cdot S \cdot \tan \gamma_6, \qquad \text{(B-4)}$$

e) Average value of instrument gain setting $\overline{G}_T$:

$$\overline{G}_T = \frac{\sum G_T}{n} = \frac{\text{sum of individual values}}{\text{number of individual values}}\ , \qquad \text{(B-5)}$$

f) Corrected recording length R_{LK}:

$$R_{LK} = R_L - D_{S-6dB} \cdot \left(1 - \frac{D_{S-6dB}}{R_L}\right) \qquad \text{(B-6)}$$

g) Sound path length without lateral wall influence:

$$S = \frac{s \cdot D_{eff}}{2 \cdot \lambda} \qquad \text{(B-7)}$$

h) Gain correction $\Delta V^{\sim}$:

$$\Delta V^{\sim} = 1.7 \cdot \sqrt{\frac{\sum G_T^2 - \frac{1}{n} \cdot \left(\sum G_T\right)^2}{n-1}} \qquad \text{(B-8)}$$

or

$$\Delta V^{\sim} = 1.7 \cdot \sqrt{\frac{\sum \left(G_T - \overline{G}_T\right)^2}{n-1}} \qquad \text{(B-9)}$$

i) Sensitivity correction ΔV_Z:

$$\Delta V_Z = 30 \cdot \lg \frac{S_2}{S_1} \qquad \text{(B-10)}$$

k) Resultant instrument sensitivity for adjustment of recording level:

$$G_R = G_K + \Delta V_T + \Delta V^{\sim} \qquad \text{(B-11)}$$

with

$$\Delta V_T = \Delta V_{koppl} + \Delta V_\kappa \qquad \text{(B-12)}$$

l) Zero point displacement at longitudinal wave dual-element probes:

$$S = 1.5 \cdot s + a \qquad \text{(B-13)}$$

m) Sound path travel distance to scanning zone centre with LLT probes:

$$S_{Just} = S_{LW} + 2 \cdot S_{TW} \qquad \text{(B-14)}$$

$$\text{with } S_{LW} = \frac{2 \cdot s - Y_s}{\cos \alpha_{LW}} \qquad \text{(B-15)}$$

$$\text{and } S_{TW} = \frac{Y_s}{\cos \alpha_{TW}} \qquad \text{(B-16)}$$

or approximated for steel

$$S_{Just} = 2 \cdot \frac{s + Y_s}{\cos \alpha_{LW}} \qquad \text{(B-17)}$$

B 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 uneveness 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.

B 4 Requirements to be met by the testing system

B 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 B-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.

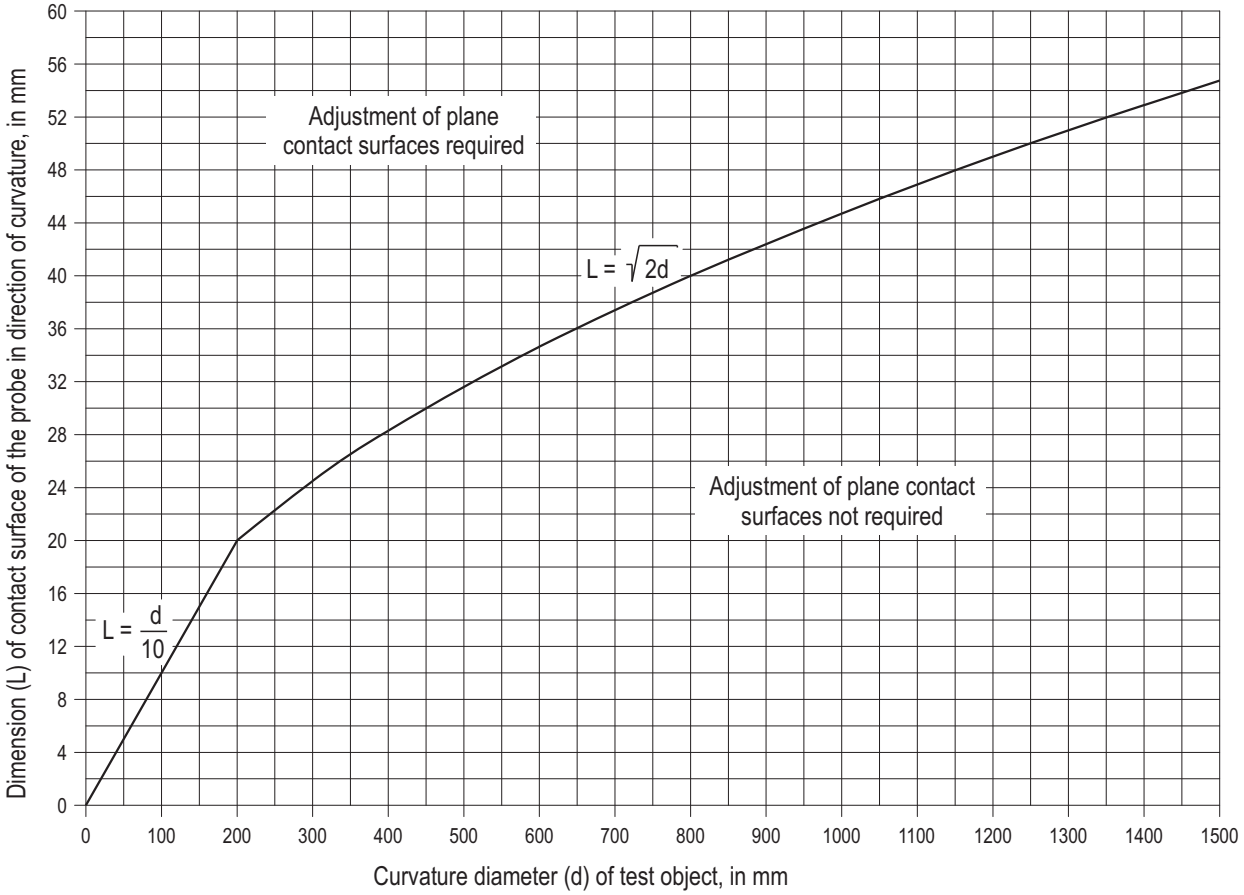


Figure B-1: Conditions for adjusting plane contact surfaces of angle-beam probes when scanning into convex scanning surfaces of the test object

B 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 B-3 shall be considered.

B 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).

B 6 Adjustment of test system

Note:
Sections B 7 to B 9 contain requirements for the test system adjustment as regards the use of wave conversion and creeping wave techniques.

B 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 B-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.

B 6.2 Adjustment of the testing level when applying the DGS method

B 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 B 2.3, equation B-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.

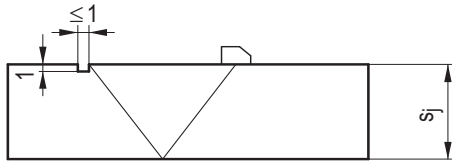
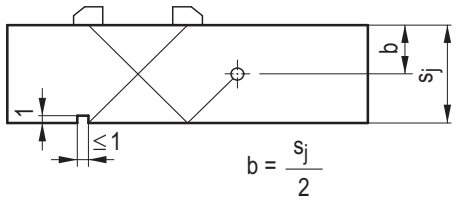
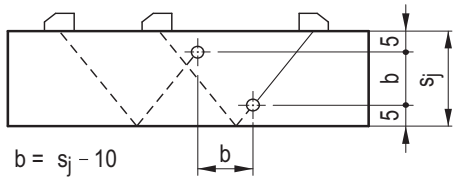
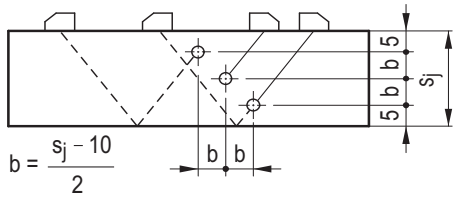
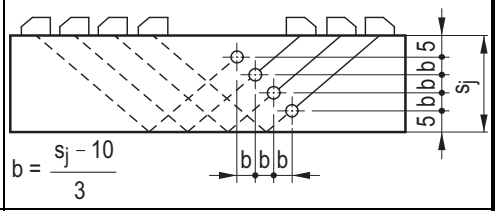
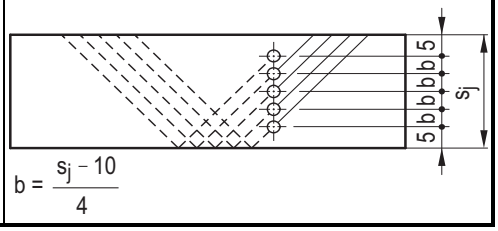
Wall thickness or nominal wall thickness of the test object in mm	Lateral view of the reference block
s ≤ 10	
10 < s ≤ 15	
15 < s ≤ 20	
20 < s ≤ 40	
40 < s ≤ 80	
s > 80	

Figure B-2: Reference blocks for adjusting the testing level for angle beam scanning

B 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 B 4.2 (2) ba),

ab) the back wall of the reference block provided the back wall meets the requirements according to clause B 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 B-3 shall be used.

B 6.3 Adjustment of the testing level for the reference block method and DAC method

B 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 B-2**) the smaller echo height shall be used as reference level.

B 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 B-2**) or by means of reference reflectors in the test object located at different distances. Clause B 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 B-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 B-4**.

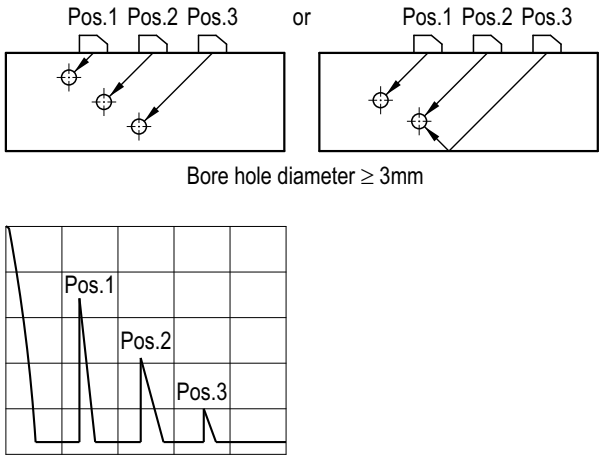


Figure B-3: Generation of reference echo heights from side-drilled holes located at different probe distances for angle beam scanning

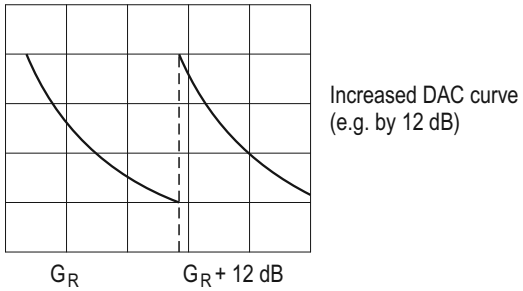


Figure B-4: Staged DAC curve

B 6.4 Corrections of testing level adjustment

B 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 B-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 B 6.2 of B 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.

B 6.4.2 Determination of the sound attenuation

(1) The sound attenuation for straight-beam scanning shall normally be determined as per **Figure B-6** and for angle-beam scanning as per **Figure B-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 B 6.4.1).

B 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 · standard deviation to be calculated in accordance with clause B 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.

B 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 B-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 B-8** when using the DGS method or as per **Figure B-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 B 6.4.3 is required, this shall be done by means of $\Delta\tilde{V}$. Otherwise, the correction value $\Delta\tilde{V}$ in equation B-11 shall be omitted.

B 6.5 Setting of the ultrasonic instrument

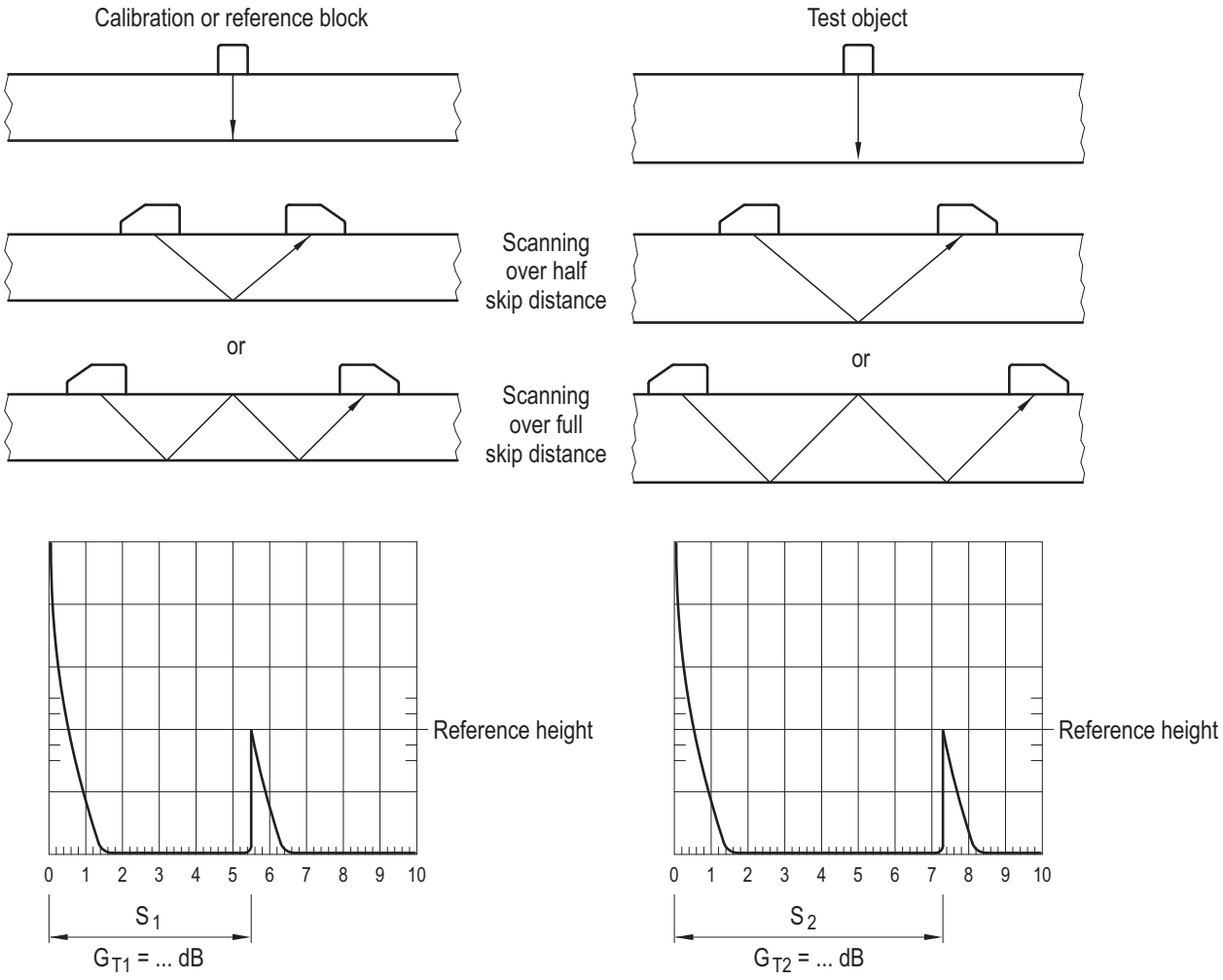
(1) Prior to adjusting the testing level it shall be ensured that

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 B 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

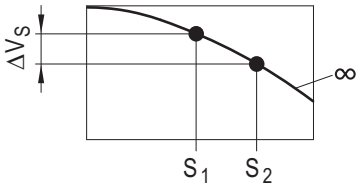
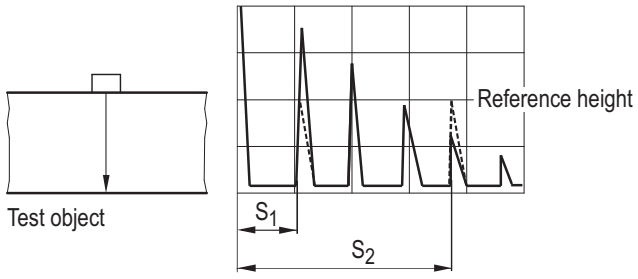
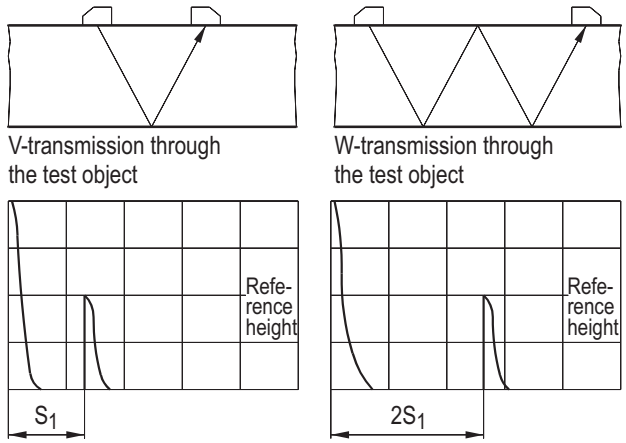


Figure B-5: Determination of transfer correction during straight and angle beam scanning performed as V or W-transmission



$$\kappa = \frac{G_{T2} - G_{T1} - V_S}{2 \cdot (S_2 - S_1)} \; [dB/mm] \qquad G_{T1} = ...dB \quad G_{T2} = ...dB$$

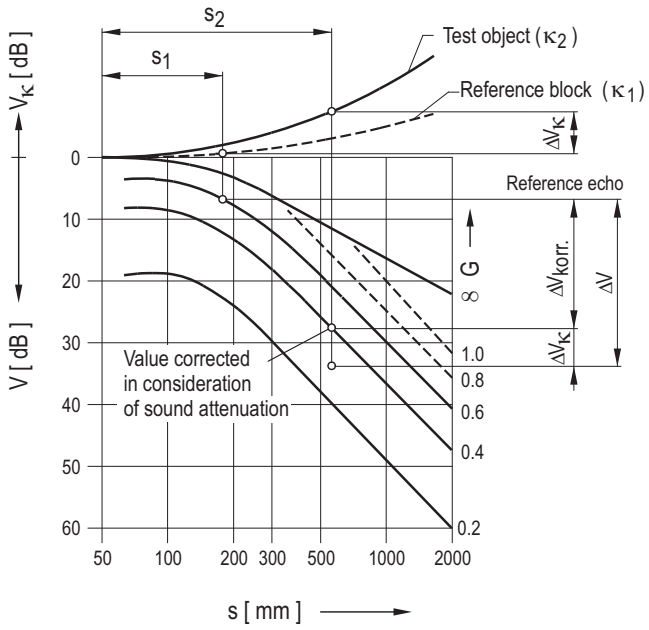
Figure B-6: Determination of sound attenuation for straight-beam scanning (example)



$G_{T1} = \ldots dB \qquad G_{T2} = \ldots dB$

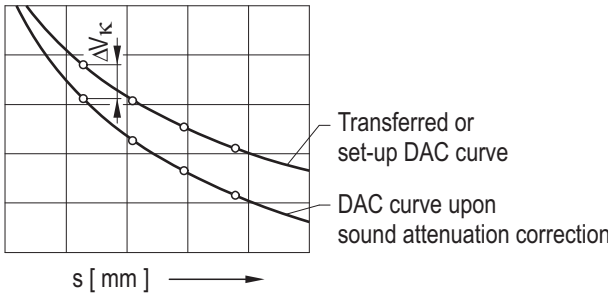
$$\kappa = \frac{G_{T2} - G_{T1} - \Delta V_S}{2 \cdot S_1} \quad [dB/mm]$$

Figure B-7: Determination of sound attenuation for angle-beam scanning



$$\Delta V_\kappa = 2 \cdot (S_2 \cdot \kappa_2 - S_1 \cdot \kappa_1) \; [dB]$$

Figure B-8: Consideration of sound attenuation in the DGS diagram for $\kappa_2 > \kappa_1$ (example)



$$\Delta V_\kappa = 2 \cdot S \cdot (\kappa_2 - \kappa_1) \quad [dB]$$

Figure B-9: Consideration of sound attenuation for the DAC method for the case $\kappa_2 > \kappa_1$ (example)

B 7 Creeping wave method

B 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.

B 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 B-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 B-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.

B 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 B 6.3 by means of scanning the respective flat bottom holes in the reference block according to clause B 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 B 7.2 (1) b).

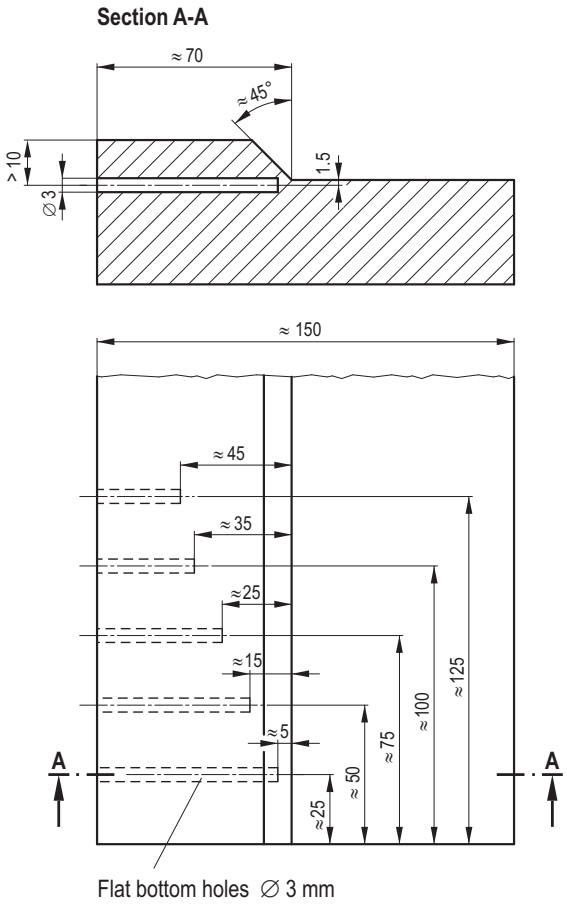


Figure B-10: Reference block for testing level adjustment when using the creeping wave technique (primary creeping wave)

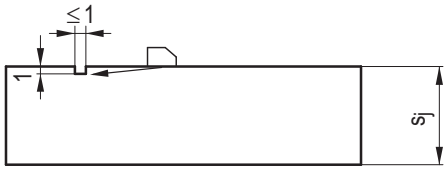


Figure B-11: Reference block for testing level adjustment when using the creeping wave technique (primary creeping wave) for testing near-surface areas

B 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 B-12**.

(2) When testing on concave scanning surfaces of the test object, specific probes with properly contoured contact surfaces shall be used.

B 8 Wave conversion method I (secondary creeping wave)

B 8.1 Description of method

(1) **Figure B-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 B-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 B-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 analysable 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 B-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 B-16**).*

B 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.

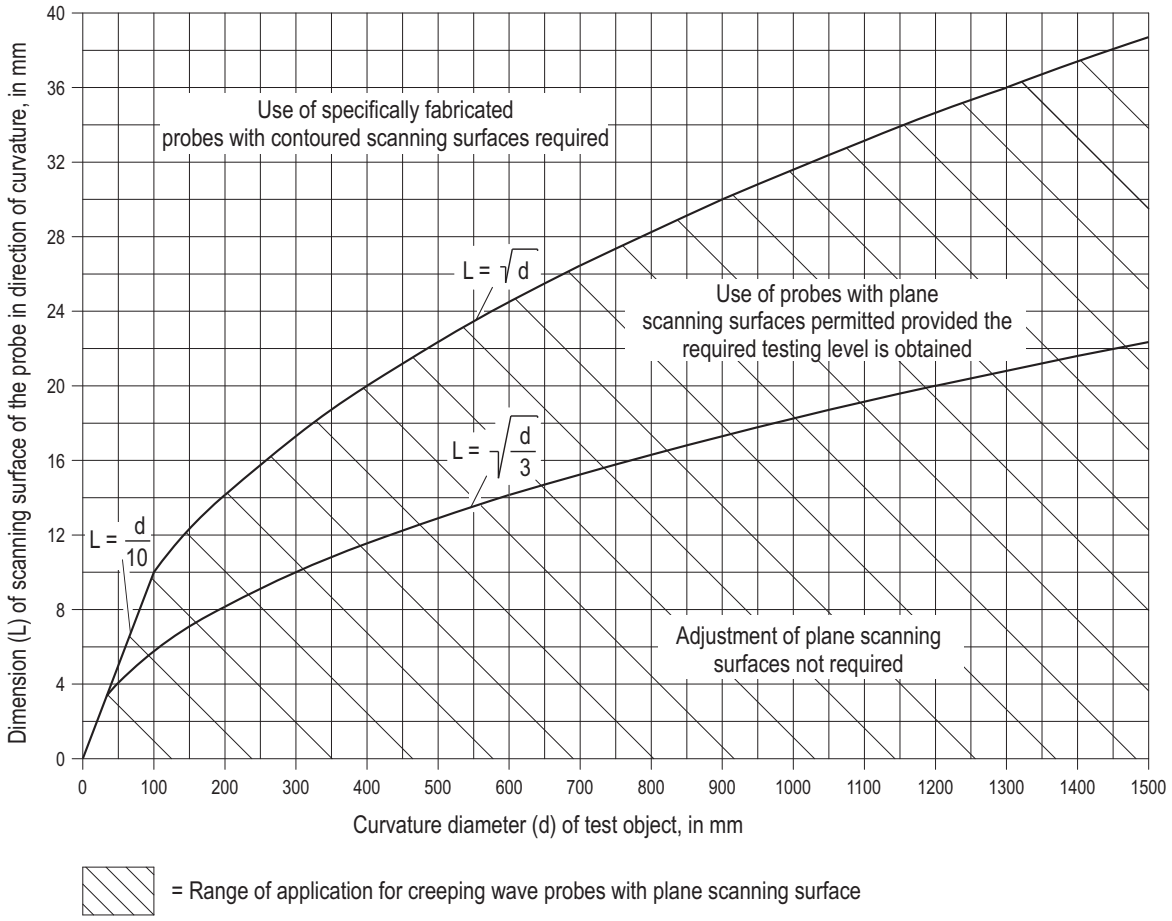


Figure B-12: Ranges of application of creeping wave probes with and without contouring of scanning surfaces for testing on convex test object scanning surfaces

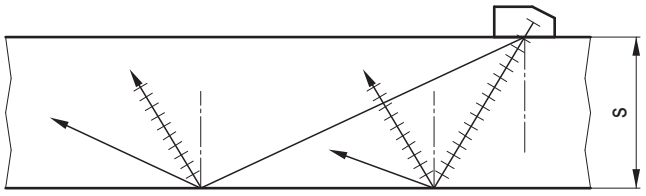


Figure B-13: Reflexion with wave conversion for longitudinal wave angle-beam probe

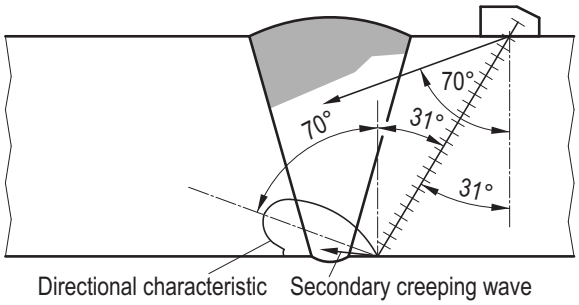


Figure B-14: Testing of internal near-surface area of welded joints by means of secondary creeping waves

B 8.3 Range calibration

(1) The time base range shall be pre-adjusted in accordance with B 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 B-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.

B 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 B 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 B 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.

B 8.5 Corrections during testing level adjustment

B 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.

B 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.

B 8.6 Performance of testing

(1) Range calibration according to the requirements of Section B 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 B 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 B-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.

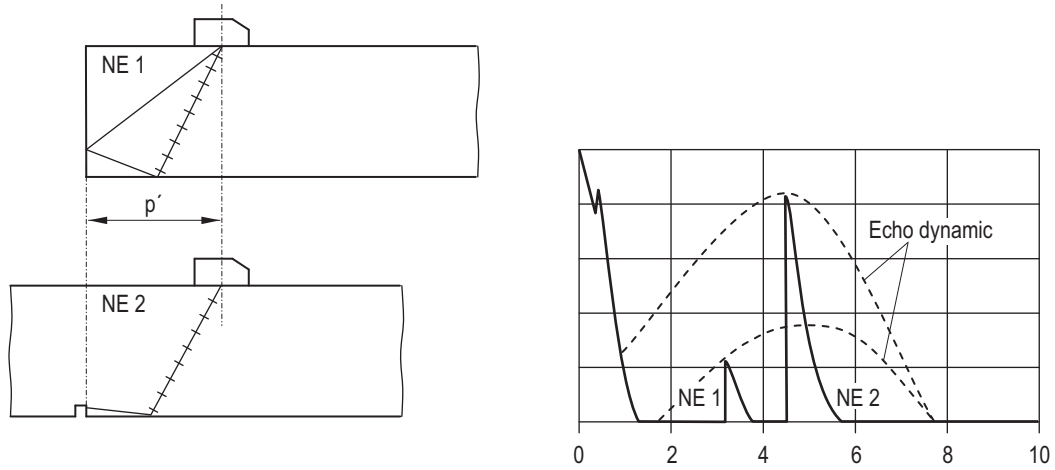
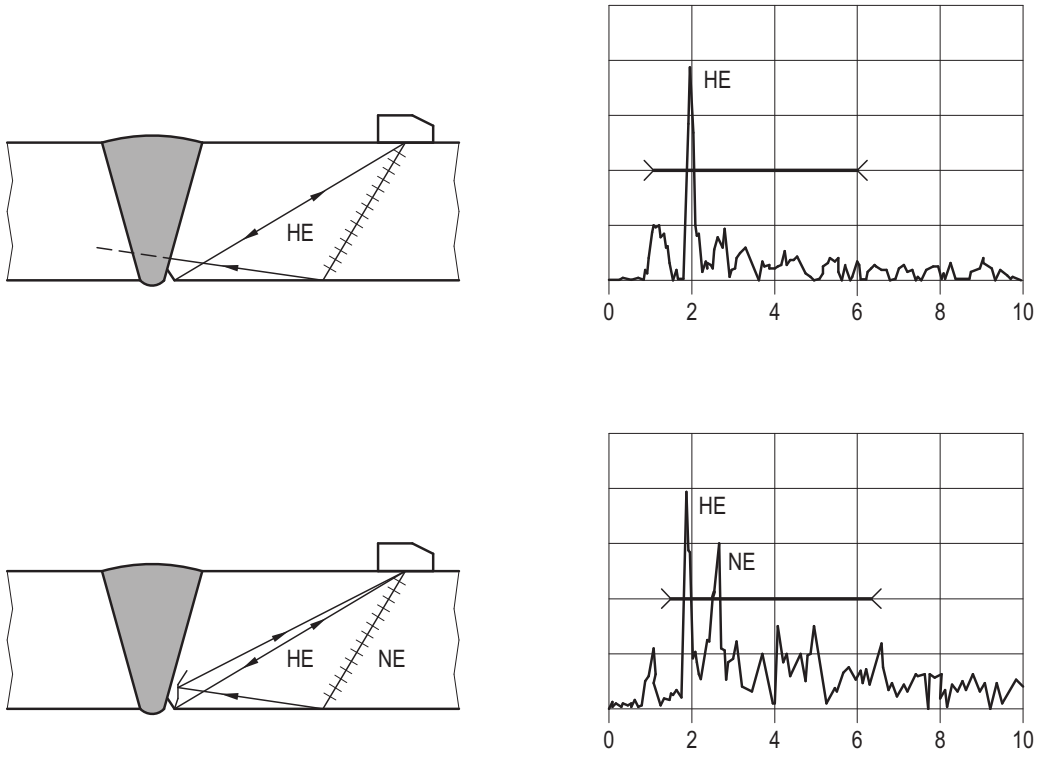


Figure B-15: Sound field geometry during transverse wave conversion



HE: Main echo, NE: Neighbour echo

Figure B-16: Testing of components with nominal wall thicknesses 8 mm < s ≤ 20 mm by means of longitudinal waves (70 degree SEL probe)

B 9 Wave conversion method II (LLT technique)

B 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 B-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.

B 9.2 Probes, scanning zones, reference blocks, LLT sensitivity diagrams

B 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.

B 9.2.2 Probes and their scanning zones

B 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 B-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 B-17**). The height of the scanning zone depends on the wall thickness, the nominal frequency and the dimensions oft the transmitting and receiving transducer.

B 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.

B 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 B-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.

B 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 B 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 B-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 B-19**). To this end, at least three flat bottom holes provided at the front-face side of the reference block are necessary.

B 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 B-14 to B-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 B 9.2.4 shall be used.

B 9.4 Testing level adjustment

B 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.

B 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 B 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 B-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.

B 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.

B 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.

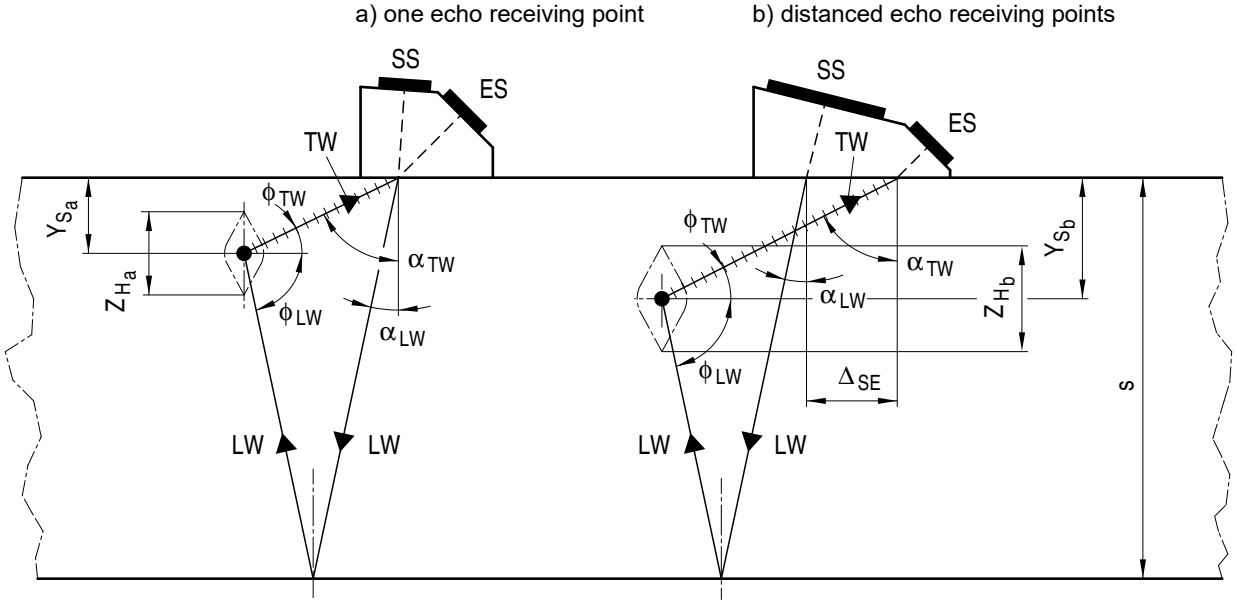
B 9.6 Performance of testing

(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 B-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 B-17: Principle of LLT technique

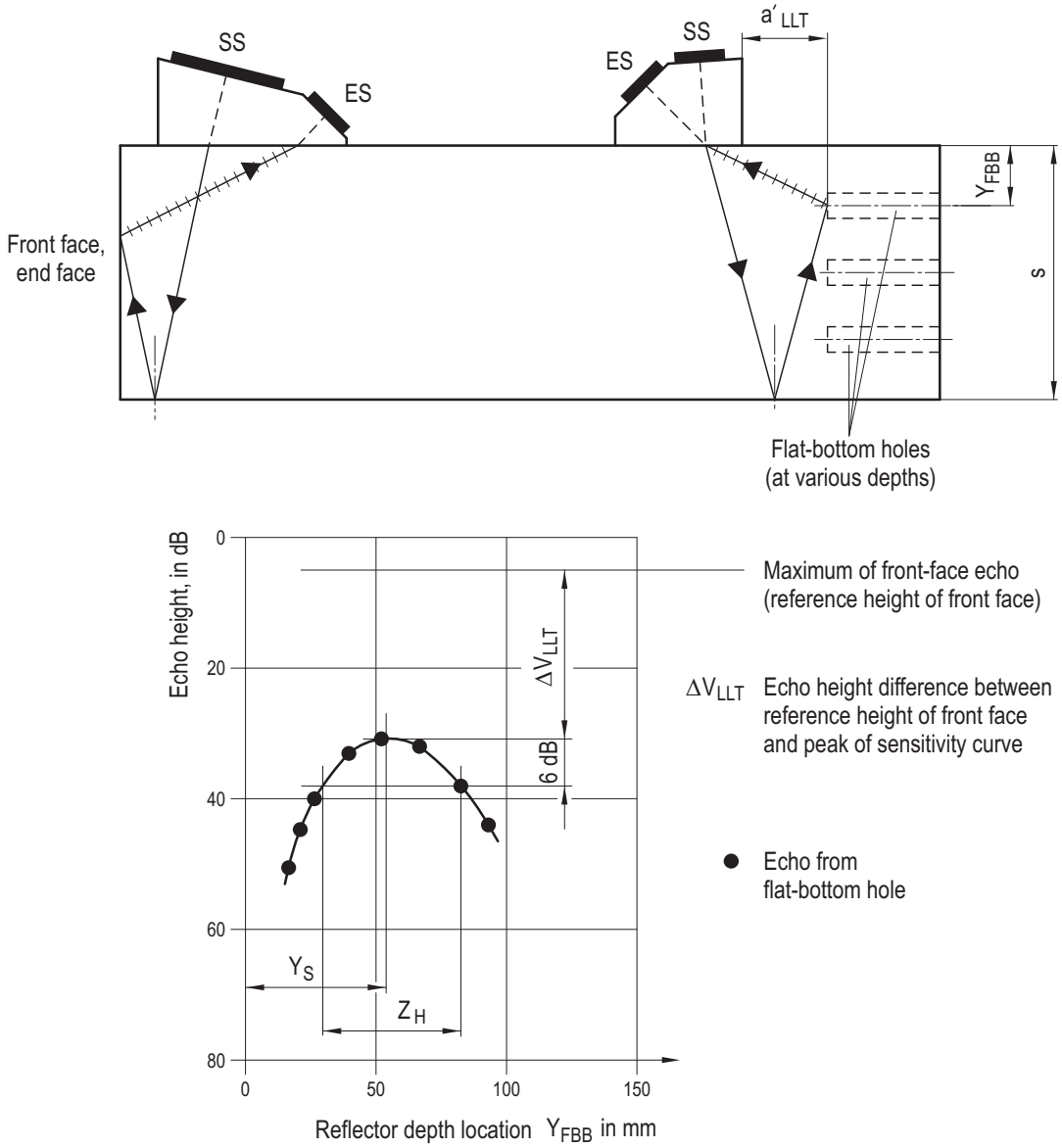


Figure B-18: Example for a LLT sensitivity diagram

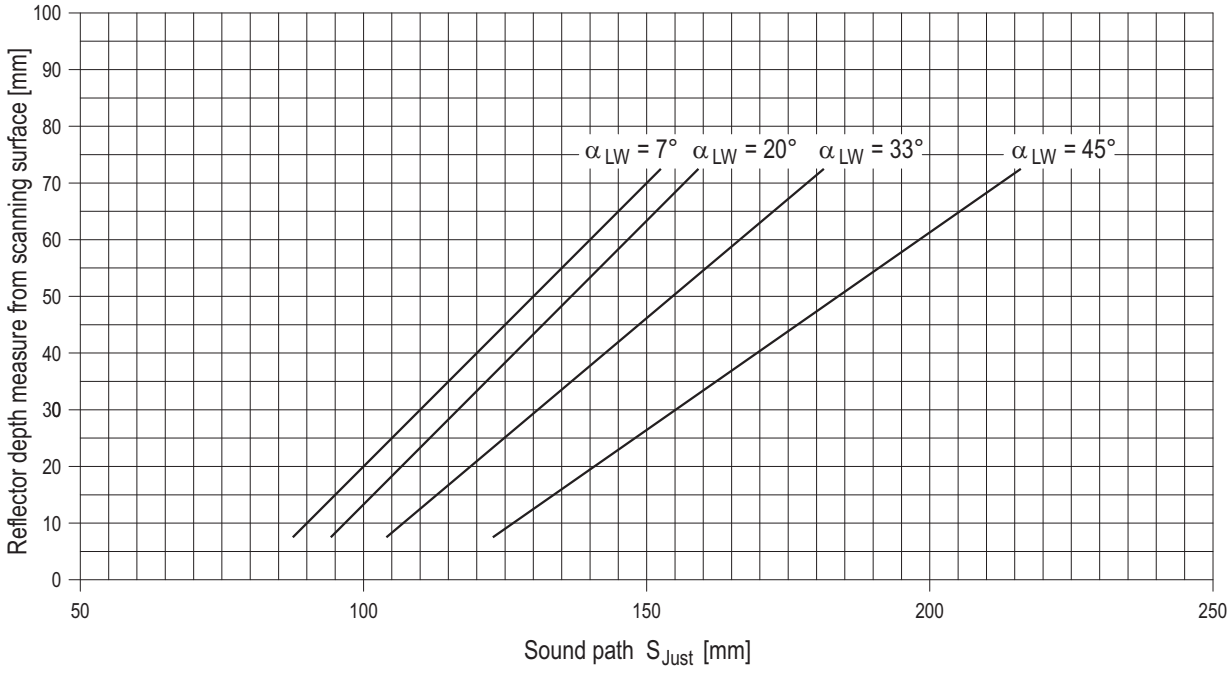


Figure B-19: Example for LLT reflector depth scales

B 10 Performance of testing

B 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.

B 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.

B 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.

B 11 Description of indications

B 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 reproducibility of the echo amplitude determination is generally ± 3 dB.

B 11.2 Extension of indications

B 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".

B 11.2.2 Determination of the recording length at fixed recording level

The extension of reflector (see **Figure B-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.

B 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.

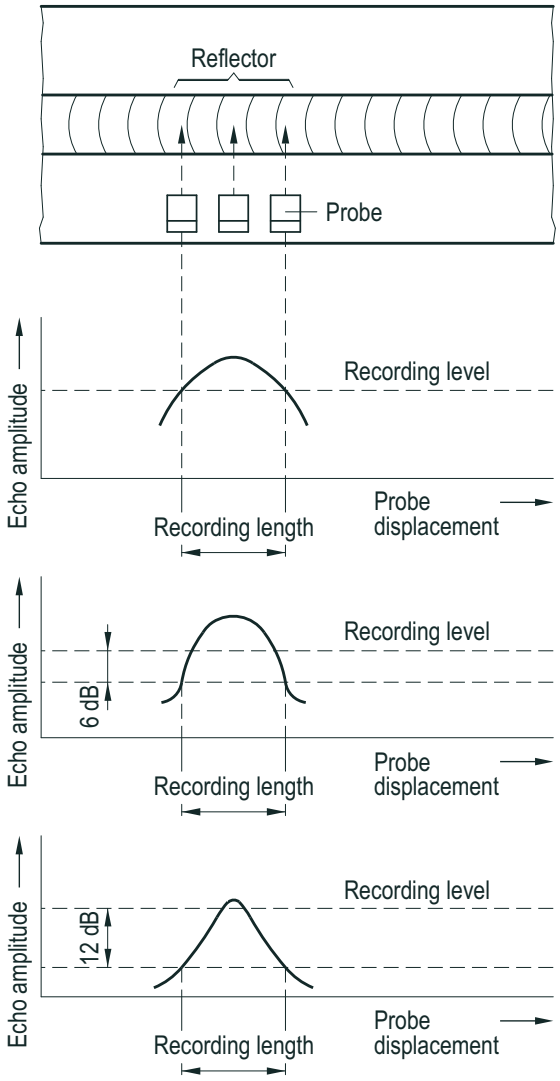


Figure B-20: Determination of recording length

B 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 B 11.2.4.1 to B 11.2.4.4 or by examinations according to clause B 11.2.5.

B 11.2.4.1 Correction for curved surfaces

For curved surfaces the length shall be determined mathematically or graphically in the reflector depth determined.

B 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.

B 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 B-6.

(2) The beam width shall be determined by calculation or experimental analysis.

(3) In the case of calculation equation B-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 B 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.

B 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 reproducibility in the case of focussing probes. The grid-line distances shall be smaller than the diameter of the focussing beam of the probe.

B 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

B 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 object (see **Figure B-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 B-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.

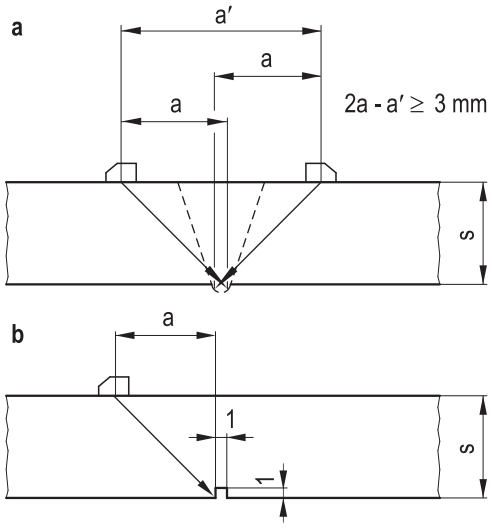


Figure B-21: Proof of indications caused by structural discontinuities from the root area of single-side welds

Annex C

Performance of surface inspections by magnetic particle and penetrant methods

C 1 General requirements

C 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.

C 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.

C 1.3 Post-cleaning

Upon completion of inspection, the parts shall be properly cleaned to remove residues from the test fluid.

C 2 Magnetic particle testing

C 2.1 Methods and performance of testing

Magnetic particle testing shall be performed to DIN EN ISO 9934-1 to meet the following requirements.

C 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

C 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.

C 2.1.3 Direction of magnetisation

Each location on the surface shall be tested from two directions of magnetisation offset by approximately 90 degrees.

C 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.

Notes:

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.

C 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

C 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.

C 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.

C 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.

C 2.3 Test instruments

The test instruments shall meet the requirements of DIN EN ISO 9934-3.

C 3 Penetrant testing

C 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.

C 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 D

Procedure for determining the delta ferrite content

D 1 Scope

This annex specifies details for the procedures required for the determination of the products' delta ferrite content under clause 3.3.7.5 (1).

D 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.

D 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.

D 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.

D 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

$$Ni_E = \%\ Ni + 30 \cdot (\%\ C + \%\ N) + 0.5 \cdot \%\ Mn \qquad \text{(D 5-1)}$$

and the chrome equivalent Cr_E according to the equation

$$Cr_E = \%\ Cr + \%\ Mo + 1.5 \cdot \%\ Si + 0.5 \cdot \%\ Nb \qquad \text{(D 5-2)}$$

(2) The calculated values of the nickel equivalent and chrome equivalent are the coordinates of a point in **Figure D-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.

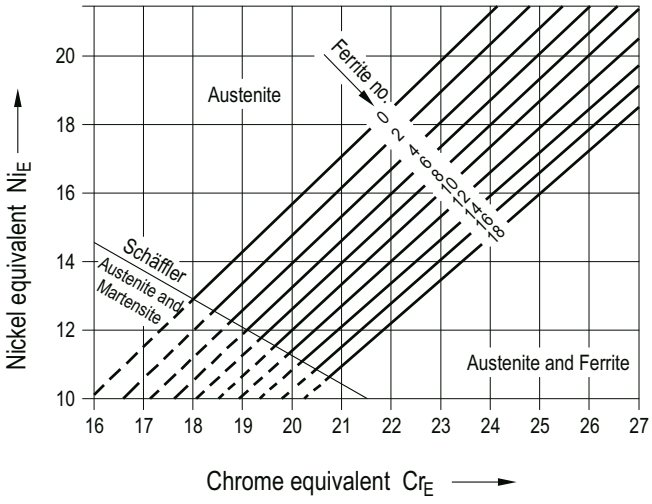


Figure D-1: Relationship between chemical composition and ferrite numbers of molten base metal or weld material (according to W.T. De Long [2])

Annex E
Form sheets

Form sheets E-1 a to c	Cover sheets
Form sheet E-2	Materials testing and specimen-taking plan
Form sheet E-3	Heat treatment plan
Form sheet E 4	Appendix

Hersteller: *manufacturer:*	Auftrags-Nr.: *contract no.*	Bestell-Nr.: *order no.*	
Anlage/Projekt: *power plant / project:*	**Deckblatt** *cover sheet* DBL-Nr.: *DBL no.*		Seite: *page:* von: *of:*

1	Komponente *component*:	Komp.-Spezifikation *component specification*:
	Gegenstand *item:*	Klasse *classification:*
	KKS/AKZ *code acc. to KKS/AKZ identification system:*	Einzelteilgruppe EG *parts group:*
	Typ, Antrieb, DN *type, drive, DN:*	
	Identnummer *identification no.:*	

2 Inhaltsverzeichnis für Vorprüfunterlagen *table of contents of design approval documents*		3 Revisionstabelle der Unterlagen der Rubrik 2 *table of revisions of documents class 2*			
Vorprüfunterlagen Nr. *design approval document no.*	Seite: von - bis *page: from - to*	Rev. 01/a Seite Nr. *page no.*	Rev. 02/b Seite Nr. *page no.*	Rev. 03/c Seite Nr. *page no*	Rev. 04/d Seite Nr. *page no.*
☐ Deckblatt DBL *cover sheet*					
☐ Zeichnung ZG *technical drawing*					
☐ Werkstoffliste WL *list of materials*					
☐ Schweißstellenliste STL *weld location list*					
☐ Prüffolgeplan PFP *test and inspection sequence plan*					
☐ Schweißplan SP *welding procedure specification*					
☐ Wärmebehandlungsplan WBP *heat treatment plan*					
☐ Werkstoffprüf- und Proben-entnahmeplan WPP *materials testing and specimen-taking plan*					
☐					
☐					
☐					
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☐ Auslegungsberechnung *design calculation*					
☐ Spannungsanalyse *stress analysis*					

SAMPLE COPY

4 Hersteller: *manufacturer:*		Geprüft *checked*				Prüfvermerk des Sachverständigen gemäß § 20 AtG *certification mark of authorized inspector to § 20 AtG*
Rev. *revision*	Datum *date*	Erstellt von *prepared by*	QST *quality dept.*	Grund der Revision *reason for revision*	Freigabe *release certification*	
00						
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Form E-1a: Cover sheet

Hersteller: *manufacturer:*	Auftrags-Nr.: *contract no.*	Bestell-Nr.: *order no.*	
Anlage/Projekt: *power plant / project:*	**Deckblatt** *cover sheet* DBL-Nr.: *DBL no.*		Seite: *page:* von: *of:*

5

Spezifikationen, Vorschriften:
specifications, instructions:

SAMPLE COPY

Rev. *revision*	Datum *date*	Hersteller: *manufacturer:* Geprüft *checked* Erstellt von *prepared by*	QST *quality dept.*	Grund der Revision *reason for revision*	Freigabe *release certification*	Prüfvermerk des Sachverständigen gemäß § 20 AtG *certification mark of authorized inspector to § 20 AtG*
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Form E-1b: Cover sheet

Hersteller: *manufacturer:*	Auftrags-Nr.: *contract no.*	Bestell-Nr.: *order no.*	
Anlage/Projekt: *power plant / project:*	**Deckblatt** *cover sheet* DBL-Nr.: *DBL no.*		Seite: *page:* von: *of:*

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7

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Rev. *revision*	Datum *date*	Hersteller: *manufacturer:* Geprüft *checked* Erstellt von: *prepared by*	QST: *quality dept.*	Grund der Revision *reason for revision*	Freigabe *release certification*	Prüfvermerk des Sachverständigen gemäß § 20 AtG *certification mark of authorized inspector to § 20 AtG*
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Form E-1c: Cover sheet

1	2	3	4	5	6	7	8	9	10		11	12	13	14	15
Prüf-Nr. *test no.*	Anforderungen nach *requirements in accordance with*	Beschreibung *description*	Anzahl je Prüfeinheit *number per test lot*	Probenabmessungen *dimensions of test specimens*	Prüftemperatur *test temperature* in °C	Probenlage *location of test specimens*	Probenkennzeichnung *identification marking of test specimens*	Prüfung durch *test performed by*	Nachweisschlüssel *certification key*		Dokuablage *document file*	Durchführungsvermerk *mark, when examination was performed*	Nachweise *certification of examinations*	Bemerkungen *remarks*	Hersteller: *manufacturer:*
															Anlage/Projekt: *power plant / project:*
															Komponente: *component:*
															Spezifikation: *specification:* Klasse: *classification:*
															KKS/AKZ/Typ, Antrieb, DN: *code KKS or AKZ / type, drive, DN:*
															Zeichnungs-Nr.: *technical drawing no.:*
															WL-Nr.: *list of materials no.:*
															Auftrags-Nr.: *contract no.:*
															Bestell-Nr.: *order no.::*
															Werk-Nr./Index-Nr. [1]: *plant no. / index no.:*
															PFP-Nr. [1]: *test and inspection sequence plan no.:* SP-Nr.: *welding procedure specification no.:*

SAMPLE COPY

(16) Hersteller: *manufacturer:*							Prüfvermerk des Sachverständigen gemäß § 20 AtG *certification mark of authorized inspector to § 20 AtG*	Dokumentationsfreigabe *release certification of documents*	**Werkstoffprüf- und Probenentnahmeplan** *materials testing and specimen-taking plan*
Rev. *revision*	Datum *Date*	Erstellt von *prepared by*	Geprüft QST *checked by quality dept.*	Grund der Revision *reason for revision*		Freigabe *release certification*		Hersteller *manufacturer:*	WPP-Nr.: *materials testing and specimen-taking plan no.*
00									
01								Sachverständiger *authorized inspector*	
02									
03								[1] nur für Rohrleitungen, Armaturen und Pumpen *only for pipes, valves and pumps*	Seite: / *page:*
04									von: / *of:*

Form E-2: Materials testing and specimen-taking plan

Skizze *sketch*	Prüf-Nr. *test no.*	Wärmebehandlungsdiagramm *heat treatment diagram*	Mitlaufende Grundwerkstoff- und Arbeitsprüfstücke *accompanying test coupons of base material and production welds*
1	2	3	4

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Hersteller:
manufacturer:

Anlage/Projekt:
power plant / project:

Komponente:
component:

KKS/AKZ/Typ, Antrieb, DN:
code KKS or AKZ/ type, drive, DN:

Spezifikation:
specification:

Klasse:
classification:

Auftrags-Nr.:
contract no.:

Bestell-Nr.:
order no.:

Zeichnungs-Nr.:
technical drawing no.:

Werk-Nr./Index-Nr. [1]:
plant no. / index no.:

PFP/WPP-Nr. [1]:
test and inspection sequence plan no. / materials testing and specimen-taking plan no.:

SP-Nr. [1]: *welding procedure specification no.:*
WL-Nr.: *list of materials no.:*

Rev. *revision*	Hersteller: *manufacturer:* Datum *date*	Erstellt von *prepared by*	Geprüft QST *checked by quality dept.*	Grund der Revision *reason for revision*	Freigabe *release certification*	Prüfvermerk des Sachverständigen gemäß § 20 AtG *certification mark of authorized inspector to § 20 AtG*
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Wärmebehandlungsplan
heat treatment plan

WBP-Nr.:
heat treatment plan no:.

Seite:
page:

von:
of:

[1] nur für Rohrleitungen, Armaturen und Pumpen
only for pipes, valves and pumps

Form E-3: Heat treatment plan

1

SAMPLE COPY

2 Hersteller:
manufacturer:

Rev. *revision*	Datum: *date*	Erstellt von: *prepared by*	Geprüft QST: *checked by quality dept.*	Grund der Revision *reason for revision*	Freigabe *release certification*	Prüfvermerk des Sachverständigen gemäß § 20 AtG *certification mark of authorized inspector to § 20 AtG*
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Anlage/Projekt:
power plant / project:

Komponente:
component:

Anhang zu:
Appendix of:

Seite:
page:

Von:
of:

Form E-4: Appendix

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)
Interpretationen	(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	(2013-11)	General Requirements Regarding Quality Assurance
KTA 1404	(2013-11)	Documentation During the Construction and Operation of Nuclear Power Plants
KTA 1408.1	(2015-11)	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	(2015-11)	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	(2015-11)	Quality Assurance for Weld Filler Materials and Welding Consumables for Pressure and Activity Retaining Systems in Nuclear Power Plants; Part 3: Processing
KTA 3201.2	(2013-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 2: Design and Analysis
KTA 3201.3	(2007-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 3: Manufacture
KTA 3201.4	(2016-11)	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 4: Inservice Inspections and Operational Monitoring
KTA 3203	(2001-06)	Surveillance of the Irradiation Behaviour of Reactor Pressure Vessel Materials of LWR Facilities
KTA 3205.1	(2002-06)	Component Support Structures with Non-integral Connections; Part 1: Component Support Structures with Non-integral Connections for Components of the Reactor Coolant Pressure Boundary of Light Water Reactors
KTA 3206	(2014-11)	Verification Analysis for Rupture Preclusion for Pressure Retaining Components in Nuclear Power Plants
KTA 3211.1	(2015-11)	Pressure and Activity Retaining Components of Systems Outside the Primary Circuit; Part 1: Materials
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 377	(2015-12)	Steel and steel products - Location and preparation of samples and test pieces for mechanical testing (ISO 377:2013, Corrected version); German version EN ISO 377:2013
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 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 1559-1	(2011-05)	Founding - Technical conditions of delivery - Part 1: General; German version EN 1559-1:2011
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 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 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 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 10028-1	(2009-07)	Flat products made of steels for pressure purposes - Part 1: General requirements; German version EN 10028-1:2007+A1:2009
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 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 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 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 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 12543-1	(1999-12)	Non-destructive testing - Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing - Part 1: Scanning method; German version EN 12543-1:1999
DIN EN 12543-2	(2008-10)	Non-destructive testing - Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing - Part 2: Pinhole camera radiographic method; German version EN 12543-2:2008
DIN EN 12543-3	(1999-12)	Non-destructive testing - Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing - Part 3: Slit camera radiographic method; German version EN 12543-3:1999
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 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 11699-2	(2012-01)	Non-destructive testing - Industrial radiographic films - Part 2: Control of film processing by means of reference values (ISO 11699-2:1998); German version EN ISO 11699-2:2011
DIN 17245	(1987-12)	Ferritic steel castings with elevated temperature properties; technical delivery conditions
DIN EN ISO 18265	(2014-02)	Metallic materials - Conversion of hardness values (ISO 18265:2013); German version EN ISO 18265:2013
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 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
AD 2000-Merkblatt HP 3	(2014-11)	Welding supervisors, welder
AD 2000-Merkblatt W 5	(2009-03)	Cast steel
SEP 1325	(1982-12)	Drop-weight test to W.S. Pellini
SEW 088	(1993-10)	Weldable fine-grained structural steels; guidelines for processing, in particular for fusion welding (incl. supplementary sheets 1 and 2)
VdTÜV Material Specif. Sheet 337	(2008-06)	High temperature steels 20 NiCrMo 14 5 I and 20 NiCrMo 14 5 II for screws, bolts and nuts, material no. 1.6772
VdTÜV Material Specif. Sheet 381	(2001-06)	High temperature quenched and tempered cast steel GS-18 NiMoCr 3 7, material no. 1.6761
VdTÜV Material Specif. Sheet 390	(1997-06)	High-strength steel 26 NiCrMo 14 6 for screws, bolts and nuts; material no. 1.6958
VdTÜV Material Specif. Sheet 395/3	(2010-09)	Weldable, rolled and forged martensic steel X3CrNiMo13-4; material no. 1.4313, sectional and bar steel, forging product
VdTÜV Material Specif. Sheet 401/1	(2000-09)	High-temperature quenched and tempered steel 20 MnMoNi 5 5, material no. 1.6310
VdTÜV Material Specif. Sheet 401/2	(2011-03)	High-temperature quenched and tempered steel 20 MnMoNi 5 5, material no. 1.6310; seamless extruded pipes
VdTÜV Material Specif. Sheet 401/3	(2011-03)	High-temperature quenched and tempered steel 20 MnMoNi 5 5, material no. 1.6310; forgings and bar steel
VdTÜV Material Specif. Sheet 439	(2001-09)	Quenched and tempered fine-grained structural steel, clad plated with Nb stabilized austenitic steel
VdTÜV Material Specif. Sheet 451	(2005-06)	Austenitic forged steel X 6 CrNiTi 18 10 S, material no. 1.4533, X 6 CrNiNb 18 10 S, material no. 1.4553, X 6 CrNiMoTi 17 12 2 S, material no. 1.4579
ASTM A262	(2015)	ASTM A262-15, Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels, ASTM International, West Conshohocken, PA, 2015
ASTM E1921	(2017)	ASTM E1921-17a, Standard Test Method for Determination of Reference Temperature, T_0, for Ferritic Steels in the Transition Range, ASTM International, West Conshohocken, PA, 2017

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

Annex G (informative)

Changes with respect to the previous edition 1998-06 and explanations

G 1 Main changes

(1) The normative references were adapted to the current state of standards.

(2) The requirements for qualification and certification of supervisory personnel and NDT operators as well as the NDT requirements were adapted to the state of science and technology.

(3) The stipulations for product forms and components made by shape welding, as laid down in the previous edition of KTA 3201.1 (1998-06), were deleted (Section 29, Annex A 10, Table AP-9). For explanations see section G 2 (30).

(4) The stipulations for nickel alloy NiCr 15 Fe (Alloy 600,) as laid down in the previous edition of KTA 3201.1 (1998-06), were deleted (Section 18, Annex A 9, Table AP-8). For explanations see section G 2 (17).

(5) New stipulations for the product forms steam generator heat exchanger tubes and bars made from nickel alloy NiCr 29 Fe (Alloy 690) were included (Sections 18 and 22, Annex A 9, Table AP-8).

G 2 Explanations to changes compared to the edition 1998-06

(1) The section “Fundamentals” was adapted in paragraph 1 to the formulation obligatory for all KTA safety standards. Paragraph 2 was supplemented to include stipulations from the “Safety Requirements for Nuclear Power Plants” (SiAnf) and from the “Interpretations on the Safety Requirements for Nuclear Power Plants” as well as references to other KTA safety standards.

(2) Section 2 ”General Principles and definitions” was changed as follows:

a) A new section 2.1 “Definitions” was included to contain the essential terms for understanding this standard – based on definitions from other KTA safety standards.

b) The stipulations for materials appraisals in section 2.2.2 were stated more precisely in para. (3) and (4) so that the fabrication of a material by a manufacturer not listed in the supplementary sheets to VdTÜV-Werkstoffblätter mentioned in Annex A is also covered.

c) In Sec. 2.5 (8) requirements for personnel performing visual inspection was taken over.

d) The requirements for NDT operators were updated and put more precisely (para. 2.5 (9) to (11).)

e) The requirements for welders and welding supervisors were laid down in consideration of the current standards such that they meet the current requirements (Sec. 2.5 (13).

f) The last sentence of para. 2.6.1 (2) was transferred to para. 2.6.4.2.4 (1) because it is a requirement for the performance of reviews.

g) The test instruction requirements for non-destructive testing in Sec. 2.6.4.2.6 were formulated to correspond to other current KTA safety standards.

h) In clause 2.6.4.4 “Validity” the former paragraph 2 was integrated into paragraph 1.

i) Section 2.8 “Test and certification of material quality” was supplemented to correspond to other KTA safety standards to require that inspection certificates 3.2 to DIN EN 10204 have to be confirmed or be established by the authorized inspector called in according to § 20 AtG.

j) In section 2.9 paragraph 3 was deleted because the description of the term “repair” is not clear and has not been defined in KTA safety standards and a definitions thus is not required. In the new paragraph 4 it was made clear that the production welding on castings is no repair for the purpose of this standard. In addition, section 2.9 was editorially revised.

k) Table 2-2 was editorially revised and the line “visual testing” was deleted, since KTA 3201.1 does not contain visual testing requirements and for visual inspection to clause 3.3.7.10 no short designation exists.

(3) In section 3 “General requirements for and testing of materials” the following changes were made:

a) In para. 3.2.4.2 (2) “ferritic quenched and tempered steels” was replaced by “ferritic steels” and in the note “ferritic quenched and tempered steels” were replaced by “quenched and tempered steels”, because KAT 3201.1 also contains requirements for martensitic steels and for steels with bainitic structure.

b) In para. 3.2.4.2 (6) a stipulation for the additional use of the reference temperature T_0 to ASTM E1921 was included. Further stipulations are not considered necessary, as the number of specimens is given in the standard, the specimen location is analogous to the location of the NDT specimens and at present there is no basis for determining minimum RT_0 values in a standard.

c) The former paragraph 12 of clause 3.2.4.2 as well as para. 4.3.2.2.1 (6) were deleted which required the determination of toughness characteristics (e.g. the K_{Ic} value). This requirement is no more necessary because

   ca) they exclusively would refer to the steels 22 NiMoCr 3 7 and 20 MnMoNi 5 5 for which however, the lower limit curve of the values to be expected is known,

   cb) according to the current state of science and technology the reference temperature T_0 to ASTM E1921 is used for positioning the fracture toughness curve and ductile fracture considerations are made on this basis.

d) The stipulations for tempering colours and ferritic impurities in 3.2.4.3 (3) were put more precisely in consideration of the requirements for manufacture in KTA 3201.3.

e) The last sentence in para. 3.2.4.3 (4) was deleted because the properties of the welded joint are not known at the time of product form fabrication. The deleted sentence is an exemption. Decision on the permissibility of deviations compared to the requirements of 3.2.4.3 (4) can only be made in each individual case.

f) In the title of clause 3.2.4.4 the words “bars and rings” were deleted, and the title of the left column of the Table in section 3.2.4.4 was changed to read “Governing thickness”. The requirements refer to the steels and do not depend on whether they are in the form of bars or rings.

g) Section 3.2.6 was supplemented to include that the type of treatment and surface condition of the product forms are to be laid down in the order.

h) In section 3.3.1 information was included as how to proceed with product forms for components for which a rupture preclusion assessment is to be performed.

i) The requirements in section 3.3.7 were adapted to the current standards. In addition, the following changes were made:

   As regards the hardness testing requirements, the standards DIN EN ISO 6506-4 and DIN EN ISO 6507-4 were

supplemented as the tables laid down in these standards are to be used for the determination of hardness.

When performing tensile testing, the manufacturer has the option of either applying method A or method B to DIN EN 6892-1 or DIN EN ISO 6982-2, where in case of using method A, the strain rates recommended in the standard shall normally be used to ensure sufficient comparability of the values such determined.

It was made clear that for the proof of reduction of area in thickness direction tensile tests to DIN EN 10164 have to be performed.

In Sec. 3.3.7.3 (6) “Technological tests” the test method “flanging test” listed under e) was deleted since this type of test is not used not within the scope of application of KTA 3201.1.

Sec. 3.3.7.5 (5) “Determining the delta-ferrite content” was supplemented to read that indications found in the melt-run are to be assessed by means of a metallographic examination.

Section 3.3.7.6 was supplemented to require that the resistance against intergranular corrosion is to be demonstrated in the sensitisation annealed condition (650 °C; 30 min) in accordance with DIN EN ISO 3651-2, method A. A new requirement was added under (2) for the testing of nickel alloys.

In section 3.3.7.7 the information was deleted, as the reference to KTA 3203 is sufficient.

For material identity checks it was laid down that they have to be performed using a spectrometric method.

Section 3.3.7.10 was supplemented to include requirements for visual inspection during the acceptance procedure.

j) Section 3.3.8 was adapted to the current standards and the state-of-the-art with the following changes:

The restriction to manual non-destructive tests was deleted. General requirements for mechanized and automated tests were included in section 3.3.8.3.4.

The terms were consistently adapted to KTA 3211.3 (2012-11). In lieu of the term “acceptance standard” the term “acceptance criteria” will be used - such as for production control tests – throughout all current KTA safety standards.

Section 3.3.8 including its structure was updated by taking over section 11.1 (except for 11.1.1 and 11.1.3) from KTA 3211.1 (2015-11) without changing the specific requirements of the primary circuit.

For reactor coolant pressure boundary components it will not suffice to examine the accessible surfaces only. Therefore, the requirement in 3.3.8.1 (5) was changed. It is pointed out that surface inspection can also be made by other test methods than magnetic particle or penetrant testing.

The requirements for surfaces in section 3.3.8.2 were formulated to comply with the other current KTA safety standards.

Requirements formulated in section 3.3.8 as well as in Annex B were replaced in section 3.3.8 by references to Annex B.

(4) In Section 4 “Seamless hollow parts, forged or rolled” the terms were adapted to the current standards and at some points the text was editorially revised.

(5) In Section 5 “Seamless hollow parts for nozzles, forged, rolled or pressed” the terms were adapted to the current standards and editorial improvements were made as well as the following changes included:

a) In section 5.4.2.1 the stipulations for sound attenuation measurements were put more precisely such that a reference to section B 6.4.2 was added and a reduction to half the number of measurements for angle-beam scanning is now possible. The same formulations for the performance of sound attenuation measurements were also included in sections 6.4.2.1, 7.4.2.2, 9.4.2.1, 11.4.2.1.3, 12.4.2.1 and 13.4.2.1.

b) In Sec. 5.4.2.2 (2) the text was supplemented by “or to cover the total area to be tested”, since besides the sensitivity this is a criterion for the necessary testing, where practicable, from both cylindrical surfaces.

c) The tables 5-4 and 5-5 were taken over from KTA 3211.3 (2012-11) in which case

ba) the formulation regarding the frequency of indications was updated again,

bb) in Table 5-4 the term “carbonitride lines” was replaced by the more accurate term “carbides, nitrides and carbonitrides”; this more precise term was uniformly formulated in KTA safety standards 3204, 3201.1 and 3211.1 to endure an identical formulation of the acceptance criteria in these standards.

(6) In Section 6 “Forged plates for tubesheets” the following changes were made:

a) The formerly used term “single-piece plates” was replaced by the term “plates” throughout this section.

b) Figure 6-2 and Table 6-1 were editorially improved and in the figure in Table 6-1 errors were corrected additionally.

c) In section 6.4.2.4 the third paragraph was deleted. The stipulation in section 6.4.2.3 is sufficient that the test is to be performed from the large surface and from the side face.

d) Section 6.4.2.5.2 was restructured (new titles). In addition, the unclear term “local reflections” was deleted and the stipulations for “planar indications” were deleted, since larger indications are already covered by the stipulated allowable lengths.

(7) In Section 7 “Plates and sheets” and Section 8 “Products dished, pressed, bent for rolled from sheets and plates” all stipulations were deleted which relate to quenched and tempered wall thicknesses greater 200 mm. This restriction corresponds to the stipulations in Tables A 1-2 and A 1-3 and has no practical consequences, as these product forms in German NPP’s are only used with quenched and tempered wall thicknesses equal to or less than 200 mm. In addition, the following changes were made in Section 7:

a) The text formulated as reference to section 7.3.2.2.3 was included in paragraph 1 of this section because it is a requirement.

b) Section 7.4 was put more precisely at some points in the text in which case the stipulations of Table 7-1 were adapted to the state-of-the-art and the acceptance criteria were laid down on the basis of DIN EN 10160.

c) In section 7.4.2.1 the last sentence was deleted because section 8.4 now requires an obligatory ultrasonic test on the original plate.

(8) In addition to the deletion of requirements referring to quenched and tempered wall thicknesses exceeding 200 mm already explained under (7) the following changes were made in Section 8:

a) In Section 8.4 “Non-destructive tests and inspections” the former optional ultrasonic testing of the original plate was laid down as obligatory test to meet the state-of-the-art.

b) At several locations editorial improvements and further specifications were made for the purpose of clarification.

(9) In Section 9 “Straight pipe fittings” and Section 10 “Seamless, forged hollow bodies for primary coolant pump casings” editorial improvements and further specifications were made for the purpose of clarification.

(10) In Section 11 ”Forged valve bodies” the title was simplified and editorial improvements and further specifications were

made for the purpose of clarification. In addition, paragraph 1 of section 11.3.1 was deleted which contained an exemption to be laid down in individual cases. The other sentences of former section 11.3.1 were moved to section 11.3.2.1 as new paragraph 3 and put more precisely.

(11) In Section 12 “Forged plates” the following changes besides editorial improvements were made:

a) The formerly used term “flat plates” was replaced throughout the text by “plates”.

b) In section 12.4.2.1 the wording for reducing the number of measurements for angle-beam scanning was put more precisely.

c) The stipulations for recording levels in section 12.4.2.3 were simplified.

d) Figure 12-1 was editorially revised and angle-beam scanning from the shell surface was shown in new Figure 12-2.

(12) In Section 13 “Hot dished or pressed products from forged plates” editorial improvements were made. In addition, the wording in section 13.4.2.1 for reducing the number of measurements for angle-beam scanning was put more precisely.

(13) In Section 14 “Forged or rolled bars” the following changes were made:

a) The section title was simplified as the requirements apply to any bar.

b) In section 14.4.2 “Ultrasonic testing” requirements for global and selected ultrasonic testing were taken over on the basis of the requirements of section 22 of this safety standard as well as of section 11.4 of KTA 3211.1.

(14) In Section 15 “Hollow-bored or hollow-forged parts made of forged or rolled bars” the text was put more precisely for the purpose of clarification.

(15) In the titles of Sections 16 and 17 the addition “for piping” was deletes as it is not necessary. The requirements for non-destructive tests and inspections in section 16.4 and 17.4 were updated as follows:

a) The testing of sub-surface areas for longitudinal and transverse flaws and the testing for lamination flaws were determined on the basis of the current standards in which case the acceptance criteria meet the testing requirements as per SEP 1915, SEP 1918 or SEP 1919.

b) Analogously to the stipulations in KTA 3201.3 and KTA 3211.3 stipulations for testing the centre range of a pipe wall with a wall thickness s > 20 mm to detect longitudinal and transverse flaws were taken over to ensure that each volumetric element is covered by ultrasonic testing.

c) In the case of pipe bends with a wall thickness less than or equal to 15 mm ultrasonic testing may be replaced by radiographic testing where, however, a combination of ultrasonic and radiographic testing is permitted. New requirements for radiographic testing were included.

(16) In Section 18 “Steam generator heat exchanger tubes” the following changes were made:

a) The nickel alloy NiCr 15 Fe was deleted in this section and in Annex A 9, as the use of this alloy for steam generator heat exchanger tubes does no more correspond to the state of science and technology and will no more be used in the future. Instead of this material, new alloy NiCr 29 Fe was taken over and the requirements adapted accordingly in the respective sections.

b) In section 18.4 “Non-destructive tests and inspections” the saw-tooth (wedge shaped) reference reflector was replaced by a rectangular groove in correspondence with the stipulations of the EPRI Report EPRI TR-016743-V2R1 “Guidelines for PWR Steam generator tubing Specifications and Repair”.

In an examination performed with several different test flaws and with test techniques typical for the task the test sensitivity was analysed when using reference notches as per 18.4.2 (1) compared to the saw-tooth reference reflectors to KTA 3201.1, Edition 1998-06. The examination results have been comprised in the following report:

Krüger A., Gruhne B.:
Ultraschall- und Wirbelstromprüfung an Testrohren aus Incoloy 800 (Ultrasonic and eddy-current testing on test tubes of Incoloy 800), Report no. KTA-15-01 dated 15 February 2016

The analysis showed that the reflectivity of the saw-tooth reference reflectors compared to the reference notches as per 18.4.2 (1) is smaller when testing for longitudinally oriented flaws. To ensure equivalent reflectivity with the rectangular notches as when using the saw-tooth reference reflectors to KTA 3201.1, Edition 1998-06, the notch width was limited to 0.12 mm and a sensitivity allowance of 6 dB fixed for the test for longitudinally oriented flaws. No allowance is necessary for transverse flaws.

The additional performance of eddy-current testing mentioned in the EPRI Report TR-016743-V2R1 is not considered necessary because the performance of ultrasonic testing with the requirements fixed will suffice with regard to safety aspects.

(17) In Section 19 “Seamless extrusion-clad composite tubes” the following changes were made:

a) In Sec. 19.3.3 requirements for ultrasonic testing were taken over as alternative to the pickling disc test.

b) The requirements for ultrasonic testing in Sec. 19.4.2 were put more precisely.

c) In Sec. 19.4.3 new requirements for the performance of surface inspection by means of ultrasonic or eddy-current testing were included.

(18) Section 20 “Bars and rings for bolts, nuts and washers, as well as bolts, nuts and washers (dimensions exceeding M 130)” was editorially improved. In Sec. 20.5.3 eddy-current testing was permitted alternatively to magnetic particle testing on the bolt shaft and alternatively to liquid penetrant testing on the threads. As regard the acceptance criteria reference is made to Tables 5-4 and 5-5 in which case indications presuming the existence of cracks or crack-type flaws are further not permitted.

(19) In Section 21 “Bars for bolts, nuts, washers and expansion sleeves as well as finished product forms fabricated from them (dimensions equal to or smaller than M 130)” the title was simplified and editorial changes were made.

(20) In Sections 22, 23 and 24 the following changes were made for product forms made of austenitic steels:

a) The restriction for product forms and components of boiling water reactors was adapted to the formulation of KTA 3201.3.

b) The nitrogen content shall always be determined to ensure a determination by calculation of the delta-ferrite content in conformance with KTA safety standards. The stipulations in Secs. 22.3.2.1 (2), 23.3.2.1 (2) and 24.3.2.1 (2) were changed accordingly.

c) The former Secs. 23.4 (2) and 24.4 (2) that permitted lengths of indications exceeding 6 mm for titanium-stabilized steels upon agreement by the authorized inspector, if caused by non-metallic inclusions, were deleted. Tolerancing of indications upon agreement with the authorized inspector is an individual decision not to be covered by KTA 3201.1.

d) The former Secs. 22.5, 23.9 and 24.3.3.3 were deleted as they are no more required due to newly included references to the performance of tests in accordance with the pertinent paragraphs of Sec. 3.3.7.

(21) In Section 22 “Sheets, plates, bars and forgings from stainless austenitic steels as well as bars from nickel alloys” the following changes were made in addition to the changes mentioned in (20).

a) New requirements for bars made of nickel alloy NiCr 29 Fe as per Annex A 9 were included.

b) The requirements for ultrasonic testing in Sec. 22.4.2 were put more precisely. Here, the acceptance criteria for forgings, bars and plates were formulated on the basis of DIN EN 10228-4 and adapted to the state-of-the-art. This leads in part to more stringent requirements compared to the former requirements of KTA 3201.1.

(22) In Section 23 “Seamless pipes from stainless austenitic steels” the following changes were made in addition to the changes mentioned in (20):

a) The stipulations for the determination of sound attenuation and transfer correction in Sec. 23.4 were put more precisely.

b) The stipulations in Sec. 23.7 took over the essential test requirements for the internal hydrostatic test from DIN EN 10216-5.

(23) In Section 24 “Seamless elbows from stainless austenitic steels” the following changes were made in addition to the changes mentioned in (20).

a) In Sec. 24.1 the restriction for outer diameters equal to or exceeding 80 mm was deleted as the range of application of the entire standard is limited to dimensions exceeding DN 50.

b) At several locations the text was simplified and put more precisely.

(24) As the use of the cast steel GS-18NiMoCr 3 7 as per Annex A 4 is only permitted for primary cooling pump casings and valve bodies, the title of Section 25 was changed and the formulation in Sec. 25.1 changed accordingly as well as the formulation in Sec. A 4.1 was correlated with the titles in Secs. 25 and 26.

(25) In Sections 25, 26 and 27 the following changes were made:

a) The stipulations for explaining the casting technology were adapted to the state-of-the-art.

b) The stipulation contained in several sections up to now that the requirements for welded joints according to KTA 3201.3 basically apply, was taken over as general requirement in sections 25.4.1, 26.4.1 and 27.4.1. Consequently, the references to KTA 3201.3 in several sub-clauses are no longer required and were deleted.

c) The definition of the "relatively large production weld" was taken over into this safety standard in compliance with the stipulations valid up to now, as the current standard DIN EN 10213-1 contains a less stringent definition valid at greater wall thicknesses, and the more stringent requirements valid up to now shall further apply.

d) The location of the notch to be used for determining the impact energy in procedure qualification and production control tests was defined in compliance with KTA 3201.3.

e) The requirements for surface quality laid down up to now in secs. 25.6.3.1 and 27.6.3.1 were updated and moved to section 3.3.8.2.

f) Stipulations for the test and inspection procedures to be carried out were deleted, as they are no more required due to new references to the performance of tests and inspections in accordance with the pertinent sub-clauses of section 3.3.7.

g) For the internal pressure test the reference to the standard DIN 50104 (1983-11) withdrawn without replacement in May 2015 was retained as no successor to this standard exists.

(26) In section 25 “Primary coolant pump casings from ferritic cast steel” and section 26 “Valve bodies made from ferritic cast steel” the following changes were made in addition to the changes mentioned under (25):

a) In Table 25-2 the information on the applicable standards was deleted in the column “Type of specimen” since the stipulations in section 3.3.7 suffices. For the tensile tests at room temperature it was renounced to specify the shape of specimen. Reference to the standard DIN EN ISO 4136 is not required as the specimen location is clearly shown in Figure 25-2//II. For the macrosection inspection certificate 3.2 is required like in KTA 3201.3. The supplementary requirements contained up to now in sub-clauses 25.4.2.2.2 (2) a) and 26.4.2.2.2 (2) a) were deleted in these sub-clauses and taken over as footnotes in Table 25-2. Footnote 3 in Table 25-2 was deleted since not assigned to any requirement.

b) Table 25-2 was editorially revised and in Table 25-3 the standards already listed in Table 25-2 were deleted.

c) The requirements for non-destructive tests and inspections in section 25.6 were adapted to the state-of-the-art on the basis of the stipulations of KTA 3211.1 (2015-11). As regards the requirements for non-destructive tests and inspections of valve bodies in section 26.6 a stipulation for using the radiograph as per DIN EN 12681, Figure 7 was taken over in addition to the reference to section 25.6, with the stipulation applying to steel castings with an external diameter less than or equal to 200 mm.

d) The former Figures 26-1 and 26-2 as well as the Tables 26-1 and 26-2 were deleted and replaced by a reference to the respective and identical Figures and Tables of section 25.

e) In secs. 26.4.2.3, 26.4.3.1 (3) a), 26.4.3.1 (3) b), 26.4.3.2 (1) and 26.5.1 (9) the term “normalized” was deleted, because neither in Annex A 4 nor in Annex A 5 normalized steels are mentioned.

(27) In section 27 “Valve bodies from austenitic cast steel” the following changes were made in addition to the changes mentioned under (25):

a) In Section 27.2 (3) the formerly lacking upper limit of the delta ferrite content to be aimed at achieving was fixed to be 12%.

b) The requirement for intergranular corrosion resistance laid down up to now in section 27.2 (4) was deleted since the stipulations in Annex A 6 (section A 6.4.3) suffice and are more precise.

c) The structure of section 27.4 was adapted to sections 25.4 and 26.4.

d) Tables 27-2 and 27-3 were editorially revised analogously to Tables 25-2 and 25-3. The stipulations contained up to now on sections 27.4.2.2.3 (1) and 27.4.3.1 (3) a) were deleted and taken over as footnote in Table 27-2. For the impact test, the room temperature was fixed as test temperature in Tables 27-2 and 27-3 in consideration of the currently defined room temperature instead of the formerly requested 20 °C.

e) In section 27.6.3.1 a new text was included that regions where hot cracking may occur shall be subject to selected radiographic testing.

(28) In section 28 “Bars and forgings from stainless martensitic steel” editorial improvements were made.

(29) Section 29 “Product forms and components from ferritic steels fabricated by shape-welding” contained in the previous edition of KTA 3201.1 (1998-06) is no more considered necessary and therefore was deleted. In existing German nuclear power plants no product forms fabricated from shape-welding have been utilized. Shape welding is not intended for the fabrication of product forms, but may be considered for repair welding. The use of shape welding for repairs is not covered by KTA

3201.1, but has to be performed to satisfy the stipulations of section 5.6 of KTA 3201.3.

(30) In section 29 “Product forms from ferritic steels for integral connections to the reactor coolant pressure boundary” and section 30 “Product forms from austenitic steels for integral connections to the reactor coolant pressure boundary” the following changes were made:

a) In section 29.2 references were made to the pertinent stipulations of sections 4, 7, 12, 14, and 15 respectively. This was made to clarify that the requirements for product forms made of 20 MnMoNi 5 5 apply.

b) In section 30.2 a reference to the pertinent stipulations of section 22 was included. This was made to clarify that for integral connections made from austenitic steel the requirements of Annex A 3 apply.

c) In section 30.3.1 new text was included that a product analysis is to be performed in accordance with clause 22.3.2.1 (2). Such requirement regarding product analysis was missing so far, although in accordance with the previous stipulations of section 30.3.3 a product analysis was also required.

d) Editorial changes were made.

(31) Annex A “Material characteristics” was adapted to the current state of standards and editorially revised. In addition, the following changes were made:

a) Annex A 1

The reference to sec. A 1.3.1 and the former footnote 3 in Table A 1-1 were deleted since footnotes 4 and 4 in Table A 1-1 suffice.

The stipulations for quenching and tempering in A 1.4.1 (1) were extended by taking over the formulation from VdTÜV-Werkstoffblatt 401/2 to apply to pressed seamless pipes under Sec. 16 and pipe elbows under Sec. 17 fabricated from them.

Para A 1.5.1 (9) was simplified by taking over a reference to welding procedure qualification or production control test in accordance with KTA 3201.3. In addition, the deviations mentioned as examples were restricted to such examples that do not require a new appraisal.

In section A 1.5.3.2 was supplemented to say that upon cold forming with degrees of forming smaller than or equal to 2% no hat treatment is required. The second sentence of this para (renunciation of stress-relief heat treatment) was deleted since such stipulation has to be made in each individual case and thus is not subject to regulation by KTA 3201.1.

In Table A 1-2 the quenched and tempered wall thickness contained up to now in Table A 1-3 was supplemented for the product forms to sections 4 to 6 and sections 10 to 14. The quenched and tempered wall thickness for the product forms to sections 7 and 8 was limited to 200 mm to correspond to the new stipulations in these sections. In addition, new footnotes 2 and 5 were included for the purpose of adapting to VdTÜV-Werkstoffblatt 401/3.

In Table A 1-3 the information on tensile strength was adapted to VdTÜV-Werkstoffblatt 401/2 and the parentheses in the last line were deleted.

b) Annex A 2

In clause A 2.6 the reference to the withdrawn VdTÜV-Werkstoffblatt 474 was deleted and an appropriate requirement for material appraisal was taken over.

c) Annex A 3

The stipulations for hot forming of austenitic steels in para. A 3.5.3 (1) were adapted to VdTÜV-Werkstoffblatt 451. In addition, it was clarified that products shall basically be solution annealed. The deviation from this basic requirement is regulated in (2).

In para. A 3.5.4 (1) it was clarified that a heat treatment shall basically be required. The deviation from this basic requirement is regulated in (4).

Para. A 3.5.4 (6) (cold bending of tubes > DN 150) was deleted since such a stipulation has to made in each individual case and thus is not subject to regulation by KTA 3201.1.

In Table A 3-1 the former requirement for the boron content was deleted since, to the current state of science and technology, boron will not have any influence on the resistance to intergranular corrosion of austenitic steels.

The verification of nitrogen formerly required by Table A 3-1 was moved to section A 3.3.1.

In Table A 3-2 the formulation of footnote 1 was adapted to the formulation in the current standards (e.g. DIN EN 10028-2, DIN EN 10126-5) thus making it more comprehensible.

In Table A 3-7 footnote 2 was deleted since VdTÜV-Werkstoffblatt 451 provides no restriction of the R_m values.

d) In Annex A 4 editorial changes were made besides the adaptation to current standards.

e) Annex A 5

The formulation contained in A 4.5.2 was taken over into section A 5.5.2 in which case the lower value of the preheating temperature for the cast steel GS-C 25 S was fixed to be 100 °C.

In section A 5.6 an appropriate requirement for material appraisal was included.

f) In Annex A 6 an appropriate requirement for material appraisal was included in section A 6.6 besides some editorial changes.

g) Annex A 7

Sections A 7.2.3.5 and A 7.3.4 were deleted as they do not contain requirements.

The information on $R_{p0.2}$ at 400 °C in Table A 7-4 was adapted to VdTÜV-Werkstoffblatt 439.

In section A 5.6 an appropriate requirement for material appraisal was included.

h) Annex A 8 was editorially changed.

i) The former Annex A 9 for nickel alloy NiCr 15 Fe was deleted since this alloy does not more correspond to the current state of science and technology and will not be employed in the future.

In new Annex A 9 the requirements for nickel alloy NiCr 29 Fe were taken over.

For steam generator tubes made of NiCr 29 Fe, the requirements for chemical composition were laid down in compliance with the recommendations in the EPRI Report TR-016743-V2R1 “Guidelines for PWR Steam Generator Tubing Specifications and Repair” in which case the sulphur content was laid down in correspondence with the French RCC-M Code and the cobalt content not being relevant to the material properties was laid down in accordance with the current deliveries. The requirements for the mechanical properties of steam generator heat exchanger tubes made of NiCr 29 Fe were also formulated in compliance with the recommendations of the EPRI Report TR-016743-V2R1 as regards the room temperature. Regarding the values at 350 °C the design values of ASME BPVC (Section II, Part D, Tables U and Y-1) were taken over into KTA 3201.1.

For bars made of NiCr 29 Fe the requirements for the chemical composition were formulated on the basis of the stipulations in ASME BPVC (Section II, ASME-SB 166) in which case the more stringent requirements for the elements carbon, chromium, sulphur and iron were taken over from the French RCC-M Code and the limit values for niobium, boron, molybdenum and nitrogen which are neither contained

in ASME SB-166 nor in the RCC-M Code were fixed in compliance with KTA 3204 (Table W-2). The requirements for the mechanical properties of bars were laid down on the basis of the existing individual material appraisals.

j) The Annex A 10 contained in the former edition of KTA 3201.1 (1998-06) for shape-welded or shape-molten materials was deleted, see (29)

k) In Annex A 10 "… supplementary requirements to DIN EN 10269" editorial changes were made. In addition, footnote 1 in Table A 10-2 was adapted to the current standards (DIN EN 100028-2, DIN EN 10216-5) and thus made more comprehensible.

l) The supplementary requirements in Annex A 11 were formulated to refer to DIN EN 10269. For the steel 25CrMo4 which was taken over to replace the steel 24 CrMo 5 no more covered by DIN EN 10269 the dimensional limits had to be reduced to 100 mm in order not to infringe upon the requirements of section 3.2.4.4.

(32) In Annex AP "Characteristic values of physical properties" the following changes were made:

a) In Table AP-3 the values for the average linear thermal expansion coefficient originally taken over from DIN 17440 were replaced by the values contained in the current standard DIN EN 10088-1. In addition, the density value was adapted to the values contained in DIN EN 10088-1.

b) In Table AP-7 the values of density and modulus of elasticity of the steel X 5 CrNi 13 4 were adapted to the values contained in DIN EN 10088-1.

c) In Table AP-8 new characteristic values of physical properties for the nickel alloy NiCr 29 Fe were included.

d) Table AP-9 contained in the former edition of KTA 3201.1 (1998-06) for shape-welded or shape-molten materials was deleted, see (29).

(33) Annex B "Performance of manual ultrasonic testing" and Annex C "Performance of surface inspections by magnetic particle and penetrant methods" were taken over from KTA 3211.3 (2012-11) and updated.

(34) As regards the specimen dimensions, Annex D "Procedure for determining the delta ferrite content" was adapted to AVS D 63/50 dated 4th June 2012 and at several text passages correlated with KTA 3211.1 (2015-11).

(35) In Annex E "Form sheets" the pertinent updates were taken over from KTA 3211.3 into KTA 3201.1.

(36) At several text passages this safety standard was editorially improved and put more precisely. The following section-overlapping changes were made:

a) The standard was adapted to the current state of standards.

b) Requirements relating to the same facts were formulated to be the same in all product-related sections.

c) Unclear wordings (e.g. "in general" and "basically" without an indication of conditions for an allowable deviation from the principle) were examined und - where required - put more precisely or deleted.

d) To avoid contradicting stipulations on the elements to be verified which were contained up to now, the stipulations for the chemical analysis were uniformly referred to in the pertinent Tables of Annex A.