Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

KTA 3401.1 (09/88)

Steel Containment Vessels;

Part 1: Materials

(Reaktorsicherheitsbehälter aus Stahl;

Teil 1: Werkstoffe)

Version 09/88 of KTA 3401.1
replaces previous version 11/82.

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 50-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in Bundesanzeiger No. 37a on February 22, 1989. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, D-50939 Koeln (Telefax 0221-4601092)

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Comment by the editor:

In these English translations of KTA Safety Standards the words **shall, should** and **may** are used with the following meanings:

shall	indicates a mandatory requirement,
should	indicates a requirement [1] to which exceptions are allowed. However, the exception used shall be substantiated during the licensing procedure,
may	indicates a permission and is, thus, neither a requirement (with or without exceptions) nor a recommendation: recommendations are worded as such, e.g., "... and it is recommended that ... ".

The word combinations **basically shall** or **shall basically** are 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 **should** - are specified in the text of the safety standard.

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[1] Please note that in the case of IAEA NUSS standards and ANSI standards, the word **should** indicates a mere recommendation.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against the damage arising from the construction and operation of nuclear facilities (Sec 7 para 2 no. 3 Atomic Energy Act), in order to attain the protective goals specified in the Atomic Energy Act and the Radiological Protection Ordinance

(2) For nuclear power plants, these protective goals are further detailed in the Safety Criteria for Nuclear Power Plants issued by the Federal Minister for the Environment, Nature Conservation and Reactor Safety (BMU).

(3) The task of the containment vessel is to withstand the postulated pressure and temperature loads which may occur during incidents involving a release of radioactive substances inside the containment vessel, and in particular in the case of the design basis leakage cross section of the primary reactor coolant pipe; it shall withstand these loads in such a way that any inadmissible release of radioactive substances into the environment is prevented. For this reason, the containment vessel, including all penetrations and cooling devices inasfar as their function is necessary for coping with the consequences of incidents, shall be designed and arranged in such a way that the containment vessel will withstand the static, dynamic and thermal loads which may occur in connection with the abovementioned incidents and their consequences, provided the design basis leakage rate is [not exceeded] Another task of the containment vessel is the air routing during normal operation

(4) To give an example, the containment vessel is designed as a technologically gas-tight steel sphere into which the necessary pipe and cable penetrations as well as airlocks are inserted

(5) The engineering and administrative measures required for this type of containment vessel such that it can fulfill the mentioned tasks are dealt with in the four parts of this safety standard

(6) The present part specifies the requirements for the materials and product forms of the containment vessel

1 Scope

This safety standard applies to materials and product forms for steel containment vessels of stationary nuclear power plants with light water reactors, including the nozzles integrally connected with the containment vessel, and to the pressure-retaining parts of airlocks.

2 General Principles

2.1 Selection of Materials and their Certification

(1) The materials shall be selected in accordance with their intended use, considering the mechanical, thermal and chemical loads involved. Special attention shall be paid to safety against brittle fracture, considering the loads of operating [and incident] conditions.

> *Note: Provided the material is admissible for the intended use, the material generally is selected by the customer, if necessary after consultation with the material manufacturer.*

(2) Only certified materials may be used

(3) The certification of materials with regard to their characteristics in respect to the above mentioned loads and to the workability of the materials is carried out by the authorized expert and, within the scope of a general approval under the building code or an individual certification, by the supreme building supervision authority or the authority commissioned by it. Once a certification has been issued it shall apply to the respective material manufacturer within the scope of the certification

> *Note: Unless otherwise specified, the term 'authorized expert' as used herein shall always refer to the authorized expert under Sec. 20 of the Atomic Energy Act*

(4) The tests by the authorized expert required for the [initial] material certification shall be specified with regard to type and extent such that, together with the supplied manufacturer documentation they form a sufficient basis for the material certification. The proof that the required material characteristics are continuously attained should best be supported by the mathematical and statistical evaluation of already available test results. If the manufacturing of the material is carried out in more than one plant, this shall be considered in the initial certification. The initial certification shall extend to the evaluation or specification of the following points

a) melting process,

b) chemical composition,

c) product form,

d) conditions upon delivery,

e) mechanical properties,

f) workability,

g) scope of applicability,

h) type and extent of tests and inspections,

i) test certification,

k) identification marking.

(5) As a result of their detailed and complete tests and their proven service life, the materials specified in **Appendix A** are considered admissible.

(6) With respect to kind and scope of the certification tests, materials for product forms under Secs. 8 through 10 shall be certified in the same way as steels of surveilled pressure vessels in fields of application other than nuclear engineering. If such materials are already admissible for surveilled pressure vessels outside of nuclear engineering, they are considered as certified

(7) Other materials are admissible if their certification was demonstrated in an initial material certification report by the authorized expert and if a general approval under the building code or an individual consent by the supreme building supervision authority or the authority commissioned by it was issued

(8) If a material is to be used beyond the scope of applicability of its certification, a supplementary certified material test report by the authorized expert is required. This also applies to a special material that is to be used in an individual application. In special cases, an individual material certification regarding the extended scope of applicability may be issued. This individual material certification shall be limited to the certified material manufacturer and to similar scopes of applications. This individual certification shall be specified in the acceptance certificate.

(9) If new kinds of manufacturing procedures (e.g. melting, pouring and shaping procedures) are applied that were not considered in the initial material certification then their equivalence to those procedures considered in the initial material certification shall be

demonstrated in the supplementary material certification by the authorized expert

(10) If the material is to be welded then it must be suited for welding. The welding suitability shall be attested in the initial material certification of the authorized expert In case special conditions must be observed during welding, these shall be specified in the initial material certification of the authorized expert

2.2 Weld Filler Materials and Weld Additives

With regard to weld filler materials and weld additives KTA 1408 shall be applied.

2.3 General Requirements for Quality Assurance

With regard to the general requirements for quality assurance KTA 1401 shall be be applied

2.4 Requirements regarding 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, shall refer to both, the materials and their product forms

(2) The manufacturers shall have testing equipment at their disposal which allow testing the materials in accordance with the corresponding DIN Standards or with other standards that apply. The automatic testing equipment shall correspond to Class 1 in accordance with DIN 51 220 and shall be inspected in accordance with DIN 51 300. The test reports in accordance with DIN 51 300 shall be presented to the authorized expert upon demand

(3) In as far as testing equipment of other facilities are employed, these requirements apply accordingly

(4) The manufacturer shall have equipment at his disposal, either in his plant or at other facilities, that allow carrying out the nondestructive tests required in accordance with this safety standard Mechanical or automated equipment employed in the nondestructive examinations in accordance with this safety standard shall be certified by the authorized expert.

(5) A listing shall be available of the required work procedures for the manufacturing and testing equipment in accordance with para. 1 through 4.

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

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

(8) The test surveillance for the nondestructive examinations shall be part of the staff of the manufacturing plant It shall be organizationally independent from fabrication and shall be named to the authorized expert.

(9) The testers carrying out the nondestructive examinations should be part of the staff of the manufacturing plant They shall have sufficient basic technical knowledge and shall be capable of performing the examinations in accordance with the requirements. This shall be demonstrated to the authorized expert by the test surveillance on the basis of testing experience, of plant-internal training, or on the basis of corresponding certificates from plant-external examinations.

(10) In the case of ultrasonic examinations and surface crack examinations, any plant-external tester may only perform test activities in addition to the testers of the manufacturing plant.

(11) The test surveillance shall be responsible to the effect that the testing procedures are applied in accordance with the requirements under the product-form related sections and that the individual steps in executing the tests are applied in accordance with the corresponding regulations The testers should be deployed by the test surveillance. This also applies to the deployment of plant-external personnel The test surveillance evaluates the test results and signs the test report

(12) The plant expert shall be part of the staff of the manufacturing plant. The name and attestation stamp of the plant expert shall be known to the authorized expert.

(13) Inasfar as welding work is performed on product forms within the scope of manufacture, the specifications in KTA 3401 3 shall be applied

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

(15) The manufacturer shall have a quality department that is organizationally independent from that of fabrication

(16) The organizational interdependence and the individual tasks of the plant expert, the test surveillance, the testers, the quality division and, if required, the weld supervision shall be specified in writing.

(17) Before initiating any fabrication steps, the authorized expert will have to verify that all requirements in accordance with para 1 through 16 are met. That these requirements are met shall be certified in writing by the authorized expert. This examination shall be repeated in time intervals of between about one and two years unless the authorized expert can verify by other means that the requirements are continually being met.

2.5 Manufacturing and Design Review Documents

(1) Within the scope of its quality assurance system, the manufacturer shall prepare the necessary project and product-form related manufacturing documents. For this purpose, documents that are entirely or partly standardized may be used

(2) If, with respect to special product forms, the removal of specimens is not unambiguously specified in the following product-form related sections, materials test and specimen removal plans shall be submitted to the authorized expert for design review

(3) Welded nozzles shall meet the requirements under Sec. 7 KTA 3401 3

2.6 Fabrication Surveillance by the Manufacturer (Quality Control)

(1) During the manufacture of the product forms - from the melting process to delivery - the quality control with records customary at the factory shall be performed by a quality department [that shall be] independent of from that of fabrication

(2) The quality control during fabrication shall cover:

(a) Review of compliance with the conditions for a proper manufacture in accordance with the following specifications

(b) Supervision and performance of the tests as specified in this safety standard, including their confirmation in test records and certificates

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(3) If deviations are ascertained in the course of manufacture, the manufacturer shall prepare a nonconformance report in which the deviations shall be described and the further procedure (correction or toleration) stated with corresponding justification The nonconformance report shall be submitted to the authorized expert for his review and, together with the authorized expert's comments, shall be attached to the quality certificate

Note: A deviation exists if given limits (tolerances) of the required state are not complied with by the actual state determined.

2.7 Fabrication Surveillance by the Authorized Expert

(1) The authorized expert should make random tests to satisfy himself of the quality control carried out by the manufacturer

(2) The authorized expert shall be entitled to be present during the manufacturing processes The flow of the manufacturing process should not be affected by his presence The manufacturing documents shall be made available to the authorized expert as necessary for this purpose,.

2.8 Testing and Demonstration of Quality Characteristics

(1) The decisive elements regarding testing and demonstration of quality characteristics shall be the specifications contained in the following product-form related sections

(2) The required quality characteristics shall be determined by tests and demonstrated by materials testing certificates in accordance with DIN 50 049 These shall contain

(a) the bases and requirements for testing,

(b) the testing conditions,

(c) the results of the tests,

(d) the name of the tester

(3) The materials should be tested at the plant of the material manufacturer.

(4) The materials shall be marked for identification in accordance with the requirements specified under Sec 3 5 The complete wording of the identification marking shall be contained in the certificate issued in accordance with DIN 50 049

2.9 Remedial Work and Repairs

(1) All fabrication steps necessary to attain the specified quality and which were not provided for during first-time manufacture shall be considered to be remedial work or repairs

(2) Remedial work and repairs require the consent of the authorized expert The reasons for remedial work and repairs shall be determined and submitted to the authorized expert In this context, it shall be considered in how far the intended remedial work or repairs will lead to safety-related advantages or disadvantages compared with leaving the deviation as it is Prior to effecting remedial work or repairs, the measures and tests required for this purpose shall be specified in writing in the nonconformance report, and the consent of the authorized expert shall be obtained

2.10 Characteristics for Design Analysis

The material characteristics which are decisive for stress analyses are contained in **Appendix A** In the case of other materials, they shall be taken from the initial material certification of the authorized expert

3 General Specifications for Materials and Material Tests

3.1 Admissible Materials

All materials are admissible that meet the requirements under Sec 3 2.

3.2 Requirements Regarding Materials

3 2 1 General

(1) The requirements reparding quality characteristics as specified in **Appendix A** or in the initial material certification of the authorized expert apply to the final condition during the assembly and pressure tests.

(2) During the preceding acceptance tests of the materials or product forms, the quality characteristics shall be demonstrated on sufficiently large test coupons in the heat treatment condition as specified under Sec 3 3 6

3 2 2 Heat Treatment

(1) The materials shall be heat treated in accordance with the specifications contained in **Appendix A** or in the initial material certification of the authorized expert In the case of deviations from the specified heat treatment, the equivalence of the methods shall be demonstrated

(2) Uniformity of the heat treatment temperature over the entire product form shall be ensured All records shall be readily available for inspection by the authorized expert

(3) If in the course of manufacture product forms made of quenched and tempered steels are subjected to additional heat treatments following the last tempering, the temperatures used for these heat treatments shall remain below the last tempering temperature

3 2 3 Materials Properties

(1) The materials to be used should have a fine-grained micro structure.

(2) The sufficiency of safety against brittle fracture shall [basically] be demonstrated within the scope of the initial material-certification This demonstration shall be carried out at the time of the acceptance test by means of notched bar impact tests, provided, the initial material certification [of the authorized expert] specifies that, beyond the tests specified in the product-form related sections, no further examinations are required.

(3) The steels as well as the weld filler materials and weld additives for components subjected to internal pressure, with the exception of bolts, nuts and washers in accordance with Secs 8 through 10, shall be of such a condition that each of the ISO-V specimens - base material, heat affected zone and weld metal - subjected to the notched bar impact test at the lowest specified temperature is characterized by an absorbed energy ≤ 68 J and a lateral expansion $\leq 0\,9$ mm. In addition, the absorbed upper shelf energy of the base material shall be ≥ 100 J (lowest single value).

3 2 4 Internal Defects and Surface Defects

The product forms shall be free from internal defects and surface defects as specified in the following product-form related sections

Note: These sections also contain the evaluation standards for indications during nondestructive tests which consider the type and the further processing of the

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product forms, their intended applications and the loads to which they will be subjected.

3.2.5 Surface Condition

The surface condition shall meet the requirements for nondestructive tests during manufacture and during in-service inspections. Details are specified in Sec. 3.3.8.

3.2.6 Subsequent Processing and Testing

The specifications in KTA 3401.3 apply to subsequent processing and testing of the materials.

3.3 Tests of the Materials

3.3.1 Material Testing and Specimen Removal Plan

If a material testing and specimen removal plan is required, this schedule shall contain the tests specified in the following product-form related sections. In the design review, it shall be specified in this schedule at which time the required tests shall be performed in the course of manufacture.

3.3.2 Designation of the Orientation and Location of Test Specimens

The following designations should be used for the test specimens with regard to their orientation in the product forms (**Figures 3-1** and **3-2**:

a) Designation of the test specimens with respect to the grain flow:

Longitudinal test specimen (L):
Major axis of specimen is parallel to the principal direction of tension (parallel to the grain flow); the notch axis of impact test specimens shall be parallel to the principal direction of compression.

Transverse test specimen (Q):
Major axis of test specimen is normal to the principal direction of tension (transverse to the grain flow); the notch axis of impact test specimens shall be perpendicular to the principal direction of compression.

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

b) Designation of the test specimens with respect to the product form shape:

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

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

Radial test specimen (R):
Longitudinal axis of test specimen is normal to the cylindrical surface; the notch of impact tests shall be parallel to the axis of rotational symmetry.

3.3.3 Location of the Test Specimens in the Product Forms (Depth of Removal)

(1) The location of the test specimen with regard to depth beneath the surface is characterized by the orientation of the test specimen axis and, with regard to distance from the rim, by the location of the specimen cross-section.

(2) Further details are specified in the following product-form related sections.

1 perpendicular test specimen
2 longitudinal test specimen
3 transverse test specimen

HSR = main direction of tension

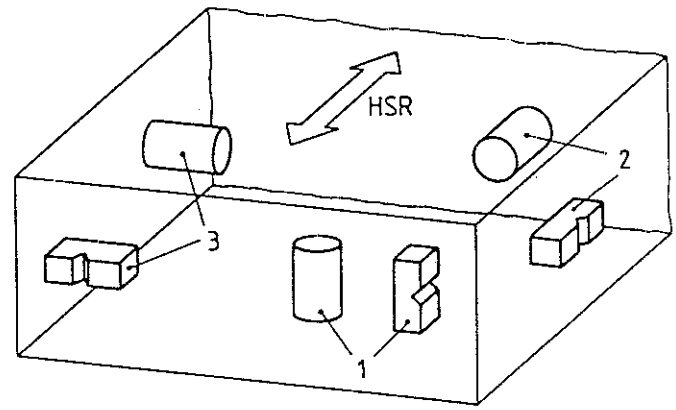
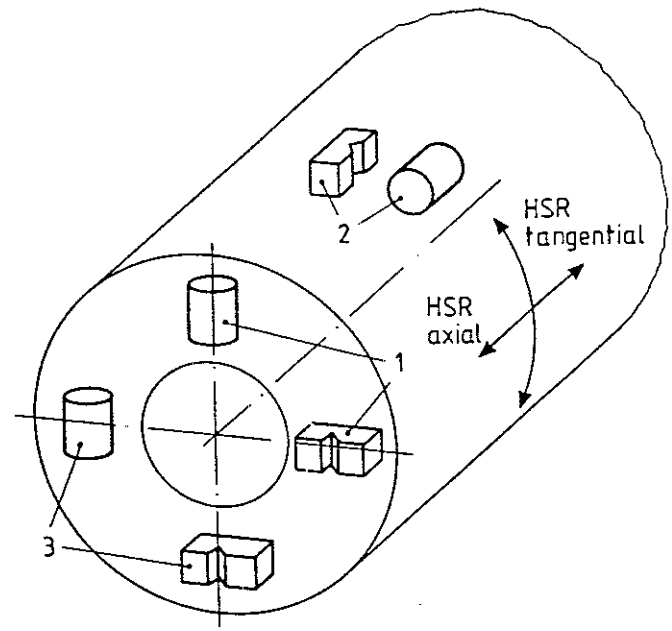


Figure 3-1: Identification of the orientation of test specimens of flat product forms



Test specimen no.	Orientation with respect to		
	shape of product form	major direction of tension	
		tangential	axial
1	radial	perpendicular	perpendicular
2	axial	transverse	longitudinal
3	tangential	longitudinal	transverse

Figure 3-2: Identification of the orientation of test specimens of rotationally symmetric product forms

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3 3 4 Size of the Test Coupons

(1) The test coupons shall be large enough that it will be possible to demonstrate the mechanical properties, and that there will be sufficient material left for replacement test specimens as well as for reserve material

(2) If additional specimen material is required for further examinations, e g production weld tests, the quantities and dimensions of the additional material coupons shall be specified when placing the order

(3) When removing the test coupons, any deformations and temperatures shall be prevented that could influence the results of the tests A sufficient processing margin shall be provided when using shears or cutting torches

3.3 5 Identification Marking of Test Specimens, Test Coupons and Reserve Material and of Required Additional Material Coupons

(1) With regard to the acceptance test, the authorized expert charged with the acceptance test shall legibly and unambiguously stampmark the test coupons prior to their removal from the product form and, likewise, the test specimens prior to their removal from the test coupons The marking of the test specimens shall make it possible to exactly determine their original location in the product form (e g dimensional drawing)

(2) The reserve material and the additional material coupons, if required, shall be marked in the same way

3 3 6 Heat Treatment Condition of the Test Specimens

(1) The test specimens shall be in the same heat treatment condition as the finished product forms

(2) The tests shall be performed in this condition or in a simulation stress-relief heat treated condition if so specified in the following [product-form related] sections

(3) In the case of a simulation stress-relief heat treatment, the duration of all stress-relief heat treatments anticipated during further processing may be combined in a single simulated stress-relief heat treatment Possible repair weldings followed by stress-relief heat treatments shall be taken into account Details are specified in the following [product-form related] sections

3 3 7 Tests and Test Methods to be Applied

3 3 7 1 Chemical Analysis

(1) The ladle analyses and the product analyses shall be performed with regard to the elements specified either in the following product-form related sections, in **Appendix A** or in the initial material certification of the authorized expert

(2) In the case of product forms from ingots made by the electroslag remelting procedure, the chemical composition of each ingot shall be determined by the ladle analysis In this case, a demonstration of the chemical composition by the product analysis is not required

(3) The chemical composition shall be determined by means of test procedures in accordance with the Manual for the Metalworks Laboratory [1], the removal and preparation of test specimens to be carried out in accordance with SEP 1805

3 3 7 2 Hardness Test

(1) Inasfar as required in the following material and product-form related sections, all product forms from quenched and tempered steels shall be subjected to hardness tests prior to further processing in order to demonstrate the uniformity of the heat treatment

(2) The hardness tests shall be performed in accordance with DIN 50 133 or DIN 50 351

3 3 7 3 Destructive Tests

3 3 7.3 1 General

If mechanical properties are to be demonstrated on a melt-by-melt basis for product forms from ingots made by the electroslag remelting procedure, the master melt shall be considered as the melt

3 3 7.3 2 Tensile Test

(1) The yield point or 0 2% proof stress, tensile strength, elongation after fracture and fracture constriction shall be determined in accordance with the specifications in the following product-form related sections

(2) The tensile test shall be carried out in accordance with DIN 50 145 using a test specimen shape in accordance with DIN 50 125

(3) The tensile test of perpendicular test specimens for the determination of the fracture constriction shall be carried out in accordance with DIN 50 145 using a test specimen shape in accordance with SEL 096 The cross section of the perpendicular test specimens should comprise the center-line section

3 3 7.3 3 Notched Bar Impact Test

(1) The notched bar impact test shall be carried out on ISO-V test specimens in accordance with DIN 50 115 Basically, sets of test specimens consisting of three test specimens each shall be tested Both the individual results and the mean result shall be stated For the demonstration of the absorbed energy, ISO-V specimens shall be tested at those testing temperatures which are specified in the following product-form related sections

(2) In the case of ferritic steels, the lateral expansion and the percentage of dull fracture area shall be determined in accordance with **Appendix D**

3 3 7 3 4 Demonstration of the Upper Shelf Absorbed Energy

(1) In accordance with the specifications in the following product-form related sections, it shall be demonstrated that the requirements the upper shelf absorbed energy are met

(2) One set of test specimens consisting of three ISO-V specimens shall [basically] be tested. The test is usually performed at a temperature of 80 °C The test is not required if it is already demonstrated at a lower testing temperature that the requirements are met

3 3 7 4 Metallographic Examinations

(1) For the determination of the grain size, microphotographs of the structure shall be made using a linear magnification which permits an unambiguous assessment (in general, 100:1)

(2) The grain size index shall be determined in accordance with Euronorm 103

(3) If a determination of the grain size of product forms with a bainite or a ferritic-bainite structure is required, the grain size index shall only be determined for the percentage of polygonal ferrite

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3 3 7 5 Material Identification Test

Material identification tests shall be carried out in accordance with a suitable method, e g by a semi-quantitative spectral analysis A comparison of identification markings is not sufficient In the case of parts already subjected to a product analysis, this analysis shall be recognized as material identification test

3 3 7 6 Dimensional Check

(1) After completion, all product forms shall be subjected to a dimensional check.

(2) The dimensions determined shall [basically] be entered into an actual dimension drawing or record. This is not required for the product forms under Secs 8 through 10

3 3 7 7 Visual Inspection

During the acceptance test, all product forms shall be subjected to a visual inspection regarding their external condition.

3 3 8 Nondestructive Tests

3 3 8 1 General

(1) Type, scope and point in time of the tests are specified in the product-form related sections

(2) The general specifications in **Appendices B** and **C** shall apply to the ultrasonic and surface crack examinations

(3) The nondestructive test should be carried out at the plant of the manufacturer of the product form and should follow the last forming and heat treatment process unless other requirements are specified in the product-form related sections

3 3 8 2 Procedure-Related Specifications

3 3 8 2 1 Ultrasonic Examinations

Note: The terms contained in DIN 54 119 shall apply to the ultrasonic examination

(1) The average roughness R_a of the surface to be examined, as specified in DIN 4762 Part 1, should not exceed the following limits, depending on the method of surface processing:

	max. R_a
rolled or ground surfaces	20 µm
machined surfaces	16 µm

(2) The sonic beam angles are specified in the product-form related sections

(3) The echo amplitudes to be recorded are specified in the product-form related sections in accordance with the respective product form and its dimensions. If the admissible results are exceeded or if there is an accumulation of reflectors that are closer together than the effective probe diameter, the further procedure shall be agreed upon between the product form manufacturer and the authorized expert

(4) The sensitivity adjustment shall be carried out in accordance with the specifications in the product-form related sections. If there is no possibility of otherwise checking the probe coupling during a manual test (e g by observing the back wall echo), the gain should be increased to such a level that the background noise becomes visible. The evaluation shall be based on the prescribed adjustment of test sensitivity

3 3 8 2 2 Surface Crack Examination

(1) The average roughness R_a of the surface to be examined, as specified in DIN 4762 Part 1, should not exceed the following limits, depending on the method of surface processing:

	max. R_a
rolled or ground surfaces	20 µm
machined surfaces	10 µm

3 3 8 3 Organization of the Nondestructive Tests

3 3 8 3 1 Tests Performed by the Manufacturer

The manufacturer shall carry out and demonstrate all nondestructive tests to the extent provided for in the specifications contained in this safety standard.

3 3 8 3 2 Tests Performed by the Authorized Expert

(1) The authorized expert shall carry out, or participate in and assess the results of, the nondestructive tests to the extent provided for in the specifications contained in this safety standard

(2) With respect to surface crack examinations, the authorized expert need only participate in the examinations, generally, carried out by the manufacturer With respect to manual ultrasonic examinations, the authorized expert shall perform these examinations, independently of the examinations carried out by the manufacturer When facilities for mechanized or partially automated tests are employed, the authorized expert shall participate in random examinations and shall check the sensitivity adjustments and the procedural sequence specified in the initial material certification in accordance with Sec 2 4.

(3) If the authorized expert has participated in the nondestructive examinations carried out by the manufacturer, he will attest to this fact in the manufacturer's certificates

(4) If the authorized expert has carried out examinations of his own, he will check the manufacturer's results for compliance, considering the examination tolerances. If the results are found to comply, he will confirm this fact in the manufacturer's certificates.

(5) If essential differences are found between the results of the ultrasonic examinations carried out by the manufacturer and of those by the authorized expert, the authorized expert and the manufacturer shall jointly carry out and record additional examinations.

3.4 Repeating of Tests

(1) Any test results shall be invalid which are traced back to an improper removal or preparation of test coupons (sets of test specimens), to an improper performance of the test or to an accidental and closely limited discontinuity in a test specimen. The test in question shall be repeated

(2) If the results of a properly conducted test do not meet the requirements, the following procedure shall be used:

(a) Batch-oriented test

(aa) The item from which the non-comforming test coupons (sets of test specimens) were removed shall be eliminated from the batch In its place, two other items shall be taken from the batch and subjected to the required tests.

(ab) The test shall be considered as having passed if the results of the repeated tests meet the requirements.

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(ac) The entire batch shall be rejected if one of the results of the two repeated tests does not meet the requirements. However, each individual item of the batch may be used to check the non-conforming property

(b) Individual test

(ba) For each non-conforming test coupon (set of test specimens), two additional test coupons (sets of test specimens) to be removed from the same location shall be tested

(bb) The results of both tests must meet the requirements.

(3) If the reason for a non-conformance in a test can be eliminated by a corresponding heat treatment, this heat treatment may be repeated; the test object shall subsequently be subjected to a repeat of the test.

(4) The reasons for the insufficient result of the first test shall be investigated

3.5 Identification Marking

All product forms shall be clearly and permanently marked for identification in a way that is as notch-free as possible and such that an unambiguous allocation of the certificates issued for the material tests will be possible at any time. Further details are specified in the product-form related sections

3.6 Certification of Quality Characteristics

(1) Unless otherwise specified in the product-form related sections, the following shall be certified by Acceptance Test Certificate B in accordance with DIN 50 049:

(a) the procedure of melting,

(b) the results of the chemical analyses,

(c) the results of the hardness test,

(d) the results of the metallographic examinations,

(e) the results of the material identification tests,

(f) the heat treatment of the product forms and, if applicable, the simulation heat treatment of the test coupons, stating the temperature and the duration of heat treatment, and

(g) the complete wording of the identification marking

(2) The following shall be certified by Acceptance Test Certificate C in accordance with DIN 50 049:

(a) the results of the destructive tests,

(b) the results of the dimensional check,

(c) the result of the visual inspection of the surface.

(3) The results of the nondestructive tests carried out by the manufacturer alone or jointly with the authorized expert shall be included in Acceptance Test Certificate B in accordance with DIN 50 049.

(4) The Acceptance Test Certificates B in accordance with DIN 50 049 will be included in Acceptance Test Certificates C in accordance with DIN 50 049.

4 Plates made of Unalloyed and Alloyed Steels for Pressure-Retaining Parts

4.1 Materials and General Requirements

The steels certified in accordance with Sec. 2 shall be admissible. The requirements to be met by these steels are specified in **Appendix A 1** or in the initial material certification of the authorized expert

4.2 Additional Requirements

With the exception of the welding-on of mounting studs, if, in the course of further processing the plates are subjected to loads acting vertically to the surface of a product form, the mean fracture constriction of three single perpendicular test specimens shall amount to at least 35% with no individual value being less than 25%

4.3 Testing

4.3.1 General

With respect to plates subjected to stress-relief heat treatment in the course of further processing, the prescribed characteristics shall be demonstrated on simulation stress-relief heat treated test specimens

4.3.2 Removal of Specimens

(1) The test specimens for the product analyses shall be removed from the test coupons for the destructive tests.

(2) The test coupons for the destructive tests shall be removed in such a way that the preparation of transverse test specimens will be possible

(3) The width of the test coupons to be removed from the rolled plates shall be one-fourth of the product form section width; in the case of supplied product form lengths ≤ 7 m, the coupon shall be removed from one end face of the rolled plate, and in the case of supplied product form lengths > 7 m, from both end faces of the rolled plate. In the case of liquid tempered rolled plates, the distance between the rolled plate end face straightened for heat treatment and the test cross section of the specimens should be at least equal to one-half of the product form thickness

(4) Vertical test coupons for the demonstration of the fracture constriction shall be removed from the mid-section of the rolled plate end faces. If the removal of such test coupons is required, the test coupons which have to be removed from the same rolled plate end face for the other destructive tests may be removed from this same test coupon section.

(5) With regard to the tensile test at room temperature in the case of rolled plates with a section width ≤ 40 mm, flat test coupons of as much of the entire product form thickness as possible shall be removed; in the case of rolled plates with a section width > 40 mm, flat test specimens shall be removed only after machining the test coupons on one side down to the largest thickness capable of being tested, which should, however, be at least 40 mm

(6) With regard to the tensile test at design temperature, round test specimens having a diameter of between 10 and 20 mm shall be removed in such a way that the axes of the test specimens is located at a distance of one-fourth of the section width down from the rolled surface

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(7) With regard to the notched bar impact test in the case of rolled plates with a section width ≤ 40 mm, one side of the test specimens shall be located as closely as possible to the rolled surface; in the case of rolled plates with a section width > 40 mm, the axes of the test specimens shall be located at a distance of one-fourth of the section width down from the rolled surface.

4 3 3 Scope of the Tests

4 3 3 1 Chemical Analysis

4 3 3 1 1 Ladle Analysis

A ladle analysis shall be performed on each melt.

4 3 3 1 2 Product Analysis

A product analysis shall be performed on two rolled plates of each melt.

4 3 3 2 Destructive Tests

4 3 3 2 1 Tensile Test

(1) For each rolled plate and specimen removal location, one transverse test specimen shall be subjected to a tensile test at room temperature.

(2) One transverse test specimen for each melt and every thirty tons or any smaller quantity submitted for testing shall be subjected to a tensile test at design temperature in order to demonstrate the 0 2% proof stress. If head and tail ends are known, the test specimens should be removed from the tail end.

4 3 3 2 2 Notched Bar Impact Test

Three ISO-V specimens from each specimen removal location shall be subjected to a notched bar impact test at the lowest intended service temperature.

4 3 3 2 3 Demonstration of Upper Shelf Absorbed Energy

For each specimen removal location, three ISO-V specimens shall be tested to demonstrate that the requirement specified for the upper shelf absorbed energy is met.

4 3 3 2 4 Load Application in the Direction of Thickness

If requirements for the fracture constriction of perpendicular test specimens are specified in accordance with Sec 4.2, three perpendicular test specimens for every rolled plate shall be removed at the mid-section from one end, if possible the head end, and shall be subjected to a tensile test. The material manufacturer shall be notified of this test when placing the order.

4 3 3 3 Material Identification Test

A material identification test shall be carried out on each rolled plate or on each sheet.

4 3 3 4 Ultrasonic Examination

(1) Each plate shall be examined by the manufacturer in the as-delivery condition in accordance with SEL 072. Unless the tests are carried out on automated testing facilities, 10% of each consignment shall be subjected to an additional test by the authorized expert.

(2) An areal examination shall be adequate if carried out on the basis of a grid with an edge length of 20 cm, or on the basis of a system of straight examination lines running parallel to each other at a distance of 10 cm, or on the basis of a system of sinusoidal examination lines where the oscillation amplitude and one-half oscillation wavelength both equal, e g , 20 cm.

(3) The requirements of Class 3 in accordance with SEL 072 shall be applied.

(4) For weld areas, including the areas of double bevel groove weld connections, the specifications of Sec 5 3 3 4(2) shall be observed.

4.4 Visual Inspection and Dimensional Check

(1) All plates shall be subjected to a surface inspection and a check for dimensional accuracy in the delivery condition.

(2) Surface defects shall be removed by grinding. However, by this process the section width may not be reduced to below the analytically required value.

(3) Any removal of [surface] defects by welding requires the agreement by the authorized expert.

4.5 Identification Marking

(1) In compliance with Sec. 3.5, each plate shall be marked with the following data :

(a) manufacturer's mark,

(b) type of steel,

(c) melt number,

(d) test coupon number,

(e) authorized expert's mark.

(2) The stamp mark shall be affixed in a direction transverse to the main direction of rolling.

4.6 Certification of Quality Characteristics

The specifications of Sec. 3 6 shall be applied.

5 Workpieces Formed from Plates made of Unalloyed or Alloyed Steels and Intended for Pressure-Retaining Parts

5.1 Materials and General Requirements

The steels certified in accordance with Sec. 2 shall be admissible. The requirements to be met by these steels are specified in **Appendix A.1** or in the initial material certification of the authorized expert.

5.2 Additional Requirements

With the exception of the welding-on of mounting studs, if, in the course of further processing the workpieces are subjected to loads acting vertically to the surface of a product form, the mean fracture constriction of three single perpendicular test specimens shall amount to at least 35% with no individual value being less than 25%.

5.3 Testing

5.3.1 General

With respect to workpieces subjected to stress-relief heat treatment in the course of further processing, the prescribed characteristics shall be demonstrated on simulation stress-relief heat treated test specimens.

5 3 2 Removal of Specimens

(1) The test specimens for the product analyses shall be removed from the test coupons for the destructive tests

(2) The test coupons for the destructive tests shall be removed in such a way that the preparation of transverse test specimens will be possible In the case of heads and similar parts, deviations of up to 20° from the theoretical transverse direction shall be admissible If this requirement cannot be met, a different specimen direction shall be agreed upon with the authorized expert

(3) The width of the test coupons to be removed from the workpieces shall be equal to one-fourth of the product form section width; in the case of supplied product form lengths equal to or smaller than 4 m, the coupon shall be removed from one end face of the workpiece, and in the case of supplied product form lengths of more than 4 m, from both end faces of the workpiece In the case of liquid tempered workpieces, the distance between the workpiece end face straightened for heat treatment and the test cross section of the specimens should be at least equal to one-half of the product form thickness

(4) In the case of heads, vertical test coupons for the demonstration of the fracture constriction shall be removed from the same test coupon section from which test specimens for the other destructive test are removed In the case of segments, the respective test coupons shall be removed from the mid-section with respect to the width of the workpiece If the removal of such test coupons is required, the test coupons which have to be removed from the same workpiece end face for the other destructive tests may be removed from this same test coupon section.

(5) With regard to the tensile test at room temperature in the case of workpieces with a section width ≤ 40 mm, flat test coupons of as much of the entire product form thickness as possible shall be removed; in the case of workpieces with a section width > 40 mm, flat test specimens shall be removed only after machining the test coupons on one side down to the largest thickness capable of being tested, which should, however, be at least 40 mm If a removal of flat specimens is not possible, round test specimens having a diameter of between 10 and 20 mm shall be removed in such a way that the axes of the test specimens is located at a distance of one-fourth of the section width down from the surface of the product form In the case of product form sections which do not permit a specimen diameter of 10 mm, the largest possible diameter shall be selected

(6) With regard to the tensile test at design temperature, round test specimens having a diameter of between 10 and 20 mm shall be removed in such a way that the axes of the test specimens are located at a distance of one-fourth of the section width down from the surface of the workpiece

(7) With regard to the notched bar impact test in the case of workpieces with a section width ≤ 40 mm, one side of the test specimens shall be located as closely as possible to the [surface of the workpiece]; in the case of workpieces with a section width > 40 mm, the axes of the test specimens shall be located at a distance of one-fourth of the section width down from the surface of the workpiece

5 3 3 Scope of the Tests

5 3 3.1 Chemical Analysis

5 3 3 1 1 Ladle Analysis

A ladle analysis shall be performed on each melt

5 3 3 1 2 Product Analysis

A product analysis shall be performed on two workpieces from different rolled plates of each melt unless the chemical analysis was already demonstrated on the rolled plate

5.3.3 2 Destructive Tests

5 3 3 2 1 Tensile Test

(1) For each workpiece and specimen removal location, one transverse test specimen shall be subjected to a tensile test at room temperature

(2) One transverse test specimen each from two workpieces of every melt shall be subjected to a tensile test at design temperature in order to demonstrate the 0 2% proof stress

5 3 3 2 2 Notched Bar Impact Test

Three ISO-V specimens from each specimen removal location shall be subjected to a notched bar impact test at the lowest intended service temperature.

5 3 3 2 3 Demonstration of Upper Shelf Absorbed Energy

For each specimen removal location, three ISO-V specimens shall be tested to demonstrate that the requirement specified for the upper shelf absorbed energy is met

5 3 3 2 4 Load Application in the Direction of Thickness

If requirements for the fracture constriction of perpendicular test specimens are specified in accordance with Sec 5 2, three perpendicular test specimens for every workpiece shall be removed at the mid-section from one end face, if possible the head end, and shall be subjected to a tensile test, provided, compliance of the fracture constriction was not already demonstrated on the rolled plate The material manufacturer shall be notified of this test when placing the order

5 3 3 3 Material Identification Test

A material identification test shall be carried out on each workpiece

5 3 3 4 Ultrasonic Examination

(1) If the initial plates were not subjected to an ultrasonic examination in accordance with Sec 4 3 3 4, this examination shall be carried out on the formed workpiece

(2) The weld region shall be subjected to an ultrasonic examination Inasfar as a preparation of weld edges is necessary, the examination shall be carried out prior to this preparation The examination shall be performed and evaluated by the material manufacturer or the subsequent processor, as determined by the latter

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5.4 Visual Inspection and Dimensional Check

(1) In the delivery condition, all workpieces shall be subjected to a surface inspection and to a dimensional check for correct shape and dimensional accuracy The sectional width shall be examined at no less than 10 points evenly distributed over the workpiece

(2) Surface defects shall be removed by grinding. However, by this process the section width may not be reduced to below the analytically required value.

(3) Any removal of [surface] defects by welding requires the agreement by the authorized expert

5.5 Identification Marking

(1) In compliance with Sec 3 5, each plate shall be marked with the following data :

(a) manufacturer's mark,

(b) type of steel,

(c) melt number,

(d) test coupon number,

(e) authorized expert's mark

(2) The stamp mark shall be affixed in a direction transverse to the main direction of rolling of the initial rolled plate

5.6 Certification of Quality Characteristics

The specifications of Sec 3 6 shall be applied

6 Seamless Hollow Parts from Unalloyed and Alloyed Steels for Nozzles and Flanges

6.1 Scope

(1) This section shall apply to seamless hollow parts for nozzles, flanges and annular workpieces which are welded directly into the load-bearing walls of the containment vessel

(2) This section shall not apply to welding-neck flanges and flanges made from plates.

6.2 Materials and General Requirements

The steels certified in accordance with Sec 2 shall be admissible The requirements to be met by these steels are specified in **Appendix A 1** or in the initial material certification of the authorized expert

6.3 Additional Requirements

With the exception of the welding-on of mounting studs, if, in the course of further processing the workpieces are subjected to loads acting vertically to the surface of the workpiece (e g. through-wall nozzles), the mean fracture constriction of three single perpendicular test specimens shall amount to at least 35% with no individual value being less than 25%.

6.4 Testing

6.4 1 General

With respect to product forms subjected to stress-relief heat treatment in the course of further processing, the specified characteristics shall be demonstrated on simulation stress-relief heat treated test specimens

6 4 2 Removal of Specimens

(1) The number and location [of the test coupons] depend on the length of the hollow parts at the decisive heat treatment (normalizing, tempering), reduced by the length of the test coupons, and on the largest nominal inner diameter D_i of the finished products to be produced from the material

(2) Hollow parts with a length of ≤ 2000 mm shall be tested at one end face, namely, in the case of

(a) $D_i \geq 500$ mm at one specimen removal location,

(b) $D_i > 500$ mm to ≤ 2000 mm at two specimen removal locations offset by 180° to each other,

(c) $D_i \geq 2000$ mm at three specimen removal locations offset by 120° to each other,

(3) Hollow parts with a length > 2000 mm shall be tested at both end faces, namely, in the case of

(a) $D_i \geq 500$ mm each end face at one specimen removal location, with the specimen removal location on the opposite end face offset by 180°,

(b) $D_i > 500$ mm to ≤ 2000 mm each end face at two specimen removal locations offset by 180° to each other,

(c) $D_i > 2000$ mm each end face at three specimen removal locations offset by 120° to each other

(4) The transverse test specimens shall be removed in such a way that the axes of the test specimens are located, if possible, at a distance of one-fourth of the product form thickness below the surface and that, in the case of liquid tempered hollow parts, the cross section is located at a distance of one-half of the product form thickness from the end face

(5) In the case of a nominal inner diameter of the finished parts of less than about 200 mm, the axial test specimens may instead be removed as longitudinal test specimens which, depending on the dimensions, may also extend to the entire wall thickness

(6) With regard to the tensile test at room temperature or at design temperature, round test specimens having a diameter of between 10 and 20 mm shall be removed. In the case of a product form thickness which does not permit a specimen diameter of 10 mm, the largest possible diameter shall be selected

(7) Perpendicular test specimens for the demonstration of the fracture constriction shall be removed from the same test coupon from which the test specimens for the other destructive tests were removed.

6 4 3 Scope of the Tests

6 4 3 1 Chemical Analysis

6 4 3 1.1 Ladle Analysis

A ladle analysis shall be performed on each melt.

6 4 3 1 2 Product Analysis

A product analysis shall be performed on two separately produced hollow parts of each melt

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6 4 3 2 Destructive Tests

6 4 3 2 1 Tensile Test

(1) For each hollow part and specimen removal location, one test specimen shall be subjected to a tensile test at room temperature.

(2) Of each melt and heat treatment batch, one test specimen shall be tested at design temperature in order to demonstrate the 0 2% proof stress

6 4 3 2 2 Notched Bar Impact Test

Three ISO-V specimens from each specimen removal location shall be subjected to a notched bar impact test at the lowest intended service temperature.

6 4 3 2 3 Demonstration of Upper Shelf Absorbed Energy

For each specimen removal location, three ISO-V specimens shall be tested to demonstrate that the requirement specified for the upper shelf absorbed energy is met

6 4 3 2 4 Load Application in the Direction of Thickness

If requirements for the fracture constriction of perpendicular test specimens are specified in accordance with Sec 6 3, three perpendicular test specimens shall be removed from one end face of every hollow part, and shall be subjected to a tensile test The material manufacturer shall be notified of this test when placing the order

6 4 3 3 Material Identification Test

A material identification test shall be carried out on each workpiece

6 4 3 4 Nondestructive Tests

6 4 3 4 1 Ultrasonic Examinations

(1) Each forged hollow part or rolled ring as well as each forged (seamless) tube shall be subjected to an ultrasonic examination by the manufacturer in the delivery condition in accordance with testing group 3 in accordance with SEP 1921 All echo indications shall be recorded which correspond to a diameter of a circular reference reflector ≥ 3 mm. The indications shall not exceed the requirements of size category C In relation to the outer surface of the test specimen, the frequency of the locations of indication per square meter shall, locally, not exceed frequency category c and should not exceed frequency category d over the entire area of the test specimen In addition, an ultrasonic examination in both circumferential directions shall be carried out by means of angle beam scanning Indications obtained as a result of angle beam scanning shall not exceed the requirements in accordance with size category D in accordance with SEP 1921 If vertical beam scanning in the axial direction is not possible, it shall be substituted by two angle beam examinations in opposite direction to each other It shall be ensured in this context that the entire volume remaining in the final condition is covered up to the inner surface of the hollow part.

(2) Hollow parts of seamless tubes shall be ultrasonically examined by the manufacturer for longitudinal flaws in accordance with SEP 1915 and, if the inner diameter exceeds 133 mm, additionally, for transverse flaws in accordance with SEP 1918.

(3) Within the scope of the acceptance test, the authorized expert shall ultrasonically examine 10% of all workpieces, however, at least one workpiece

6 4 3 4 2 Surface Crack Examination

(1) The manufacturer shall subject the outer surface of each workpiece in the finished condition and, in the case of a nominal width > 50 mm, also the inner surface, to a surface crack examination to the extent possible In the case of an inner diameter < 600 mm, the surface crack examination of the inner surface shall be carried out as far as the inner surface is accessible from the end facess, at least, however, over a length that is equal to the inner diameter

(2) Within the scope of the acceptance test, the authorized expert shall ultrasonically examine 10% of all workpieces, however, at least one workpiece.

(3) In the surface crack examination, no indications are admissible from which cracks or crack-like discontinuities can be inferred Indications up to a length of 6 mm are admissible if they can be demonstrated as being caused by nonmetallic inclusions

(4) In the liquid penetrant examination, local indications are admissible if their actual extent is smaller than 1 5 mm and their image has not changed essentially after one hour of development

(5) The frequency of admissible local indications shall not exceed 10 per square decimeter In the case of larger extents or frequencies, these points shall be repaired, or the manufacturer, in agreement with the authorized expert, shall carry out investigations which will permit a decision regarding the possible use.

6.5 Visual Inspection and Dimensional Check

(1) In the delivery condition, all workpieces shall be subjected to a surface inspection and to a dimensional check for correct shape and dimensional accuracy

(2) Local surface defects of a notchlike or cracklike character shall be removed by grinding. However, by this process the section width may not be reduced to below the analytically required value The ground regions shall be subjected to a surface crack examination

(3) Any removal of [surface] defects by welding requires the agreement by the authorized expert

6.6 Identification Marking

In compliance with Sec 3 5, each plate shall be marked with the following data :

(a) manufacturer's mark,

(b) type of steel,

(c) melt number,

(d) test coupon number,

(e) authorized expert's mark

6.7 Certification of Quality Characteristics

The specifications of Sec 3 6 shall be applied.

7 Nozzles Welded from Plates of Unalloyed and Alloyed Steels

7.1 General Specifications

The manufacture of the workpieces and production weld test coupons, the surface crack examination of the weld edges, the

nondestructive testing of the workpiece welds and the nondestructive and destructive testing of the production weld test coupons as well as the certification of the results of these tests shall be carried out in accordance with the respective specifications contained in KTA 3401 3

7.2 Materials and General Requirements

The steels certified in accordance with Sec 2 shall be admissible The requirements to be met by these steels are specified in **Appendix A1** or in the initial material certification of the authorized expert

7.3 Additional Requirements

With the exception of the welding-on of mounting studs, if, in the course of further processing the workpieces are subjected to loads acting vertically to the surface of the workpiece (e g trough-wall nozzles), the mean fracture constriction of three single perpendicular test specimens shall amount to at least 35% with no individual value being less than 25%

7.4 Tests

7 4 1 General

(1) With respect to product forms subjected to stress-relief heat treatment in the course of further processing, the prescribed characteristics shall be demonstrated on simulation stress-relief heat treated test specimens

(2) The initial plates shall be tested in the heat treatment condition which results from the corresponding fabrication sequence in accordance with **Table 7-1**

7 4 2 Test of the Initial Plates

The initial plates shall be tested in accordance with Sec 4 3 taking Secs 7 3 and 7 4 1 as well as **Table 7-1** into consideration

7 4 3 Test of the Base Material

If the workpieces are subjected to the property determining heat treatment only after the machining procedures, then an additional test of the base material is required after the heat treatment (Case 2 or Case 3 **Table 7-1**).

7 4 3 1 Removal of Test Coupons

(1) The test coupons shall be removed either directly from the workpiece (specimen ring), or the test coupons shall be removed from the bent ends or cut-offs of the plate used. If test coupons are removed prior to the property determining heat treatment, it shall be assured that the test coupons are subjected to the same heat treatment The test of the base material may also be carried out within the scope of the test of the production weld test coupons which are welded from cut-offs of the plate used

(2) In the case of workpieces with only one weld which were individually subjected to the property determining heat treatment, only one test coupon is required for each workpiece In the case of workpieces with two welds, an individual test coupon for each plate is only required if the plates stem from different rolled plates

(3) If two or more workpieces in the batch are subjected to the property determining heat treatment, the test coupons shall be removed in such a way that each heat treatment batch and each rolled plate is covered by one test coupon each

(4) With the exception of the tensile test specimens for the determination of the fracture constriction, the test coupons shall be removed in the direction of thickness and transverse to the main direction of rolling and in such a way that the axis of the test coupon is located at a distance of at least one-fourth of the thickness inside from the plate surface of the product form and, in the case of liquid tempered workpieces, in such a way that the cross section to be tested is located at a distance of one-half of the thickness inside from the end face of the product form This specification shall apply analogously to the location of test coupons for the test of base materials in production weld test coupons.

(5) Round specimens with a diameter of 10 to 20 mm shall be removed for the tensile test at room temperature or design temperature In the case of a product form thickness not permitting a specimen diameter of 10 mm, the largest possible diameter shall be used.

7 4 3 2 Scope of the Tests

7 4 3 2 1 Hardness Test

If two or more workpieces are quenched and tempered in a batch, the hardness HB in accordance with DIN 50 351 shall be determined on both end faces of each workpiece at locations opposite to each other in order to verify the uniformity of hardness

Note: The uniformity of hardness is considered to have been demonstrated if the difference between the

Case	Fabrication Procedure	Testing mechanical characteristics of the finished product	Initial rolled sheet	
			delivery condition	tests
1	cold roll forming welding stress relief heat treatment	Weld connection of the production weld test coupon	normalized or quenched and tempered	Initial sheet and, in addition, simulation stress relief heat treated test coupons
2	warm roll forming heat treatment [1] welding stress relief heat treatment	Base material on the workpiece (specimen ring) or on a separate test coupon and	Case a: normalized or quenched and tempered	Case a: initial sheet and, in addition, simulation stress relief heat treated test coupons
3	cold roll forming heat treatment [1] welding stress relief heat treatment	Weld connection of the production weld test coupon	Case b: rolled condition	Case b: Simulation heat treated [1] test coupons and, in addtion, simulation stress relief heat treated test coupons
[1] Nomalizing or quenching and tempering: Procedure whereby the mechanical characteristics of the component are adjusted				

Table 7-1: Different cases for the testing of welded workpieces as a function of the fabrication sequence

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highest and the lowest measured hardness value within one and the same batch does not exceed 30 HB units.

7 4 3 2 2 Tensile Test

(1) For each test coupon removal location, a tensile test shall be performed at room temperature.

(2) One test coupon from each melt and heat treatment batch shall be tested at design temperature.

7 4 3 2 3 Notched Bar Impact Test

Three ISO-V specimens from each test coupon removal location shall be subjected to a notched bar impact test at the projected lowest thermal loading temperature.

7 4 3 2 4 Demonstration of Absorbed Upper Shelf Energy

For each test coupon removal location, three ISO-V specimens shall be used to demonstrate that the requirement for the absorbed upper shelf energy is met.

7 4 3 2 5 Load Application in the Direction of Thickness

If in accordance with Sec. 7 3 requirements for the fracture constriction of perpendicular test specimens are specified, three perpendicular test specimens from each rolled plate shall be subjected to a tensile test at room temperature. The manufacturer shall be notified accordingly when placing the order.

7 4 4 Testing the Workpiece prior to Welding the Longitudinal Seam

7 4 4 1 Material Identification Test

A test for the correct identification of materials shall be carried out on each workpiece.

7 4 4 2 Ultrasonic Examination

(1) Provided, the initial plate was already subjected to an ultrasonic examination (areal examination as well as regional examination of the edge zones of longitudinal seams, nozzle connection seams and the weld-in area where the nozzle is inserted), no further ultrasonic examination of the base material of the workpiece is required.

(2) If the initial plate was not subjected to an ultrasonic examination, the base material of each workpiece shall be subjected to an areal examination in accordance with Sec. 4.3 3 4 (1), and the edge zones (longitudinal seams, nozzle connection seams and the weld-in area where the nozzle is inserted) to a regional examination in accordance with Sec. 5 3 3.4 (2).

7.5 Visual Inspection and Dimensional Check

(1) After completion, and if necessary after the final heat treatment, all nozzles shall be subjected to a surface inspection and to a dimensional check with respect to correct shape, roundness and dimensional accuracy.

(2) Surface defects shall be removed by grinding. However, the wall thickness shall not be reduced to below the arithmetically required value in this process.

(3) A removal of [surface] defects by welding requires the consent of the authorized expert.

7.6 Identification Marking

In compliance with Sec. 3 5, each workpiece shall be marked with the following data :

(a) manufacturer's mark,

(b) type of steel,

(c) melt number,

(d) specimen number,

(e) authorized expert's mark.

7.7 Certification of Quality Characteristics

The specifications of Sec. 3 6 shall be applied.

8 Bolts and Nuts as well as Steel Rods or Bars for Bolts and Nuts

8.1 Scope

This section applies to

(a) bolts and nuts machined from quenched and tempered ferritic steel rods or bars,

(b) bolts and nuts hot formed or cold formed and subsequently quenched and tempered ferritic steel rods or bars,

(c) bolts and nuts from unalloyed and alloyed ferritic steels of the strength categories in accordance with DIN/ISO 898 Parts 1 and 2 or DIN 267 Part 4 as well as of austenitic steels of steel grades A 2 and A 4 in accordance with DIN 267 Part 11 within the limits specified in **Table 8-1**.

Note: Thread rolling is not considered as a cold forming procedure requiring another heat treatment.

8.2 Materials

8 2 1 General

The following types of steel may be used:

(a) Types Ck 35 (Material Number 1.1181) and 24 CrMo 5 (Material Number 1.7258) in accordance with DIN 17 240 with a diameter ≤ 100 mm.

(b) Ferritic steel types for bolts of strength categories 4.6, 5.6 and 8.8 in accordance with DIN/ISO 898 Part 1.

(c) Ferritic steel types for nuts of strength categories 5 and 8 in accordance with DIN/ ISO 898 Part 2 and DIN 267 Part 4.

(d) Austenitic steel types of group A2 and A4 for bolts and nuts of strength categories 50 and 70 in accordance with DIN 267 Part 11.

(e) Other steel types meeting the requirements of Sec. 2 1.

Note: Securing by welding is not admissible.

8 2 2 Additional Requirements with Respect to Materials

The ferritic steels for bolts, with the exception of the steel types in accordance with Sec. 8.1 item c, shall meet the following requirements in the notched bar impact tests on ISO-V logitudinal test specimens at room temperature:

(a) In the case of dimensions between > M 24 and ≤ M 100, the smallest individual value of lateral expansion shall be ≥ 0 6 mm

(b) In the case of dimensions > M 100, the smallest individual value of absorbed energy shall be ≥ 61 J, and the smallest individual value of lateral expansion shall be ≤ 0 6 mm

8.3 Bolts and Nuts Machined from Quenched and Tempered Ferritic Steel Rods or Bars

8 3 1 Testing of the Steel Rods or Bars

8 3.1 1 Removal of Test Specimens

(1) Test specimens shall be removed as longitudinal test specimens.

(2) The testing cross section of the tensile and notched bar impact test specimens shall be located at a distance of at least one-half of the diameter beneath the end face, and the axis of the test specimen shall be located in the middle of the rod or bar if the diameter is ≤ 40 mm and at a distance of one-sixth of the diameter below the surface if the diameter is > 40 mm

8 3.1.2 Test Lots

The rods or bars shall be tested in lots of ≤ 5000 kg consisting of rods or bars of equal dimensions and originating from one and the same melt and one and the same heat treatment batch

8 3 1 3 Extent of Testing

8 3 1 3 1 Chemical Analysis

A ladle analysis shall be carried out on each melt

8 3 1 3.2 Hardness Test

In the case of ferritic steel rods or bars, a hardness test in accordance with DIN 50 351 shall be carried out as follows:

(a) in the case of rods or bars of a diameter > 120 mm, on each rod or bar of the test lot, each with one impression at one end;

(b) in the case of rods or bars of a diameter ≤ 120 mm, on 10% of the rods or bars of the test lot, each with one impression at one end; but at least on 10 rods or bars or, if the test lot comprises less than 10 rods or bars, on each rod or bar

8.3 1 3 3 Tensile Test

One tensile test at room temperature shall be carried out each on the rod or bar with the lowest and the rod or bar with the highest hardness in accordance with Sec. 8 3 1 3 2

8.3.1 3 4 Notched Bar Impact Test

In the case of rods or bars of a diameter ≥ 14 mm, both rods or bars which are subjected to the tensile test in accordance with Sec. 8 3 1 3 3 shall be subjected to a notched bar impact test at 20 °C in order to determine the absorbed energy and the lateral expansion

8 3.1.3 5 Ultrasonic Examination

(1) All rods or bars with a diameter ≥ 30 mm intended for bolts and nuts shall be tested by the manufacturer for internal defects in the delivery condition. Within the scope of the acceptance test, the authorized expert shall test 10% of the rods or bars for bolts, but at least 10 items of each consignment, and 5% from the rods or bars for nuts, but at least 2 rods or bars of each consignment.

(2) In the case of round rods or bars, the ultrasonic examination of the rods or bars shall be carried out along two test paths offset by 90°, and in the case of hexagonal rods or bars along three test paths offset by 60°. All echo amplitudes corresponding to a circular reference reflector diameter of ≥ 1.5 mm shall be recorded. For the specification of the recording limit, a reference reflector in the form of a radial flat-bottom borehole shall be provided, with the bottom of the hole at the center of the rod or bar. The borehole should have a diameter between 4 and 6 mm. The above-mentioned test sensitivity shall be adjusted by means of a suitable gain margin.

(3) In the case of radial beam scanning, indications up to 12 dB above the recording limit and up to a length equal to the rod or bar diameter shall be admissible for rods or bars intended for bolts, and up to a length of one-half the rod or bar diameter shall be admissible for rods or bars intended for nuts. The length of the indication shall be determined by the half-amplitude method

8.3.1.3.6 Visual Inspection

Each rod or bar shall be subjected to a visual inspection with regard to its outer appearance.

8 3.1 3 7 Dimensional Check

Each rod or bar shall be examined for dimensional accuracy

8 3 1 3 8 Check of Identification Markings

Each rod or bar shall be checked for the identificattion markings as specified under Sec. 8.6 1

8.3.1 3 9 Material Identification Test

In the case of alloyed steels, each rod or bar shall be subjected to a material identification test taking the provisions of Sec. 3 3 7 5 into account.

8.3.2 Testing of Finished Parts

8 3 2 1 Surface Crack Examination

(1) Bolts and nuts shall be subjected to a surface crack examination. No indications from which cracks can be inferred are admissible. Further findings shall be evaluated in accordance with **Table 8-10**

(2) The surface crack examination shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**

8 3.2.2 Dimensional Check

(1) A dimensional check shall be performed to check the primary and secondary characteristics in accordance with **Table 8-2**. The secondary characteristics specified in **Table 8-2** may be supplemented or substituted by application-specific data in agreement with the authorized expert

(2) A dimensional check shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**.

8 3 2 3 Check of Identification Markings

The identification markings in accordance with Sec. 8 6 2 shall be checked on random samples. The size of the random sample shall

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equal the one specified in **Table 8-3** for the dimensional check of the primary characteristics. The acceptance number is zero, irrespective of the size of the random sample.

8 3 2 4 Material Identification Test

Random samples of bolts and nuts of alloyed steels shall be subjected to a material identification test, considering the provisions of Sec. 3.3 7.5. The size of the random sample is specified in **Table 8-4**. The acceptance number shall be zero, irrespective of the size of the random sample

8.4 Bolts and Nuts Hot Formed or Cold Formed from Ferritic Steel Rods or Bars Subsequently Quenched and Tempered

8 4 1 Testing

8 4 1 1 Removal of Test Coupons

(1) The tests should be carried out on the individual bolts and nuts themselves

(2) If this is not possible as a result of the dimensions of the bolts and nuts, the test specimens for the tensile and notched bar impact tests shall be removed from rod or bar cut-offs which have been turned down to the heat treatment diameter which is relevant to the tempering of the formed bolts and nuts and which have been quenched and tempered together with them. In this case, the specifications of Sec. 8 3 1.1 shall apply to the removal of test coupons

8 4 1 2 Test Lots

(1) Following the final heat treatment, the tests shall be carried out on test lots which consist of similar dimensioned parts originating from one and the same melt and one and the same heat treatment batch.

(2) The number of the items to be tested depends on the number of items in the test lot and on the testing method. The specifications of **Table 8-5** shall apply

8 4 1 3 Scope of Testing

8 4 1 3 1 Chemical Analysis

A ladle analysis shall be carried out on each melt

8 4 1 3 2 Hardness Test

(1) The [number of] bolts and nuts of each test lot as specified in **Table 8-5** shall be subjected to a hardness test in accordance with DIN 50 351

(2) The hardness shall also be determined on the bar or rod cut-offs that were quenched and tempered for tests in accordance with Secs. 8 4 1 3 3 and 8 4 1 3 4

8 4 1 3 3 Tensile Test

(1) The tensile test shall be carried out at room temperature [on the number] as specified in **Table 8-5**, i.e. in accordance with DIN/ISO 898 Part 1 in the case of turned test specimens, or in accordance with DIN 50 125 in the case of quenched and tempered rod or bar cut-offs.

(2) That part for which the lowest hardness value was determined in accordance with Sec. 8 4 1 3 2 shall be included in the test

8 4 1 3 4 Notched Bar Impact Test

(1) In the case of bolts with a dimension > M 14, a notched bar impact test shall be carried out at 20 °C in accordance with **Table 8-5** on sets of test specimens each comprising three ISO-V specimens to determine the absorbed energy; in the case of bolts > M 24, the lateral expansion shall, additionally, be determined

(2) That part for which the highest hardness value was determined in accordance with Sec. 8 4 1 3 2 shall be included in the test

8 4 1 3 5 Flaring Test

(1) The flaring test in accordance with DIN 267 Part 21 shall be carried out on [the number of] nuts as specified in **Table 8-5**

(2) That part for which the highest hardness value was determined in accordance with Sec. 8 4 1 3 2 shall be included in the test

8 4 1 3 6 Surface Crack Examination

(1) The bolts and nuts shall be subjected to a surface crack examination. No indications from which cracks can be inferred are admissible. Further findings shall be evaluated in accordance with **Table 8-10**.

(2) The surface crack examination shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**.

8 4 1 3 7 Dimensional Check

(1) A dimensional check shall be carried out in order to check the primary and the secondary characteristics in accordance with **Table 8-2**. The secondary characteristics specified in **Table 8-2** may be supplemented or substituted by application-specific data in agreement with the authorized expert

(2) The dimensional check shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**

8 4 1 3 8 Check of the Identification Marking

The identification marking in accordance with Sec. 8 6.2 shall be checked on random samples. The specifications in **Table 8-3** concerning the dimensional check of the primary characteristics shall apply to the size of the random sample. The acceptance number is zero, irrespective of the size of the random sample

8 4 1 3 9 Material Identification Test

Random samples of bolts and nuts of alloyed steels shall be subjected to a material identification test, taking the provisions of Sec. 3.3.7 5 into account. The size of the random sample is specified in **Table 8-4**. The acceptance number is zero, irrespective of the size of the random sample

8.5 Bolts and Nuts of the Strength Categories in Accordance with DIN/ISO 898 Parts 1 and 2 as well as DIN 267 Parts 4 and 11 (Table 8-1)

8 5 1 Testing

8 5 1 1 Removal of Test Specimens

(1) The tests should be carried out on the individual bolts and nuts.

(2) If this is not possible due to the dimensions of the bolts and nuts,

(a) in the case of ferritic steels, the test specimens for the tensile and notched bar impact tests shall be removed from rod or bar cut-offs which have been turned down to the heat treatment diameter of the formed bolts and nuts and which have been heat treated in the same batch as the bolts and nuts In this case, the specifications of Sec 8 3 1 1 shall apply to the removal of test coupons.

(b) in the case of austenitic steels, [the test specimens] for the tensile tests shall be produced in each test lot as correspondingly longer bolts.

8 5.1 2 Test Lots

(1) The test shall be carried out after the final heat treatment on test lots which consist of parts of similar dimensions and the same material and which have undergone the same heat treatment

(2) The number of the items to be tested shall depend on the number of items in the test lot The specifications in **Table 8-6** shall be applied.

8.5 1.3 Extent of Testing

8 5 1 3 1 Destructive Tests

(1) Bolts of ferritic steels shall, [basically], be tested in accordance with DIN/ISO 898 Part 1, Testing Program A In case the Testing Program A cannot be carried out, the tests shall be carried out in accordance with Testing Program B In the case of dimensions > M 14, a demonstration of the absorbed energy is required

(2) In the case of bolts of ferritic steels of strength category 8 8 intended for design temperatures > 50 °C, the 0 2% proof stress shall be demonstrated on test specimens in accordance with DIN 50 125.

(3) Nuts of ferritic steels shall be tested in accordance with DIN/ISO 898 Part 2 in connection with DIN 267 Part 21.

Note: The test of nuts in accordance with DIN/ISO 898 Part 2 requires the use of nuts of a nut size > 0.8 d in accordance with DIN 970 In agreement with the authorized expert, nuts of a nut size of 0 8 d in accordance with DIN 934 may also be used However, these nuts shall be tested in accordance with DIN 267 Part 4.

(4) Bolts and nuts of austenitic steels shall be tested in accordance with DIN 267 Part 11

8 5 1.3 2 Surface Evaluation

The bolts shall be tested in accordance with DIN 267 Part 19, the nuts in accordance with DIN 267 Part 20, for types of defects as specified in **Table 8-7**; the indications shall be evaluated as specified in **Table 8-10**

8 5 1 3 3 Dimensional Check

1) A dimensional check shall be carried out in order to check the primary and the secondary characteristics in accordance with **Table 8-2**. The secondary characteristics specified in **Table 8-2** may be supplemented or substituted by application-specific data in agreement with the authorized expert.

(2) The dimensional check shall be carried out on random samples The size of the random sample and the acceptance numbers are specified in **Table 8-3**

8.6 Identification Marking

8 6.1 Identification Marking of Rods or Bars

(1) In the case of rods or bars of a diameter ≤ 25 mm, the identification marking shall be affixed to labels, and in the case of a diameter > 25 mm on the actual rod or bar itself

(2) Taking Sec 3 5 into account, the rods or bars shall be marked as follows:

(a) manufacturer's mark,

(b) type of steel,

(c) melt number or acronym, if applicable,

(d) authorized expert's stamp

8 6 2 Identification Marking of Bolts and Nuts

Taking Sec 3 5 into account, bolts and nuts shall be marked as follows:

(a) manufacturer's mark,

(b) type of steel or strength category,

(c) melt number in the case of dimensions > M 52; or acronym in the case of nuts, if applicable,

(d) authorized expert's stamp in the case of bolts > M 52,

(e) in the case of bolts > M 24, with the exception of bolts made from steels in accordance with Sec. 8 5, an allocation symbol indicating the respective [test] certificate

8.7 Certification of Quality Characteristics

(1) The specifications of **Table 8-8** shall apply to the certification of quality characteristics of parts in accordance with Secs 8 3 and 8.4

(2) The specifications of **Table 8-9** shall apply to the certification of quality characteristics of parts in accordance with Sec 8 5

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Types of Steel	Product Forms	Strength Types	Limits of Application
Unalloyed and alloyed ferritic steels	Bolts	4 6, 5.6 and 8 8 in accordance with DIN/ISO 898 Part 1	≤ M 30 in the scope of application: ≤ 25 bar and ≤ 100 °C; strength type 8.8 only in connection with connecting pieces ≤ DN 500
	Nuts	5 and 8 in accordance with DIN/ISO 898 Part 2 and DIN 267 Part 4	≤ M 30 in the scope of application: ≤ 40 bar and ≤ 300 °C; strength type 8 only in connection with connecting pieces ≤ DN 500
Austenitic steels in steel group A 2 and A 4 in accordance with DIN 267 Part 11	Bolts and Nuts	50 and 70 in accordance with DIN 267 Part 11	≤ M 39

Table 8-1: Limits of application of bolts and nuts in accordance with DIN/ISO 898 Part 1 or DIN/ISO 898 Part 2 and DIN 267 Part 4 as well as DIN 267 Part 11

Primary Characteristics Limit dimensions of the thread (accuracy to guage), bearing surface during erection, transition below the bolt head, thread base radius at the transition between thread and shaft
Secondary Characteristics Lengths (bolt length, thread length), deviations in shape and length, contact surfaces, heights (bolt head height, nut height), diameters
Note: Additional characteristics and their categorization may be specified when placing the order.

Table 8-2: Characteristics to be examined during the dimensional check of bolts and nuts as well as their classification as primary and secondary characteristics

Number of Pieces per Testing Lot	Size of Random Sample				Acceptance Numbers	
	Dimensional check of the primary characteristics		Surface crack examination as well as dimensional check of the secondary characteristics		Dimensional check of the primary characteristics	Surface crack examination as well as dimensional check of the secondary characteristics
	Bolts	Nuts	Bolts	Nuts		
≤ 150	32	20	20	13	0	0
151 to 280	32	20	80	50	0	1
281 to 500	125	80	80	50	1	1
501 to 1200	125	80	125	80	1	2
1201 to 3200	200	125	200	125	2	3
3201 to 10000	315	200	315	200	3	5

Table 8-3: Size of random sample as a function of the number of items of the lot to be tested as well as acceptance numbers for the dimensional check and the surface crack examination of bolts and nuts

Number of Pieces per Testing Lot	Random Sample
≤ 150	20
151 to 280	32
281 to 500	50
501 to 1200	80
1201 to 3200	120
3201 to 10000	200

Table 8-4: Size of random sample as a function of the number of items of the lot to be tested for the material identification test

Hardness Test		Tensile Test, Notch Bar Impact Test, Flanging Test	
Number of pieces per testing lot	Number of pieces to be tested	Number of pieces per testing lot	Number of pieces to be tested
≤ 150	8		
151 to 280	13	≤ 300	1
281 to 500	20	301 to 800	2
501 to 1200	32	> 800	4
1201 to 3200	50		
3201 to 10000	80		

Table 8-5: Number of pieces to be tested as a function of the testing method and of the number of pieces per lot to be tested when carrying out the destructive tests of bolts and nuts in accordance with Sec. 8 4

Number of Pieces per Testing Lot	Number of Pieces to be Tested
≤ 800	1
801 to 1300	2
> 1300	3

Table 8-6: Number of pieces to be tested as a function of the number of items per testing lot when carrying out the destructive tests of bolts and nuts in accordance with Sec 8 5

Type of Flaw	Tests performed on the			
	Bolts		Nuts	
	ferritic	austenitic	ferritic	austenitic
hardness cracks	X	-	X	-
shear cracks	X	X	X	X
head cracks	X	X	-	-
cracks from thrust force	X	X	X	X
grooves	X	X	X	X
scars	X	X	X	X
cracks in the thread	X	X	X	X
damages (e g tool marks)	X	X	X	X
flaking	-	-	X	X
folds	X	X	X	X

Table 8-7: Flaws of bolts and nuts of ferritic and austenitic steels and tests for such flaws in accordance with Sec 8 5 1.3.2 (manifestations as in **Figure 8-1**, sketches 1 through 5; evaluation in accordance with **Table 8-10**)

Tests	Type of Test Certification in accordance with DIN 50 049					
	Rods or bars in accordance with Sec 8 3		Finished parts in accordance with Sec 8 3		Finished parts in accordance with Sec 8 4	
	Bolts	Nuts	Bolts [1]	Nuts [1]	Bolts	Nuts
Ladle Analysis	2 2 [2]	2 2 [2]	-	-	2 2 [2]	2 2 [2]
Hardness test	3 1 B	3 1 B	-	-	3 1 B	3 1 B
Tensile test	3 1 C	3 1 B	-	-	3 1 C	3 1 B
Notched bar impact test	3 1 C	3 1 B	-	-	3 1 C	-
Flanging test	-	-	-	-	-	3 1 B
Nondestructive examinations	3 1 C	3 1 B	3 1 C	3 1 B	3 1 C	3 1 B
Visual inspection	3 1 C	3 1 B	-	-	-	-
Dimensional check	3 1 B	3 1 B	3 1 B	3 1 B	3 1 C	3 1 B
Check of identification marking	3 1 C	3 1 B	3 1 C	3 1 B	3 1 C	3 1 B
Material identification check	3 1 B	3 1 B	3 1 B	3 1 B	3 1 B	3 1 B

[1] Additionally required are the test certificates for the rods or bars
[2] This certificate may also be contained in the acceptance test certificate.

Table 8-8: Survey of tests and certificates for product forms in accordance with Secs 8 3 and 8 4

Types of Steel	Product Form	Strength type	Certification
Unalloyed and alloyed ferritic steels	Bolts	4 6 and 5 6 8.8	DIN 50 049 - 3 1 B [1] DIN 50 049 - 3.1 C
	Nuts	5 and 8	DIN 50 049 - 3 1 B [1]
Austenitc steel types in the groups A 2 and A 4	Bolts and nuts	50 and 70	DIN 50 049 - 3 1 B

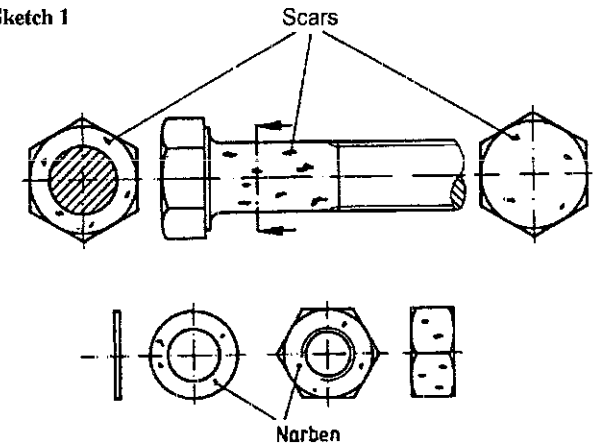
[1] An acceptance test certificate B in accordance with DIN 50 049 may be waived, provided, the manufacturer has continuously performed the tests necessary for this type of certification and keeps the test results at all times available for perusal by the authorized expert

Table 8-9: Survey of the certificates for bolts and nuts in accordance with Sec 8 5

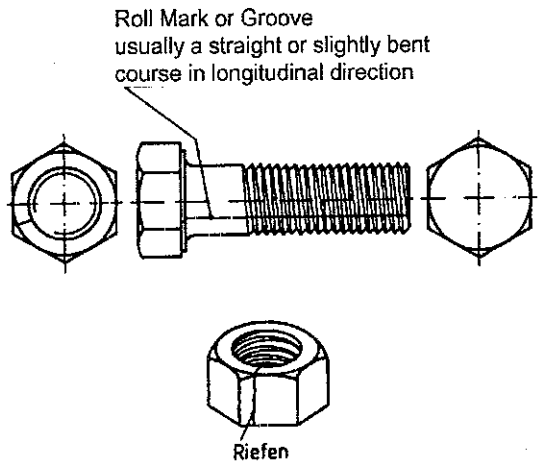
type of flaw:	Scars (shallow indentations in the surfaces)	Grooves (shallow, straight or curved indentations)	Tool Marks	Surface Flaws on the Thread	Folds	Damages
applying to :	full shank bolts, nuts	full shank bolts, nuts	full shank bolts, scant shank bolts nuts	full shank bolts, scant shank bolts	nuts	full shank bolts, scant shank bolts, nuts
appearance, location:	a) bolt shank, contact faces of the bolts and nuts b) other surfaces of the bolt head and of the nut **Figure 8-1** (sketch 1)	**Figure 8-1** (sketch 2)	**Figure 8-1** (sketch 3)	**Figure 8-1** (sketch 4)	**Figure 8-1** (sketch 5)	no definite geometric shape, location and direction that indicates the cause to be an external event
evaluation criteria:	a) **Bolts:** allowable depth ≤ 0.02 d, max. 0.25 mm; ratio of scarred surface $\leq$ 5% of contact surface **Nuts:** allowable depth ≤ 0.25 mm; ratio of scarred surface $\leq$ 5% of contact surface b) **Bolts:** allowable depth ≤ 0.03 d, max. 0.4 mm; **Nuts:** allowable depth ≤ 0.02 D, max. 0.6 mm;	**Bolts:** allowable depth ≤ 0.015 d + 0.1 mm, max. 0.4 mm, allowable width ≤ 0.13 mm; **Nuts:** allowable depth ≤ 0.3 mm, allowable width ≤ 0.02 D	**Bolts:** roughness depth (R_z) ≤ 16 µm; No tool marks are allowable in the transition between head and shank nor on the shank. **Nuts:** roughness depth (R_z) ≤ 16 µm on the contact surface	Overlaps and folds in the following locations are not allowable: - in the thread base - on the loadcarrying thread flanks The following flaws are allowable: - folds in the top land of the thread to a maximum depth of 0.25 H_1 , - not fully rolled top lands of the thread, - overlaps and folds on the non-loadcarrying thread flank, provided, they are not directed toward the outer diameter and have a depth ≤ 0.25 H_1 , [and a length of] no more than one half turn per thread	No folds are allowable that are located in the contact surface or that are directed into the contact surface.	In case of damage, the further use of the part shall be based on an individual decision. Any damage by external events shall not be detrimental to the function and use of the parts.
	D = inner diameter of thread (nuts)	d = inner diameter of thread (bolts)	R_z = mean roughness depth	H_1 in accordance with DIN 13 Part 13		

Table 8-10: Evaluation criteria for surface defects of bolts and nuts

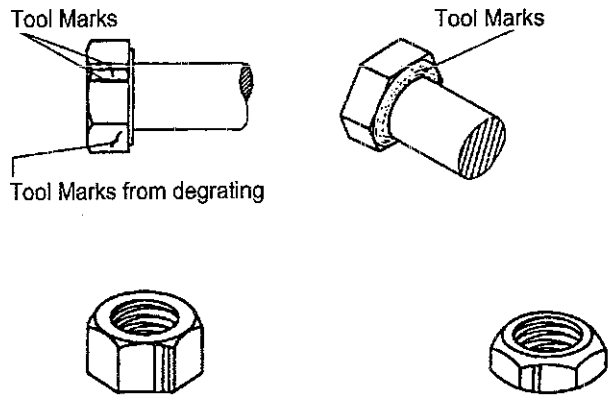
Sketch 1



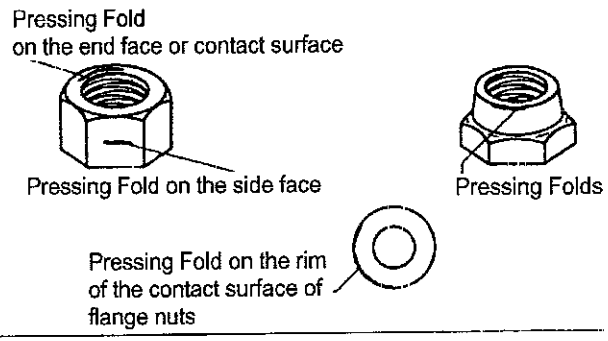
Sketch 2



Sketch 3



Sketch 4



Sketch 5

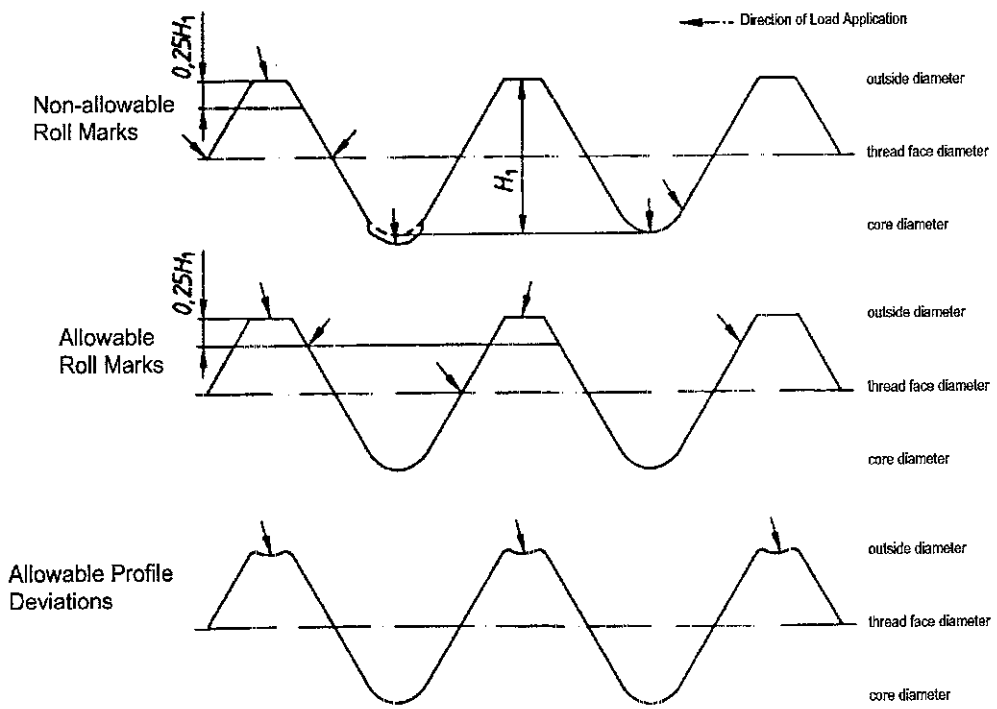


Figure 8-1: Appearance, shapes and locations of flaws in bolts and nuts

9 Rod or Bar Steel for High-Strength Bolts and Nuts as well as High-Strength Bolts and Nuts for Friction-Type Bolt Connections

9.1 Scope

This section applies to

(a) quenched and tempered rods or bars for bolts and nuts,

(b) bolts and nuts machined from quenched and tempered rods or bars,

(c) bolts made from rods or bars by hot forming of the bolt head followed by quenching and tempering,

(d) nuts made from rods or bars by hot forming followed by quenching and tempering

which will be used for friction-type bolt connections of dimensions up to M 36

9.2 Materials and General Requirements

(1) Steels certified in accordance with Sec. 2.1 shall be admissible. The requirements to be met by these steels are specified in **Appendices A2** through **A4** or in the initial material certification of the authorized expert

(2) The following shall also be admissible:

(a) steel 34 CrMo 4 (Material Number 1.7220) in accordance with DIN 17 200 for nuts as specified in Sec. 9.7 and having a relevant heat treatment diameter between > 16 mm and ≤ 40 mm and

(b) steel 42 CrMo 4 (Material Number 1.7225) in accordance with DIN 17 200 for nuts as specified in Secs. 9.5 and 9.7 and having a relevant heat treatment diameter between > 16 mm and ≤ 100 mm

9.3 Ultrasonic Examinations of the Rods or Bars

Note: Sec. 3.3.8 shall be observed

(1) All rods or bars with a diameter ≥ 30 mm intended for bolts and nuts shall be tested by the manufacturer for internal defects in the delivery condition. Within the scope of the acceptance test, the authorized expert shall test 10% of the rods or bars for bolts, but at least 10 items of each consignment, and 5% from the rods or bars for nuts, but at least 2 rods or bars of each consignment

(2) In the case of round rods or bars, the ultrasonic examination of the rods or bars shall be carried out along two test paths offset by 90°, and in the case of hexagonal rods or bars along three test paths offset by 60°. All echo amplitudes corresponding to a circular reference reflector diameter of ≥ 1.5 mm shall be recorded. For the specification of the recording limit, a reference reflector in the form of a radial flat-bottom borehole shall be provided, with the bottom of the hole at the center of the rod or bar. The borehole should have a diameter between 4 and 6 mm. The above-mentioned test sensitivity shall be adjusted by means of a suitable gain margin.

(3) In the case of radial beam scanning, indications up to 12 dB above the recording limit and up to a length equal to the rod or bar diameter shall be admissible for rods or bars intended for bolts, and up to a length of one-half the rod or bar diameter shall be admissible for rods or bars intended for nuts. The length of the indication shall be determined by the half-amplitude method

9.4 Test of Quenched and Tempered Bars for Bolts and Nuts

9.4.1 Test Lots

The test shall be carried out in the condition after final heat treatment on test lots consisting of rods or bars of the same dimension and originating from the same melt and the same heat treatment batch, with the maximum size of the test lots limited to 100 rods

9.4.2 Test Specimen Removal

(1) Logitudinal test specimens shall be used. As a function of the material used, the test specimen removal location shall depend on the specifications in **Appendices A2** through **A4** or in DIN 17 200 or in the initial material certification of the authorized expert

(2) The test specimens for the destructive test shall be removed from the hardest and the softest rod or bar (see Sec. 9.4.3.2) of each test lot

9.4.3 Extent of Testing

9.4.3.1 Chemical Analysis

(1) A ladle analysis shall be carried out on each melt.

(2) One product analysis each shall be carried out on the hardest and the softest rod or bar (see Sec. 9.4.3.2) of each test lot in order to ascertain the chemical elements specified for the respective type of steel in **Appendices A2** through **A4** or in DIN 17 200 or in the initial material certification of the authorized expert

9.4.3.2 Hardness Test

The Brinell hardness (HB 30) shall be determined on 50% of the rods or bars by one indentation each at one end

9.4.3.3 Tensile Test

(1) One test specimen shall be subjected to a tensile test at room temperature for each specimen removal location in accordance with Sec. 9.4.2.

(2) In the case of rods or bars for the manufacture of bolts, one test specimen from the specimen removal location with the lowest hardness shall be subjected to a tensile test at design temperature

9.4.3.4 Notched Bar Impact Test

(1) The absorbed energy at 20 °C shall be determined on one set of three ISO-V test specimens from the specimen removal location with the highest hardness value

(2) The notch shall be affixed in the radial direction

9.4.3.5 Flaring Test

In the case of rods or bars for the manufacture of nuts, one test specimen from the specimen removal location with the highest hardness shall be subjected to a flaring test in accordance with DIN 267 Part 21. For this purpose, the test specimen whose external dimensions shall be identical with those of the ultimate nut shall be bored to the external thread diameter

9.4.3.6 Ultrasonic Examination

The ultrasonic examination of the rods or bars after quenching and tempering shall be carried out in accordance with the specifications of Sec. 9.3

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9 4 3 7 Visual Inspection

Each rod or bar shall be subjected to a visual inspection regarding its outer condition

9 4 3 8 Dimensional Check

Each rod or bar shall be checked for its dimensional accuracy

9 4 3 9 Check of Identification Marking

The identification marking in accordance with Sec. 9.8.1 shall be checked on each rod or bar.

9 4 3.10 Material Identification Test

Each rod or bar shall be subjected to a material identification test

9.5 Testing of Bolts and Nuts Machined from Rods or Bars of Quenched and Tempered Steels

9 5 1 Testing of the Rods or Bars

Only rods or bars [tested] in accordance with Sec. 9 4 shall be used.

9 5 2 Surface Crack Examination of Bolts and Nuts

(1) The bolts and nuts shall be subjected to a surface crack examination. Any indications from which cracks can be inferred are inadmissible. Further findings shall be evaluated in accordance with **Table 8-10**.

(2) The surface crack examination shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**.

9 5 3 Dimensional Check

(1) A dimensional check shall be carried out in order to check the primary and the secondary characteristics in accordance with **Table 8-2**. The secondary characteristics specified in **Table 8-2** may be supplemented or substituted by application-specific data in agreement with the authorized expert

(2) The dimensional check shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**.

9.5.4 Check of the Identification Marking

The identification marking in accordance with Sec. 9 8.2 shall be checked on random samples. The specifications in **Table 8-3** concerning the dimensional check of the primary characteristics shall apply to the size of the random sample. The acceptance number is zero, irrespective of the size of the random sample

9.5.5 Material Identification Test

Random samples of bolts and nuts shall be subjected to a material identification test, taking the provisions of Sec. 3 3 7 5 into account. The size of the random sample is specified in **Table 8-4**. The acceptance number is zero, irrespective of the size of the random sample.

9.6 Testing of Bolts Made of Rods or Bars by Hot Forming of the Bolt Head Followed by Quenching and Tempering

9.6.1 Ultrasonic Examination of the Rods or Bars

The rods or bars shall be subjected to an ultrasonic examination in accordance with Sec. 9 3

9.6.2 Test Lots

The tests shall be carried out in the final heat treatment condition on test lots consisting of bolt blanks of the same melt and the same heat treatment batch. When applicable, an entire consignment may be defined as the test lot

9 6 3 Removal of Test Specimens

(1) In each test lot, the test specimens to be subjected to the destructive tests shall be removed from the two bolt blanks having the lowest and the highest hardness (see Sec. 9.6.4.2)

(2) The axes of the longitudinal test specimens to be tested shall be parallel to the axis of the bolt blank (cf. **Figure 9-1**).

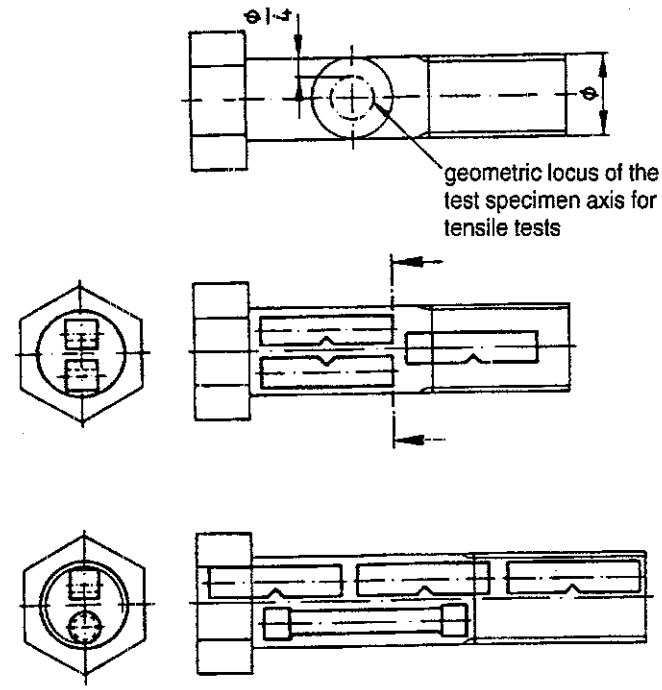

Figure 9-1: Specimen removal from bolt blanks with hot formed bolt head and subjected to subsequent quenching and tempering

9 6 4 Extent of Testing

9 6 4 1 Chemical Analysis

9 6 4 1.1 Ladle Analysis

A ladle analysis shall be carried out on each melt

9.6.4.1.2 Product Analysis

For each test lot, a product analysis shall be carried out on the bolt blanks having the lowest and the highest hardness in accordance with Sec. 9 6 4.2 in order to ascertain the chemical elements specified in **Appendices A2** through **A4** or in the initial material certification of the authorized expert.

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9 6 4 2 Hardness Test

In accordance with **Table 8-5**, the head ends of the bolt blanks of each test lot shall be subjected to a hardness test in accordance with DIN 50 351

9 6 4 3 Tensile Test

(1) Two test specimens each from two bolt blanks with the lowest and two bolt blanks with the highest hardness shall be subjected to a tensile test at room temperature

(2) One test specimen each from two bolt blanks with the lowest hardness shall be subjected to a tensile test at design temperature

9 6 4 4 Notched Bar Impact Test

(1) The absorbed energy at 20 °C shall be determined on one set of three ISO-V test specimens from the two bolt blanks with the highest hardness

(2) The notch shall be affixed in the radial direction

9 6 4 5 Surface Crack Examination

(1) The bolts shall be subjected to a surface crack examination Any indications from which cracks can be inferred are inadmissible. Further findings shall be evaluated in accordance with **Table 8-10**.

(2) The surface crack examination shall be carried out on random samples The size of the random sample and the acceptance numbers are specified in **Table 8-3**

9 6 4 6 Dimensional Check

(1) A dimensional check shall be carried out in order to check the primary and the secondary characteristics in accordance with **Table 8-2**. The secondary characteristics specified in **Table 8-2** may be supplemented or substituted by application-specific data in agreement with the authorized expert

(2) The dimensional check shall be carried out on random samples The size of the random sample and the acceptance numbers are specified in **Table 8-3**.

9 6 4 7 Check of the Identification Marking

The identification markings in accordance with Sec. 9 8 2 shall be checked on random samples The size of the random sample shall equal the one specified in **Table 8-3** for the dimensional check of the primary characteristics. The acceptance number is zero, irrespective of the size of the random sample.

9 6 4 8 Material Identification Test

Random samples of bolts shall be subjected to a material identification test. The size of the random sample is specified in **Table 8-4.** The acceptance number is zero, irrespective of the size of the random sample

9 6 4 9 Carburization State

If, after hot forming the head, the bolts are first finished, threaded and then quenched and tempered, the bolt with the lowest hardness in each test lot shall be used to determine the carburization state in accordance with Sec 8 8 of DIN/ISO 898 Part 1

9.7 Testing of Nuts Hot Formed from Bars and subsequently Quenched and Tempered

9 7 1 Ultrasonic Examination of the Bars

The bars shall be subjected to an ultrasonic examination in accordance with Sec. 9 3

9 7 2 Test Lots

At the plant of the manufacturer of the nut sections, one test coupon cut-off for every 1000 nuts per melt and heat treatment batch, but no more than four per melt, shall be removed for destructive testing; the test coupons shall be turned down to the heat treatment diameter relevant to the tempering of the hot formed nuts and shall be quenched and tempered together with the nuts

9 7 3 Removal of Test Specimens

The axes of the tensile and notched bar impact test specimens shall be identical to the axis of the test coupon

9 7 4 Extent of Testing

9 7 4 1 Chemical Analysis

9 7 4 1 1 Ladle Analysis

A ladle analysis shall be carried out for each melt

9 7 4 1 2 Product Analysis

For each test lot, a product analysis shall be carried out on the nuts with the lowest and the highest hardness in accordance with Sec. 9 7 4 2 in order to ascertain the elements specified in **Appendices A2** through **A4**, in DIN 17 200 or in the initial material certification of the authorized expert

9 7 4 2 Hardness Test

The hardness shall be tested on the test coupons in the quenched and tempered condition at three locations over the length and on the nuts in accordance with **Table 8-5** at three measuring points on the seat area offset by 120°; the hardness test shall ascertain the Vickers hardness (HV 30) by one measurement at each location

9 7 4 3 Tensile Test

One test specimen from each test coupon shall be subjected to a tensile test at room temperature.

9 7 4 4 Notched Bar Impact Test

The absorbed energy at 20 °C shall be determined on a set of three ISO-V specimens from each test coupon

9 7 4 5 Flaring Test

In accordance with **Table 8-5**, the nuts with the highest hardness in each test lot shall be subjected to flaring tests in accordance with DIN 267 Part 21

9 7 4 6 Surface Crack Examination

(1) The nuts shall be subjected to a surface crack examination Any indications from which cracks can be inferred are inadmissible. Further findings shall be evaluated in accordance with **Table 8-10**.

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(2) The surface crack examination shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**

9 7.4.7 Dimensional Check

(1) A dimensional check shall be carried out in order to check the primary and the secondary characteristics in accordance with **Table 8-2**. The secondary characteristics specified in **Table 8-2** may be supplemented or substituted by application-specific data in agreement with the authorized expert.

(2) The dimensional check shall be carried out on random samples. The size of the random sample and the acceptance numbers are specified in **Table 8-3**.

9 7.4 8 Check of the Identification Marking

The identification markings in accordance with Sec. 9 8 2 shall be checked on random samples. The size of the random sample shall equal the one specified in **Table 8-3** for the dimensional check of the primary characteristics. The acceptance number is zero, irrespective of the size of the random sample.

9 7.4 9 Material Identification Test

Random samples of nuts shall be subjected to a material identification test. The size of the random sample is specified in **Table 8-4**. The acceptance number is zero, irrespective of the size of the random sample.

9.8 Identification Marking

9 8.1 Identification Marking of Rods or Bars

(1) In the case of rods or bars of a diameter $\leq$ 25 mm, the identification marking shall be affixed to labels, and in the case of a diameter > 25 mm on the actual rod or bar itself.

(2) The identification marking shall comprise the following data:

(a) manufacturer's mark,

(b) type of steel,

(c) melt number or accronym, if applicable,

(d) authorized expert's stamp

9 8.2 Identification Marking of Bolts and Nuts

The identification marking shall comprise the following data:

(a) manufacturer's mark,

(b) type of steel,

(c) in the case of bolts > M 24, an allocation symbol indicating the respective certificate,

(d) the mark "HV".

9.9 Certification of Quality Characteristics

(1) The specifications of **Table 9-1** apply to the certification of quality characteristics.

(2) The Acceptance Test Certificates B in accordance with DIN 50 049 shall also include a statement of the heat treatment condition including heat treatment temperature and duration.

10 Flat Steel Bars for Washers as well as Washers for Friction-Type Bolt Connections

10.1 Scope

This section appplies to washers made of flat steel rods or bars that are intended for friction-type bolt connections of dimensions up to M 36.

10.2 Material and General Requirements

Steel C 45 (Material Number 1.0503) in accordance with DIN 17 200, quenched and tempered to a hardness value HV10 between 295 and 350 shall be admissible for washers up to a thickness of 7 mm.

10.3 Extent of Testing

10 3 1 Chemical Analysis

A ladle analysis shall be carried out on each melt.

10 3 2 Hardness Test

A hardness test in accordance with Vickers (HV10) shall be performed on 1% of the washers with one indentation each.

10 3 3 Dimensional Check

A dimensional check shall be performed on 1% of the washers.

10 3 4 Visual Inspection

A visual inspection shall be performed on 1% of the washers with regard to their outer condition.

10 3 5 Check of Identification Marking

A check of the identification marking shall be performed on 1% of the washers.

10.4 Identification Marking

The washers shall be marked with the symbol "HV".

10.5 Certification of Quality Characteristics

The tests carried out shall be certified by Acceptance Test Certificate B in accordance with DIN 50 049.

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Appendix A
Material Characteristics

A.1 Steel 15 MnNi 6 3 (Material Number 1.6210)

A.1.1 Scope

(1) This appendix specifies the details of the chemical composition, the characteristic mechanical and physical properties and the further processing of the steel 15 MnNi 6 3 for the following product forms:

(a) plates and workpieces formed or, if applicable, welded from such plates with a section width ≤ 150 mm in accordance with Secs. 4, 5 and 7,

(b) seamless tubes for nozzles, flanges and annular workpieces with a nominal section width ≤ 130 mm in accordance with Sec. 6,

(c) seamless forged hollow bodies or rolled rings for nozzles, flanges and annular workpieces with a nominal section width ≤ 350 mm in accordance with Sec. 6

(2) The specifications shall apply to all sections of the product forms supplied

A.1.2 Material Properties and Manufacturing Processes

(1) The material is a weldable and specially killed, fine-grained steel which is tough at subzero temperatures and meets additionally specified requirements regarding high-temperature properties

(2) The material may be manufactured in the electric arc furnace, by the electroslag remelting process or the basic oxygen process. If other processes are used, a proof of equivalency is required.

A.1.3 Delivery Condition

The material shall be delivered in a normalized or, perhaps additionallly, in a stress-relief heat treated condition, or in an equivalent condition, depending on the initial material certification (e.g. hot pressed, in the case of product forms in accordance with Sec. 5)

A.1.4 Chemical Composition

The material shall have the chemical composition specified in **Table A.1-1** with respect to the ladle analysis and the product analysis

Note: Some of the differences between the chemical composition in accordance with the ladle analysis and the product analysis, as can be inferred from the values in the table, are smaller than expected on the basis of metallurgical considerations. This is due to the fact that the limits of the chemical composition in accordance with the product analysis are based only on the melting baths covered in the initial material certification. Therefore, these limits will be reviewed as soon as further information is available.

A.1.5 Mechanical Properties

A 1.5 1 General

(1) The mechanical properties apply to the conditions following the heat treatments in accordance with Sec. A 1 7 as well as in accordance with Secs. 3 through 7.

(2) Depending on the product form concerned, the characteristics shall be demonstrated for the shapes, locations and orientations of the test specimens as specified in Secs. 4 3 2, 5 3 2, 6 4 2 or 7.4 3 1

A 1 5 2 Tensile Test at Room Temperature

The characteristics of the mechanical properties at room temperature are specified in **Table A.1-2**

A 1 5 3 Tensile Test at 145 °C

The characteristics of the mechanical properties at the test temperature of 145 °C are specified in **Table A.1-3**

A 1 5 4 Notched Bar Impact Test

The characteristics of the toughness properties are specified in **Table A 1-4**

A.1.6 Ferrite Grain Size

The characteristic number of the ferrite grain size in the delivery condition shall be ≥ 6 in accordance with European Standard 103

Note: No demonstration is required in the acceptance tests.

A.1.7 Heat Treatment

(1) Normalizing

Normalizing shall be carried out at a temperature between 880 °C and 960 °C. As soon as this temperature has been reached over the entire cross section, cooling down should be carried out in standing atmosphere.

Note: If cooling down is carried out on the furnace cart (hearth bogie?), moving air may be used, provided this requirement is met.

(2) Stress Relief Heat Treatment

Stress relief heat treatment shall be carried out at a temperature between 530 °C and 580 °C. The holding time (DIN 17 014 Part 1) shall be at least 30 minutes. If several stress-relief heat treatments are carried out in the course of manufacturing, the total holding time should not exceed 150 minutes. In case of a holding time > 90 min., the lower limit of the temperature range specified above should be aimed at. Cooling down should be carried out in standing atmosphere.

Note: If cooling down is carried out in the furnace, special attention shall be paid to make sure that compliance with the strength requirements is achieved.

(3) Heat Treatment after Cold Forming

In the case of product forms in accordance with Secs. 5 and 7, the following heat treatments are necessary, depending on the degree of forming:

Degree of Forming %	Heat Treatment Subsequently Required
≤ 2 [1]	none
> 2 to ≤ 5	stress relief heat treatment
> 5	normalizing heat treatment

[1] Depending on the production technology, the certification of the procedure may specify a special kind of heat treatment with regard to the Bauschinger efffect.

A.1.8 Forming

(1) Cold and hot forming are possible without difficulty as far as the material is concerned

Note: In the case of product forms in accordance with Sec. 6 forming is generally not used for the application purposes herein considered.

(2) For hot forming process, the material shall be heated at least to the lowest temperature specified for normalizing (880 °C). Hot forming shall be carried out in the temperature range between 750 °C and 1050 °C. Prior to the last hot forming step, or in the case of a single hot forming step, the workpiece shall not be heated above 980 °C. If hot forming is perfomed in several steps, an intermediate cooling down to below 500 °C is required prior to the last step

(3) The process shall be subjected to an initial certification by the authorized expert. The specifications in accordance with Sec. 2.1.3 of SEW 088 shall be complied with. In the case of hot forming outside the temperature range specified, and in the case of hot forming with localized heating up, it is required to normalize the entire component

A.1.9 Welding and Thermal Cutting

(1) The steel may be welded in compliance with KTA 3401.3 by the following processes:

(a) manual arc welding with coated basic welding electrodes,

(b) submerged arc welding with basic flux,

(c) tungsten inert gas welding,

(d) welding with cored wires

(2) The surveilled operating ranges for welding are specified in **Table A.1-5**. Other operating ranges for welding are admissible if a corresponding procedure qualification test in accordance with KTA 3401.3 is carried out.

(3) The specifications contained in SEW 088 shall be complied with during welding and thermal cutting.

(4) In the case of a product form thickness > 38 mm, a stress-relief heat treatment is necessary after welding. The decisive factor shall be the cross section to be joined.

(5) The content of diffusible hydrogen, determined in accordance with DIN 8572 Parts 1 and 2, should not exceed the specifications HD 5 under DIN 8572 in the case of manual arc welding and HD-7 under DIN 8572 in the case of submerged arc welding

(6) In the case of unnormalized welds, the nondestructive examination shall not be carried out in the time up to 48 hours after completion of welding.

A.1.10 Physical Properties (Characteristic Values)

The characteristic values for the physical properties are contained in **Table A.1-6**. If necessary, they shall be used as a basis for the calculation

A.1.11 Material Certification

Manufacturers with completed material certification in accordance with Sec. 2.1 are listed in VdTÜV Material Sheet 427 which specifies the product form, the manufacturing procedure, the delivery condition and the range of dimensions

Type of Proof	Mass Content in %							
	C	Si	Mn	P	S	Ni	Al_{tot}	As
Ladle Analysis [1]	0.12 to 0.18	0.15 to 0.35	1.20 to 1.65	≤ 0.015	≤ 0.015	0.50 to 0.85	0.020 to 0.055	≤ 0.015
Product Analysis	0.10 to 0.20	0.15 to 0.37	1.15 to 1.70	≤ 0.017	≤ 0.007	0.50 to 0.90	0.015 to 0.065	≤ 0.016
Type of Proof	**Mass Content in %**							
	Cr	Cu	Mo	N	Nb	Sn	Ti	V
Ladle Analysis [1]	≤ 0.015	≤ 0.06	≤ 0.05	≤ 0.015	≤ 0.004	≤ 0.010	≤ 0.020	≤ 0.020
Product Analysis	≤ 0.020	≤ 0.07	≤ 0.05	≤ 0.016	≤ 0.004	≤ 0.013	≤ 0.020	≤ 0.020
[1] Refer also to the Note in Sec. A.1.4								

Table A.1-1: Chemical composition in accordance with the ladle and the product analysis of the steel 15 MnNi 6 3

Product Form	Orientation of Test Specimen	Section Thickness of Product Form	Upper Yield Point R_{eH} [1]		Tensile Strength R_m		Elongation after Fracture A_t			Fracture Constriction Z				
			normalized	normalized and additionally stress relief heat treated	normalized	normalized and additionally stress relief heat treated	longitudinal	tangential	transverse	longitudinal	tangential	transverse	perpendicular single value	perpendicular mean value
		mm	N/mm²		N/mm²		%	%	%	%	%	%	%	%
Plates and workpieces formed or welded from plates in accordance with Secs. 4, 5 or 7	transverse	> 5 to ≤ 38	≥ 370	≥ 330	510 to 630	490 to 610	-	-	≥ 22	-	-	≥ 45	-	-
		> 38 to ≤ 50	≥ 350	≥ 330	510 to 630	490 to 610								
		> 50 to ≤ 80	≥ 330	≥ 330	490 to 610	490 to 610								
		> 80 to ≤ 100	≥ 320	≥ 320	470 to 600	470 to [600]								
		> 100 to ≤ 150	≥ 310	≥ 310	470 to 600	470 to 580								
	perpendicular	≤ 150	-	-	-	-	-	-	-	-	-	-	≥ 35	≥ 45
Seamless tubes for nozzles, flanges or ring shaped workpieces in accordance with Sec. 6	tangential or longitudinal	≤ 70	≥ 330	≥ 330	490 to 610	490 to 610	≥ 22	≥ 22	-	≥ 45	≥ 45	-	-	-
		> 70 to ≤ 130	≥ 310	≥ 310	470 to 590	470 to 590								
	perpendicular	≤ 130	-	-	-	-	-	-	-	-	-	-	≥ 35	≥ 45
Seamless forged hollow bodies and rolled rings for nozzles, flanges or ring shaped workpieces in accordance with Sec. 6	longitudinal, transverse or tangential	≤ 70	≥ 320	≥ 320	470 to 590	470 to 590	≥ 22	≥ 22	≥ 22	≥ 45	≥ 45	≥ 45	-	-
		> 70 to ≤ 100	≥ 310	≥ 310	470 to 590	470 to 590								
		> 100 to ≤ 150	≥ 300	≥ 300	470 to 590	470 to 590								
		> 150 to ≤ 250	≥ 285	≥ 285	440 to 580	440 to 580								
		> 250 to ≤ 350	≥ 275	≥ 275	440 to 580	440 to 580								
	perpendicular	≤ 350	-	-	-	-	-	-	-	-	-	-	≥ 35	≥ 45

[1] These values apply to the upper yield point, R_{eH}; if this is not strongly developed, these values shall apply to the 0.2%-proof stress, $R_{p0.2}$.

Table A.1-2: Characteristics of the mechanical properties in the tensile test at room temperature for the steel 15 MnNi 6 3 in the normalized, and in the normalized and additionally stress-relief heat treated condition

Product Form	Orientation of Test Specimen	Section Thickness of Product Form	0.2%-Proof Stress, $R_{p0.2}$		Tensile Strength, R_m	
			normalized	normalized and additionally stress relief heat treated	normalized	normalized and additionally stress relief heat treated
		mm	N/mm²		N/mm²	
Plates and workpieces formed or welded from plates in accordance with Secs. 4, 5 or 7	transverse	> 5 to ≤ 38	≥ 320	≥ 290	≥ 450	≥ 410
		> 38 to ≤ 50	≥ 320	≥ 290	≥ 450	≥ 410
		> 50 to ≤ 80	≥ 290	≥ 290	≥ 440	≥ 410
		> 80 to ≤ 100	≥ 280	≥ 280	≥ 420	≥ 410
		> 100 to ≤ 150	≥ 270	≥ 270	≥ 420	≥ 410
Seamless tubes for nozzles, flanges or ring shaped workpieces in accordance with Sec. 6	tangential or longitudinal	≤ 70	≥ 275	≥ 275	≥ 415	≥ 415
		> 70 to ≤ 130	≥ 240	≥ 240	≥ 375	≥ 375
Seamless forged hollow bodies and rolled rings for nozzles, flanges or ring shaped workpieces in accordance with Sec. 6	longitudinal, transverse and tangential	≤ 70	≥ 280	≥ 280	≥ 410	≥ 410
		> 70 to ≤ 100	≥ 270	≥ 270	≥ 410	≥ 410
		> 100 to ≤ 150	≥ 260	≥ 260	≥ 410	≥ 410
		> 150 to ≤ 250	≥ 225	≥ 225	≥ 410	≥ 410
		> 250 to ≤ 350	≥ 215	≥ 215	≥ 410	≥ 410

Table A.1-3: Characteristics of the mechanical properties in the tensile test at 145 °C for the steel 15 MnNi 6 3 in the normalized condition,and in the normalized and additionally stress-relief heat treated condition

Product Form	Orientation of Test Specimen	Section Thickness of Product Form	Absorbed Impact Energy, A_v [1], in J												Lateral Expansion, in mm	
			Mean value of three test specimens						Single value						Single value	
		mm	-20 °C	0 °C	5 °C	20 °C	30 °C	80°C	-20 °C	0 °C	5 °C	20 °C	30 °C	80 °C	-20 °C	5 °C
Plates and workpieces formed or welded from plates in accordance with Secs. 4, 5 or 7	transverse	≥ 5 to ≤ 150	≥ 80	≥ 110	≥ 130	≥ 130	≥130	≥ 130	≥ 68	≥ 90	≥ 100	≥ 100	≥ 100	≥ 100	≥ 0,9	≥ 1,3
Seamless tubes for nozzles, flanges or ring shaped workpieces in accordance with Sec. 6	tangential or longitudinal	≤ 130	≥ 80	≥ 110	≥ 130	≥ 130	≥130	≥ 130	≥ 68	≥ 90	≥ 100	≥ 100	≥ 100	≥ 100	≥ 0,9	≥ 1,3
Seamless forged hollow bodies and rolled rings for nozzles, flanges or ring shaped workpieces in accordance with Sec. 6	longitudinal, transverse or tangential	≤ 150	≥ 80	≥ 110	≥ 130	≥ 130	≥ 130	≥ 130	≥ 68	≥ 90	≥ 100	≥ 100	≥ 100	≥ 100	≥ 0,9	≥ 1,3
		> 150 to ≤ 350	≥ 70	≥ 90	≥ 110	≥ 130	≥ 130	≥ 130	≥ 56	≥ 72	≥ 88	≥ 100	≥ 100	≥ 100	≥ 0,9	≥ 1,3
[1] In the case of test specimens with a thickness < 10 mm, the requirements are reduced proportionately to the the testing cross section.																

Table A.1-4: Toughness characteristics in the notch bar impact test on ISO-V test specimens for the steel 15 MnNi 6 3

Product Form	Section Thickness of Product Form	Preheating Temperature T_V [1] Intermediate Layer Temperature T_Z [1]	Holding Temperature T_H [2]	Cooling-off Time between 800 °C and 500 °C, $t_{8/5}$	Energy per Unit Length
	mm	°C	°C	s	kJ/cm
Plates and workpieces formed or welded from plates in accordance with Secs. 4, 5 or 7	≤ 15 > 15 to ≤ 30 > 30 to ≤ 50 > 50 to ≤ 150	20 to 150 80 to 180 100 to 220 120 to 220	≥ 20 ≥ 20 ≥ 100 ≥ 120	8 to 25	to be determined in accordance with SEW 088
Seamless tubes for nozzles, flanges or ring shaped workpieces in accordance with Sec. 6	≤ 15 > 15 to ≤ 30 > 30 to ≤ 350	20 to 150 80 to 180 100 to 220	≥ 20 ≥ 20 ≥ 120	8 to 25	to be determined in accordance with SEW 088
[1] With respect to definitions, cf. DIN 1910 Part 12. [2] With respect to this definition, cf. DIN 32 524					

Table A.1-5: Verified operating range for welding of the steel 15 MnNi 6 3

Temperature	Density	Modulus of Elasticity	Heat Conductivity	Average Specific Isobaric Heat Capacity	Thermal Diffusivity	Average Thermal Linear Expansion Coefficient between 20 °C and T
T	P	E		$\overline{c_p}$	a	α
°C	kg/m³	kN/mm²	W/(m.K)	J/(kg.K)	10^{-6}m²/s	10^{-6}/K
20	7840	211	42	440	12,18	-
100	-	206	43	460	11,92	12,4
150	-	202	43	470	11,67	12,7

Table A.1-6: Characteristic values for the physical properties of the steel 15 MnNi 6 3

A.2 Steel 40 NiCrMo 8 4 (Material Number 1.6562)

A.2.1 General

This appendix specifies the details of the chemical composition, the mechanical properties and the further processing of the steel 40 NiCrMo 8 4 for the bolts and nuts in accordance with Sec. 9.

A.2.2 Material Properties and Manufacturing Processes

(1) This material is a high-strength quenched and tempered structural steel with specified minimum values of high temperature properties.

(2) The basic oxygen process and the electric-arc process may be used for melting.

(3) If other processes are used, a proof of equivalency is required.

A.2.3 Delivery Condition

(1) The material shall be delivered in the quenched and tempered condition.

(2) Materials for bolts and nuts to be manufactured by hot forming may also be delivered in the rolled or in the soft-annealed condition.

A.2.4 Chemical Composition

The material shall have the chemical composition specified in **Table A.2-1** with respect to the ladle analysis and the product analysis.

A.2.5 Mechanical Properties

A 2 5 1 General

(1) The mechanical properties apply to the quenched and tempered condition in accordance with Secs. A.2.6 and in accordance with Secs. 3 and 9.

(2) The values apply to rod or bar steel with a product form dimension ≤ 70 mm and to bolts and nuts manufactured by hot forming.

(3) The test specimens shall be removed from the rods or bars as longitudinal test specimens, with the axis at a distance of one-sixth of the diameter below the surface.

(4) In the case of bolts and nuts, the locations and orientations of the test specimens apply as specified in Sec. 9.

A 2 5 2 Tensile Test at Room Temperature

The mechanical properties at room temperature are specified in **Table A.2-2**.

A 2 5 3 Tensile Test at 145 °C

The mechanical properties at a test temperature of 145 °C are specified in **Table A.2-3**.

A 2 5 4 Notched Bar Impact Test

The characteristic values for the fracture toughness are specified in **Table A.2-4**.

A.2.6 Heat Treatment

The heat treatment conditions are specified in **Table A.2-5**.

A.2.7 Processing

(1) Only a single machining or hot forming process shall be applied.

(2) Hot forming shall be followed by quenching and tempering.

Note: Cold forming is not provided for (thread rolling is not considered to be a cold forming process).

A.2.8 Welding

This material is not suitable for welding.

A.2.9 Material Certification

Manufacturers with completed material certification in accordance with Sec. 2.1 are listed in VdTÜV Material Sheet 380 which specifies the product form, the manufacturing procedure, the delivery condition and the range of dimensions.

Type of Proof	Mass Content in %								
	C	Si	Mn	P	S	Cr	Mo	Ni	Al_{tot}
Ladle Analysis	0.37 to 0.44	0.20 to 0.35	0.70 to 0.90	≤ 0.020	≤ 0.015	0.70 to 0.95	0.30 to 0.40	1.65 to 2.00	0.005 to 0.050
Product Analysis	0.35 to 0.46	0.17 to 0.38	0.66 to 0.94	≤ 0.025	≤ 0.020	0.65 to 1.00	0.26 to 0.44	1.60 to 2.05	0.005 to 0.055

Table A.2-1: Chemical composition in accordance with the ladle and the product analysis of the steel 40 NiCrMo 8 4

Dimension of Product Form mm	Application	0.2%-Proof Stress $R_{p0.2}$ N/mm²	Tensile Strength R_m N/mm²	Elongation after Fracture A_5 %	Percentage Reduction in Area after Fracture Z %	Brinell Hardness HB30
≤ 70	Bolts	≥ 940	1040 to 1190	≥ 14	≥ 40	293 to 363
	Nuts	≥ 725	860 to 1010	≥ 15	≥ 50	248 to 311
Orientation of test specimens: longitudinal						

Table A.2-2: Mechanical properties in the tensile test and the Brinell hardness at room temperature of the steel 40 NiCrMo 8 4

Dimension of Product Form mm	Application	0.2%-Proof Stress $R_{p0.2}$ N/mm²
≤ 70	Bolts	≥ 840
Orientation of test specimens: longitudinal		

Table A.2-3: Mechanical properties in the tensile test at 145 °C of the steel 40 NiCrMo 8 4

Dimension of Product Form mm	Application	Absorbed Impact Energy A_5 Mean Value J	Absorbed Impact Energy A_5 Single Value J
≤ 70	Bolts	≥ 52	≥ 43
	Nuts	≥ 52	≥ 43
Orientation of test specimens: longitudinal			

Table A.2-4: Toughness characteristics in the notched bar impact test at 20 °C on ISO-V test specimens of the steel 40 NiCrMo 8 4

Processing Step	Holding Temperature °C for Bolts	Holding Temperature °C for Nuts	Holding Duration	Cooling Off
Hardening	840 to 860	840 to 860	-	oil or water
Annealing	550 to 600	600 to 650	≥ 6h	furnace or atmosphere

Table A.2-5: Specifications for the heat treatment of the steel 40 NiCrMo 8 4

A.3 Steel 26 NiCrMo 14 6 (Material Number 1.6958)

A.3.1 General

This appendix specifies the details of the chemical composition, the mechanical properties and the further processing of the steel 26 NiCrMo 14 6 for the bolts mentioned in Sec. 9.

A.3.2 Material Properties and Manufacturing Processes

(1) This material is a high-strength quenched and tempered structural steel with specified minimum values of high temperature strength.

(2) The electric furnace process followed by electroslag remelting may be used for melting.

(3) If other processes are used, a proof of equivalency is required.

A.3.3 Delivery Condition

(1) The material shall be delivered in the quenched and tempered condition.

(2) Materials for bolts to be manufactured by hot forming may also be delivered in the rolled or in the soft-annealed condition.

A.3.4 Chemical Composition

The material shall have the chemical composition specified in **Table A.3-1** with respect to the ladle analysis and the product analysis.

A.3.5 Mechanical Properties

A 3 5 1 General

(1) The mechanical properties apply to the quenched and tempered condition in accordance with Secs. A 2.6 and in accordance with Secs. 3 and 9.

(2) The values apply to rod or bar steel with a product form dimension ≤ 70 mm and to bolts and nuts manufactured by hot forming.

(3) The test specimens shall be removed from the rods or bars as longitudinal test specimens at a distance of D/2 below the surface in the case of diameters $D \leq 40$ mm, and with the longitudinal axis at a distance of D/6 below the surface in the case of diameters $D > 40$ mm.

(4) In the case of bolts, the locations and orientations of the test specimens apply as specified in Sec. 9.

A 3.5.2 Tensile Test at Room Temperature

The mechanical properties at room temperature are specified in **Table A.3-2**.

A.3.5.3 Tensile Test at 145 °C

The mechanical properties at a test temperature of 145 °C are specified in **Table A.3-3**.

A 3 5.4 Notched Bar Impact Test

The characteristics of the toughness properties are specified in **Table A.3-4**.

A.3.6 Heat Treatment

The heat treatment conditions are specified in **Table A.3-5**.

A.3.7 Processing

(1) Only a single machining or hot forming process shall be applied.

(2) Hot forming shall be followed by quenching and tempering.

Note: Cold forming is not provided for (thread rolling is not considered to be a cold forming process).

A.3.8 Welding

The material is not suitable for welding.

A.3.9 Material Qualification

Manufacturers with completed material certification in accordance with Sec. 2.1 are listed in VdTÜV Material Sheet 390 which specifies the product form, the manufacturing procedure, the delivery condition and the range of dimensions.

Type of Proof	Mass Content in %								
	C	Si	Mn	P	S	Cr	Mo	Ni	V
Ladle Analysis	0.25 to 0.30	≤ 0.030	0.20 to 0.50	≤ 0.020	≤ 0.015	1.2 to 1.7	0.35 to 0.55	3.3 to 3.8	≤ 0.12
Product Analysis	0.23 to 0.23	≤ 0.033	0.16 to 0.54	≤ 0.025	≤ 0.020	1.15 to 1.75	0.31 to 0.59	3.25 to 3.85	≤ 0.14

Table A.3-1: Chemical composition in accordance with the ladle and the product analysis of the steel 26 NiCrMo 14 6

Dimension of Product Form mm	0.2%-Proof Stress $R_{p0.2}$ N/mm²	Tensile Strength R_m N/mm²	Elongation after Fracture A_5 %
≤ 70	≥ 940	1040 to 1240	≥ 14
Orientation of test specimens: longitudinal			

Table A 3-2: Mechanical properties in the tensile test at room temperature of the steel 26 NiCrMo 14 6

Dimension of Product Form mm	0.2%-Proof Stress $R_{p0.2}$ N/mm²
≤ 70	≥ 865
Orientation of test specimens: longitudinal	

Table A 3-3: Mechanical properties in the tensile test at 145 °C of the steel 26 NiCrMo 14 6

Dimension of Product Form mm	Absorbed Impact Energy A_5 Mean Value J	 Single Value J
≤ 70	≥ 48	≥ 34
Orientation of test specimens: longitudinal		

Table A 3-4: Toughness characteristics in the notched bar impact test at 20 °C on ISO-V test specimens of the steel 26 NiCrMo 14 6

Processing Step	Holding Temperature °C	Holding Duration	Cooling Off
Hardening	840 to 870	-	water or oil
Annealing	530 to 580	≥ 2h	atmosphere

Table A 3-5: Specifications for the heat treatment of the steel 26 NiCrMo 14 6

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A.4 Steel 20 NiCrMo 14 5 (Material Number 1.6772)

A.4.1 General

This appendix specifies the chemical composition, the mechanical properties and the further processing of the steel 20 NiCrMo 14 5 for the bolts mentioned in Sec 9.

A.4.2 Material Properties and Manufacturing Processes

(1) The material is a high-strength rolling and forging steel with specified minimum values of high temperature strength.

(2) The electric furnace process may be used for melting.

(3) If other processes are used, a proof of equivalency is required.

A.4.3 Delivery Condition

(1) The material shall be delivered in the quenched and tempered condition.

(2) Materials for bolts to be manufactured by hot forming may also be delivered in the rolled or in the soft-annealed condition.

A.4.4 Chemical Composition

The chemical composition of the material is specified in **Table A.4-1** with respect to the ladle analysis and the product analysis.

A.4.5 Mechanical Properties

A.4.5.1 General

(1) The mechanical properties apply to the tempered condition in accordance with Sec. A 4.6 and in accordance with Secs 3 and 9.

(2) The values shall apply to rod or bar steel with product form dimensions ≤ 70 mm and to bolts manufactured by hot forming.

(3) The test specimens shall be removed from the rods or bars as longitudinal test specimens at a distance of D/2 below the surface in the case of diameters $D \leq 40$ mm, and with the longitudinal axis at a distance of D/6 below the surface in the case of diameters $D > 40$ mm.

(4) In the case of bolts, the locations and orientations of the test specimens apply as specified in Sec. 9.

A.4.5.2 Tensile Test at Room Temperature

The mechanical properties at room temperature are specified in **Table A.4-2**.

A.4.5.3 Tensile Test at 145 °C

The mechanical properties at a test temperature of 145 °C are specified in **Table A.4-3**.

A.4.5.4 Notched Bar Impact Test

The characteristics of the toughness properties are specified in **Table A.4-4**.

A.4.6 Heat Treatment

The heat treatment conditions are contained in **Table A.4-5**.

A.4.7 Processing

(1) Only a single machining or hot forming process shall be applied.

(2) Hot forming shall be followed by quenching and tempering.

Note: Cold forming is not provided for (thread rolling is not considered to be a cold forming process).

A.4.8 Welding

The material is not suitable for welding.

A.4.9 Material Qualification

Manufacturers with completed material certification in accordance with Sec. 2.1 are listed in VdTÜV Material Sheet 337 which specifies the product form, the manufacturing procedure, the delivery condition and the range of dimensions.

Type of Proof	Mass Content in %							
	C	Si	Mn	P	S	Cr	Mo	Ni
Ladle Analysis	0.18 to 0.25	0.15 to 0.40	0.30 to 0.50	≤ 0.020	≤ 0.010	1.20 to 1.50	0.25 to 0.50	3.40 to 4.00
Product Analysis	0.16 to 0.27	0.10 to 0.45	0.26 to 0.54	≤ 0.025	≤ 0.015	1.15 to 1.55	0.20 to 0.55	3.30 to 4.10

Table A.4-1: Chemical composition in accordance with the ladle and the product analysis of the steel 20 NiCrMo 14 5

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Dimension of Product Form	0.2%-Proof Stress	Tensile Strength	Elongation after Fracture	Percentage Reduction in Area after Fracture
mm	$R_{p0.2}$ N/mm²	R_m N/mm²	A_5 %	Z %
≤ 70	≥ 940	1040 to 1240	≥ 14	≥ 55
Orientation of test specimens: longitudinal				

Table A.4-2: Mechanical properties in the tensile test at room temperature of the steel 20 NiCrMo 14 5

Dimension of Product Form	0.2%-Proof Stress
mm	$R_{p0.2}$ N/mm²
≤ 70	≥ 865
Orientation of test specimens: longitudinal	

Table A.4-3: Mechanical properties in the tensile test at 145 °C of the steel 20 NiCrMo 14 5

Dimension of Product Form	Absorbed Impact Energy A_5		Lateral Expansion
	Mean Value	Single Value	Single Value
mm	J	J	mm
≤ 70	≥ 75	≥ 61	≥ 0.6
Orientation of test specimens: longitudinal			

Table A.4-4: Toughness characteristics in the notched bar impact test at 20 °C on ISO-V test specimens of the steel 20 NiCrMo 14 5

Processing Step	Holding Temperature °C	Cooling Off
Hardening	830 to 900	water or oil
Annealing	520 to 600	-

Table A.4-5: Specifications for the heat treatment of the steel 20 NiCrMo 14 5

KTA 3401.1

Appendix B

Procedure of Manual Ultrasonic Examinations

Note: The standard DIN 54 125 on the procedure of manual ultrasonic examinations is in preparation.

B.1 Scope

(1) This appendix describes the procedure of performing manual ultrasonic examinations.

(2) Requirements are specified for adjusting the systems for performing examinations by the pulse echo method in reflection or through transmission and for describing the indications

B.2 Definitions, Nomenclature, Equations

B.2.1 Definitions

The definitions in accordance with DIN 54 119 apply.

B.2.2 Nomenclature

In this appendix, the following nomenclature is used:

Nomenclature	Physical Quantity or Term	Units
A	near-field sonic path in the general DGS diagram	-
a, a'	projected lengths	mm
DGS	distance / gain / size	-
C	sonic beam width, with respect to 20 dB echo decrease	mm
D_0	vibrator diameter	mm
D_{eff}	effective diameter of vibrator	mm
D_k	diameter of spherical bottom bore hole	mm
D_{CRR}	diameter of circular reference reflector	mm
D_Z	diameter of cylindrical bore hole	mm
D_S	sonic beam diameter with respect to 6 dB echo decrease	mm
d	curvature diameter of test object	mm
d_{ref}	curvature diameter of back wall	mm
f	band width (difference between upper and lower limit frequency) with respect to 3 dB decrease	MHz
f_N	nominal frequency	MHz
G	ratio of vibrator diameter to reflector diamter	-
G_K	equipment amplification for the adjustment at which the reference reflector indication is equal to the nominal CRT height	dB
G_T	equipment amplification for the adjustment at which the through transmission indication is equal to the nominal CRT height	dB
$\overline{G}_T$	arithmetic average of the G_T values	dB
G_R	equipment amplification for the recording limit	dB
γ_6	opening angle of the 6 dB limit	degree
H	ratio of echo amplitude to CRT height	-
K1	calibration block in accordance with DIN 54 120	-
K2	calibration block in accordance with DIN 54 122	-
κ	sonic attenuation coefficient (in deviation to DIN 54 119: sonic attenuation relative to sonic path)	dB/m
L	search unit length in direction of curvature	mm
λ	ultrasonic wave length	mm
N	near-field length	mm
n	number of individual measurements	-
p	projected skip distance [of V path]	mm
R_a	mean roughness value in accordance with DIN 4768 Part 1	µm
R_L	recorded length	mm
R_{LK}	corrected recorded length	mm
S	sonic path (distance between vibrator and reflector	mm
SE	sender - receiver [SE search unit = dual search unit]	-
s	wall or sectionthickness	mm
s_j	thickness of the calibration block	mm
V	amplification in the general DGS diagram	dB
ΔV	sonic attenuation correction for a specific sonic path	dB
ΔV_{coupl}	coupling correction	dB
ΔV_S	divergence correction of the back wall echo curve	dB
$\Delta V_\sim$	amplification correction with respect to transfer fluctuation	dB
ΔV_T	transfer correction	dB

B.2.3 Equations

The physical quantities shall be calculated in accordance with the following equations:

a) The sonic beam width with respect to 20 dB echo decrease:

$$C = 2 \cdot \lambda \cdot \frac{S}{D_0} \qquad \text{(B-1)}$$

b) Conversion of transverse bore hole echo amplitude into circular reference reflector amplitude:

$$D_{CRR} = \sqrt{\frac{\sqrt{2}}{\pi} \cdot \lambda \cdot \sqrt{D_Z \cdot S}} \qquad \text{(B-2)}$$

where $S > 0.7\,N$ and $D_z > 1.5\,\lambda$

c) Conversion of sperical bottom bore hole echo amplitude into circular reference reflector amplitude:

$$D_{CRR} = \sqrt{\frac{\lambda}{\pi} \cdot D_k} \qquad \text{(B-3)}$$

where $S > 0.7\,N$ and $D_z > 1.5\,\lambda$

d) The sonic beam diameter with respect to 6 dB echo decrease:

$$D_S = 2 \tan \gamma_6 \qquad \text{(B-4)}$$

e) Arithmetic average of the equipment amplification:

$$\overline{G}_I = \frac{\sum G_I}{n} = \frac{\text{sum of individual values}}{\text{number of indivual values}} \qquad \text{(B-5)}$$

f) Corrected recorded length:

$$R_{LC} = R_L - D_S \ (1 - D_S/R_L) \qquad \text{(B-6)}$$

g) Sonic path without side-wall effects:

$$S = s \cdot D_{eff}/(2 \cdot \lambda) \qquad \text{(B-7)}$$

h) Amplification correction:

$$\Delta V = 1\,7\sqrt{\frac{\sum G_T^2 - \frac{1}{n}(\sum G_T)^2}{n-1}} \qquad \text{(B-8)}$$

or

$$\Delta V = 1\,7\sqrt{\frac{\sum (G_T - \bar{G}_T)^2}{n-1}} \qquad \text{(B-9)}$$

B.3 General Requirements

B.3.1 Examination Procedure

(1) The similar coupling medium shall be used in performing the adjusting and the examination. Only such coupling media shall be used that do not damage the test object (e.g. corrosion). After the examination any residues from the coupling medium shall be removed from the test object.

(2) Test object, calibration block and sonic search unit should all be at about the same temperature

(3) During sensitivity adjustment and during the examination only the amplification and no other control device may be changed that would influence the echo amplitude (e.g. frequency, pulse strength, resolution, threshold level). A threshold level may only be used in exceptional, well founded cases.

(4) Before starting with the examination, the sensitivity and distance adjustments shall be performed following the warm up procedure specified by the equipment manufacturer. Both adjustments shall be repeated in adequate time intervals. If significant differences with respect to the former adjustment are encountered, all examinations performed in the interim shall be repeated with the new settings

(5) The nominal frequency should lie in the range between 1 and 16 MHz. Nominal frequency and search unit dimension for the examination shall be chosen on the basis of, both, the required measurement sensitivity (recording limit) for the volumetric region to be examined and the geometry of the component (sonic path). Generally, a frequency of 4 MHz shall be used for a wall thickness $\leq$ 40 mm and 2 MHz for a wall thickness > 40 mm.

(6) When examining from curved test surfaces, the search unit should be mounted centrally to the exit region of the sonic signal. The gap between the search unit base and the test surface should at no point exceed 0 5 mm. If the distance is larger, the base of the search unit shall be ground to fit accordingly. This is the case if $L^2 > 2d$.

(7) The use of technical devices for determining the echo amplitude (e.g. detachable scales) is allowed, provided, the evaluation is performed in accordance with Sec. B 4.

B.3.2 Test Equipment

(1) The test equipment and the technical aids including the required auxiliary equipment shall have an accuracy and stability as is required for the intended application.

(2) A combination of equipment, cables and sonic probes of different manufacturers is allowed, provided it is ensured (e.g. by measurements on calibration blocks) that the accuracy of the results is not detrimentally affected

B.3.3 Test Object

(1) The test surfaces shall be free of roughness and of impurities (e.g. rust, scales, weld spatter, machining grooves), both to an extent that the examination is not disturbed

(2) If the back wall is used as a reflecting surface then it shall meet the same requirements as the test surface.

(3) The waviness of the test surfaces shall be so small that a sufficient contact with the sonic search unit base is achieved. This is usually the case if the distance between search unit base and test surface is nowhere more than 0 5 mm.

B.3.4 Calibration Blocks and Reference Reflectors

(1) In the case that the calibration block and the test object are of different materials, the difference in sonic velocities shall be considered in the distance adjustment and, in case of angle-beam examination, in determining the angular deviation

(2) If the calibration blocks K1 or K2 are not used for the adjustment then the following applies

a) to the calibration block:

aa) There shall, basically, be no hindrance to the forming of the sonic beam, i.e, for sonic paths up to 2 N all dimensions perpendicular to the main beam should be larger than the size of the vibrator and, for sonic paths beyond 2 N, larger than the sonic beam width C

ab) The dimensions of the coupling surface should be larger than 1.5 times the effective dimension of the sonic search unit base.

ac) The location of the reference reflectors in the calibration block shall be chosen such that the adjustment echoes do not interfere with each other and cannot be mistaken for edge echoes

ad) The calibration block shall only be clad welded if the acoustic characteristics of the cladding on the test object cannot be taken into consideration any other way

b) to the reference reflector:

ba) The back walls should be plane and be perpendicularly oriented to the main beam and should have a size that is larger than the sonic beam width C, however not smaller than the size of the vibrator.

bb) Transverse bore holes should run perpendicular to the main beam and parallel to the coupling surface. The length of the transverse should be larger than the sonic beam width C, however, not smaller than the size of the vibrator

bc) In the case of the single search unit technology, the base of flat bottom bore holes should run parallel to the main beam

bd) Spherical bottom bore holes should be oriented such that the directions of the length axis of the bore hole and of the main sonic beam deviate as little as possible from each other

be) Rectangular grooves should be perpendicular (transverse) to the main sonic beam and the groove flank should be perpendicular to the test surface. The groove should have a rectangular cross section with a width $\leq$ 1 0 mm and, unless product form related specifications state otherwise, a depth of 1 0 mm. The length of rectangular grooves should be larger than the sonic beam width C, however, not smaller than the size of the sonic vibrator

bf) In case the echo amplitudes from transverse and spherical bottom bore holes shall be transformed into echo amplitudes of circular reference reflectors, the equations B-8 and B9 shall, additionally, be taken into consideration

B.4 Adjusting the Sonic Examination System

B.4.1 Distance Adjustment

(1) The distance adjustment should be performed on the test object, on the calibration blocks K1 or K2 or on calibration blocks similar in type.

(2) In the case of longitudinal wave angle beam search units a calibration block (e.g. as shown in **Figure B-1**) should be used

Note: This is necessary because of the transverse wave portion occurring when using a different beaming angle.

(3) The following two procedures are allowed:

a) Distance adjustment with a straight-beam sonic search unit on the test object or on the calibration block with a subsequent zero-adjustment with an angle-beam sonic search unit (leading distance).

b) Adjustment on the basis of two far apart bore holes

(4) In each case the straight-beam sonic search unit should be preadjusted on the calibration blocks K1 or K2.

B.4.2 Application of the DGS Method

B.4.2.1 Criteria for Applying the DGS Method

The following criteria apply:

a) Echoes may not be influenced by the initial sonic pulse

b) The sonic path for evaluation begins at S = 0.7 N for single vibrator search units and at the start of the focussing range for dual search units.

c) In case of a side-wall influence, the DGS method may only be used up to a sonic path as specified under Sec. B.2.3 g).

d) The DGS method with angular beaming may only be used for a wall thickness > 5 λ.

e) If a DGS diagram specific to the search unit is not available, the required special diagram may be derived for the corresponding search unit from the general diagram (**Figure B-2**), provided, information is available regarding the near-field length.

f) In the case of highly damped sonic search units, the DGS method may only be employed if the ratio of bandwith (Δf) to nominal frequency is less than 0.75

g) The DGS method should not be used with dual longitudinal wave, angle-beam search units

h) In the case of curved test surfaces, the requirements specified in **Table B-1** shall be met when employing the DGS method. If the sonic search units must be adapted in accordance with Sec. B.3.1(7), then the DGS method may only be employed if, in addition to the requirements specified in **Table B-1**, transverse, flat-bottom or spherical-bottom bore holes in the test object or in a reference block (maximum diameter and thickness deviation 10 %) are used as reference reflectors

B4.2.2 Required Reference Reflectors

(1) In case no back wall echoes can be created from the test object, the following reflectors should be used to create the refence echoes:

a) calibration block K1 with a thickness of 25 mm and calibration block K2 with a thickness of 12.5 mm.

b) calibration block K1 with a circular arc of 100 mm and calibration block K2 with a circular arc of 25 mm if the correction factors specific to the sonic search unit (i.e., the difference between the echo indication from a circular arc and that from a plane back wall) are known or have been determined.

c) transverse, flat-bottom or spherical-bottom bore holes

(2) The conversion of the echo amplitude from a transverse or spherical-bottom bore hole to that of a circular reference reflector shall be performed with equations B-2 and B-3

B.4.3 Sensitivity Adjustment for the Reference Echo and the Reference Line Method

(1) With the reference echo method, the indication from the test object is directly compared with the indication from a reference reflector at about the same sonic path. This may be carried out with reference reflectors in the test object or in reference blocks.

(2) The comparison should be carried out with the reference reflector of the same or next larger sonic path. By way of exception (e.g. the reflector is close to the back wall surface), the reference reflector may be a maximum of 20 % of the wall thickness, however, no more than 20 mm, away from the back wall surface.

(3) To simplify the description of the echo amplitude, it is recommended to create a reference line with the aid of a number of similar reflectors at different depths in reference blocks (e.g. a stepped wedge or in accordance with **Figure B-1**) or with the aid of reference reflectors in the test object at different distances. With respect to the reference blocks the requirements under Sec. B.3.4 b) apply.

(4) After having conducted the distance adjustment, the reference line shall be created from at least three echo indications of the reference reflectors (e.g. transverse bore holes) in different positions (cf. **Figure B-3**). The echo closest to the sonic search unit should be adjusted to be at about 80 % of the CRT height. The resulting reference line may be extrapolated to a maximum of 20 % beyond the distance range as defined by the reference reflectors. The amplification of the equipment shall be adjusted such that the reference line lies at between 20 % and 80 % of the CRT height. If this is not possible over the entire adjustment range, then the amplification shall be adjusted in accordance with **Figure B-4**.

B.4.4 Corrections of the Sensitivity Adjustment

B.4.4.1 Transfer Correction

(1) The transfer correction should be determined for at least four locations of the test object in the corresponding beaming direction.

(2) The transfer correction should be determined by through transmission in accordance with **Figure B-5** on the calibration block and on the test object

(3) In order to take a general transfer correction into account for the angle-beam examination, the ΔV_T from the V-type through transmission should be used.

B.4.4.2 Sonic Wave Attenuation Corection

(1) The sonic wave attenuation should be determined in accordance with **Figure B-6** for the straight-beam examination and in accordance with **Figure B-7** for the angle-beam examination, both under consideration of ΔV_T.

(2) The individual determination of the sonic wave attenuation may be waived, provided it is included in a constant margin that is applied independently of the sonic path (e.g. the general transfer correction).

B.4.4.3 Coupling and Wave Attenuation Variance

(1) A transfer correction shall be applied that shall be determined as the average of the through transmission values on the test object, provided the range of variance is ≤ 6 dB. In case of a variance range larger than 6 dB, the transfer correction shall be determined as the average value of 20 trough transmissions plus the value of $\Delta V^{-} = 1.7$ x standard deviation in accordance with Sec. B.2.3 h)

(2) If the value determined for ΔV^{-} is larger than 6 dB then the test object shall be divided into examination sections for each of which the transfer correction shall be individually applied. The sections shall be chosen such that for each one $\Delta V^{-} \leq 6$ dB.

B.4.4.4 Consideration of Corrections

(1) Under consideration of the sensitivity corrections specified above, the resulting equipment sensitivity for the recordable limit calculates as follows:

$$G_R = G_K + \Delta V + \Delta V_T + \Delta V^{-} \qquad \text{(B-10)}$$

where

$$\Delta V_T = \Delta V_{coupl} + \Delta V_K \qquad \text{(B-11)}$$

(2) If the sonic wave attenuation is considered as dependent on the sonic path then the attenuation component ΔV_K contained in ΔV_T shall be determined in accordance with **Figure B-8** for the DGS method and in accordance with **Figure B-9** for the reference line method.

(3) If a sonic path dependency of the wave attenuation is not required then ΔV_T shall contain a constant wave attenuation component ΔV_K that is independent of the sonic path.

(4) If an additional correction is required to account for larger variations in accordance with Sec. B.4.4.4.3, this shall be considered by the factor ΔV^{-}. Otherwise this correction factor shall be dropped from the above equation.

B.4.5 Adjustment of Equipment Amplification

The equipment amplification shall be adjusted such that, under consideration of the coupling and attenuation losses, the registration limit lies at least at 20 % of the CRT height within the individual adjustment range.

B.5 Description of the Displays

B.5.1 Echo Amplitude

The maximum echo amplitude of a reflector location shall be specified in dB relative to the applicable registration limit.

Note: The reproducibility of the determination of the echo amplitude is, generally, ± 3 dB

B.5.2 Reflector Size

B.5.2.1 General Requirements

Registration lengths ≥ 10 mm shall be determined by more exact measurements. The determined length shall be rounded up or down and specified as whole digit multiples of 5 mm (e.g. 10, 15, 20). Shorter registration lengths shall be documented as "< 10".

B.5.2.2 Determination of the Registration Length

The size of a reflector (cf. **Figure B-10**) shall be documented as the distance of search unit movement. This distance is determined as the distance between locations where the echo amplitude is lower than the registration limit either by 0 dB, 6 dB or 12 dB. If the noise limit is reached in this procedure, the registration length shall be documented as the distance between the points where the signal disappears in the noise level.

B.5.2.3 Determination of the Half-Value and Quarter-Value Lengths

When determining the half-value and quarter-value lengths of a reflector the distance between search unit locations where the echo amplitude is 6 dB or 12 dB, respectively, below the maximum echo amplitude shall be documented. The separation plane in the case of dual search units, and the line focus in the case of line focussing search units, shall be oriented perpendicularly to the largest length of the refelector for this measurement.

B.5.2.4 Methods for the Exact Determination of the Reflector Size

(1) The determination of the reflector size shall be optimized by one of the following additional corrections or examinations, provided, this measurement alone is decisive for an evaluation of the admissibility of an indication.

(2) The reflector size shall be determined from that beaming location or with that beaming angle where the sonic path is as close as possible to 1.0 times the near-field length but is larger than 0.7 times the near-field length. Hereby, a different frequency may be used than the one for determining the maximum echo amplitude.

(3) The sonic beam diameter shall be determined at the location of the reflector. If the measured length [of the reflector] is larger than this sonic beam diameter then the registration length shall be the one corrected in accordance with equation B-6.

(4) The sonic beam diameter shall be determined either analytically or experimentally. The analytical determination may be performed using equation B-4, unless fitted search units are used.

(5) In the case of an angular beaming, the opening angle of the beam shall be entered as γ_6. The opening angle shall be determined from the data sheets of the search units used.

(6) If the opening angle must be determined experimentally, the measurements shall be performed on a reference block corresponding to the test object.

(7) For this purpose, reference reflectors shall be inserted into the reference block at the same depth as the indication that is to be corrected. A suited reference reflector is a cylindrical bore hole or flat-bottom bore hole with a 3 mm diameter or spherical-bottom bore hole with a diameter larger than $1.5\,\lambda$.

(8) The half-value length shall be determined on the reference block for the similar sonic path as for the reflector to be corected. The measure thus determined corresponds to the sonic beam diameter at the respective indicator depth.

(9) Using suitable dual search units or focussing search units, the reflector size shall be determined within the focussing range and shall be evaluated as follows:

a) If the measured difference between quarter-value length and half-value length is ≤ 1.5 times the sonic beam diameter, then the half-value length shall be applied as the reflector length.

b) If the measured difference between quarter-value length and half-value length is > 1.5 times the sonic beam diameter, then the quarter-value length minus the sonic beam diameter shall be applied as the reflector length.

c) If the half-value length is smaller than the sonic beam diameter then the sonic beam diameter or the focussing width at the corresponding depth shall be applied as the reflector length.

(10) When determining the size with focussing search units, a number of echo dynamics shall be evaluated for the individual testing grid in order to increase the measurement accuracy and reproducibility. The distance between grid points should be smaller than the diameter of the focus tunnel. A typical experimental arrangement for the evaluation of echo dynamics is shown in **Figure B-11**.

B.5.2.5 Determining the Depth Extension

Note: Corresponding specifications are in preparation in conjunction with KTA 3201.1

B.5.3 Shape Accountable Indications

(1) If indications inside the root of a weld seam shall be categorized as accountable to shape, control measurements are required to verify the cause of the indications.

(2) If it shall be demonstrated that the echoes from either side of the weld seam originate from the root reinforcement and not from the weld seam region, this demonstration may be performed on the test object by determining the projected distances. The exact determination of the projected distances shall be performed with rectangular grooves 1 mm wide and 1 mm deep in reference blocks (cf. **Figure B-12**). If the result shows that the projected distances of the corresponding indications clearly overlap (i.e., $2a\text{-}a' \geq 2$ mm) then the echo indications may be categorized as shape-accountable. If the distance [overlap] is less than 2 mm, the reflector locations may not anymore be treated as separate from each other.

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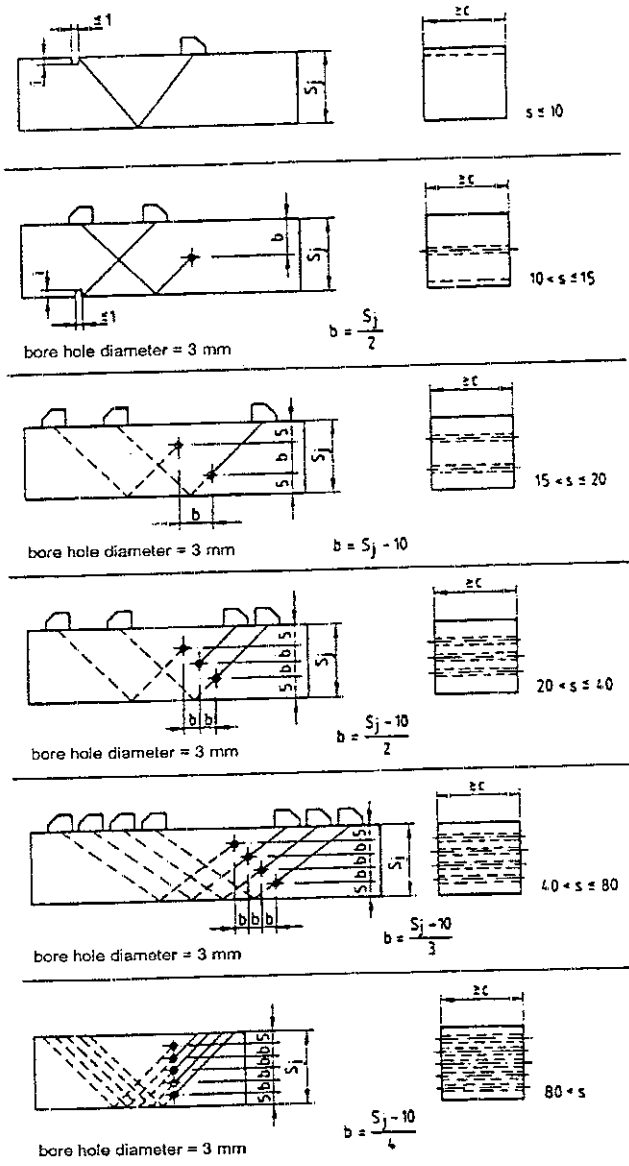
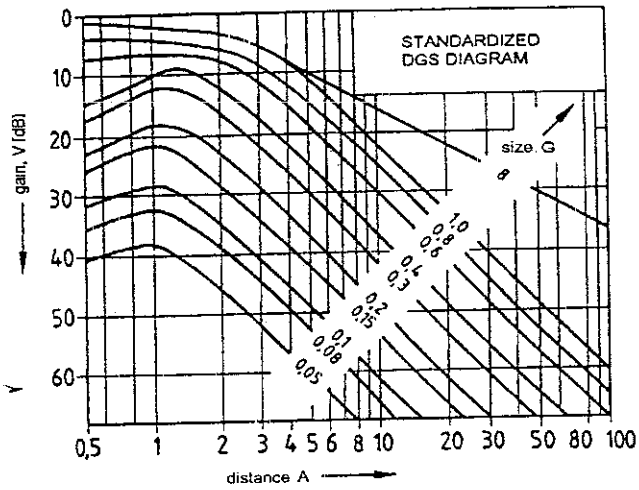


Figure B-1: Reference bodies for the sensitivity adjustments of the angle beam examination



$$A = \frac{s}{N}$$

$$G = \frac{D_{CSR}}{D_{eff}}$$

Figure B-2: Standardized DGS diagram

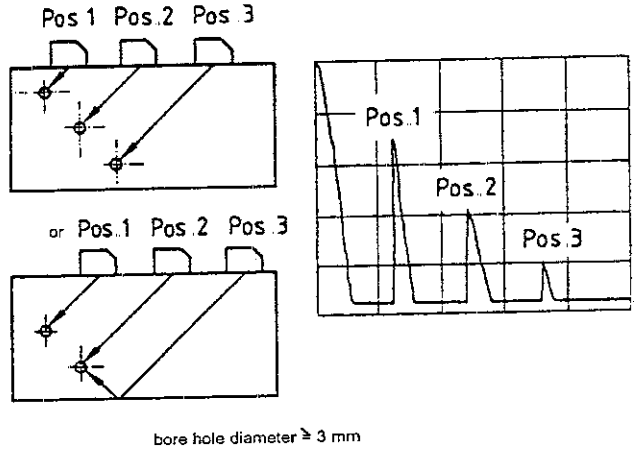


Figure B-3: Creation of indications from transverse bore hole in various distances

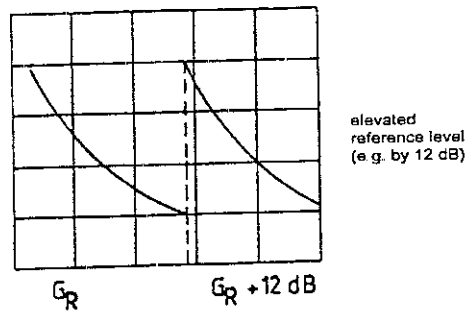


Figure B-4: Different reference levels

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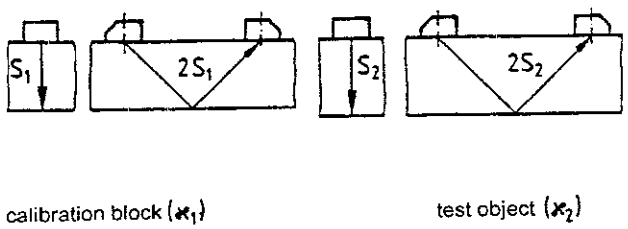
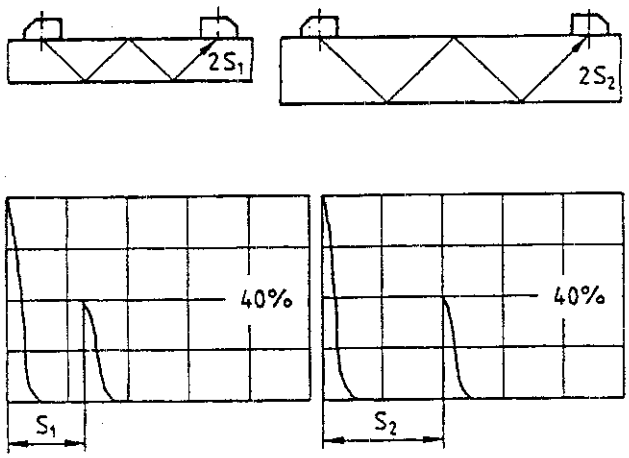


calibration block ($\varkappa_1$) test object ($\varkappa_2$)



G_{T1} = ... dB G_{T2} = . dB

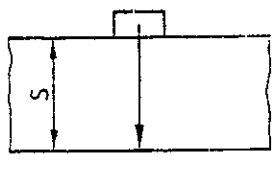
$\Delta V_T = G_{T2} - G_{T1} - \Delta V_S = \Delta V_{coupl.} + \Delta V_{\varkappa}$

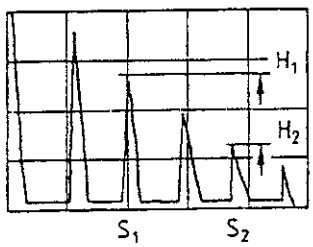
$\Delta V_{\varkappa} = 2(\varkappa_2 \cdot S_2 - \varkappa_1 \cdot S_1)$ = sonic wave attenuation correction

$\Delta V_{coupl.}$ = sonic coupling correction

ΔV_S = divergence correction of backwall echo curve = $V_{S2} - V_{S1}$

Figure B-5: Determination of the transfer correction for the straight-beam or angle-beam examination with a single or double V sonic path

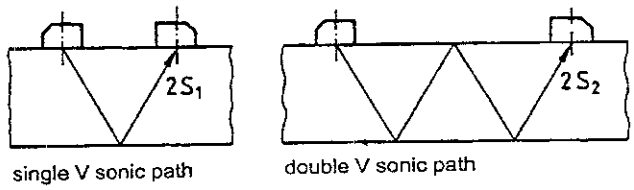




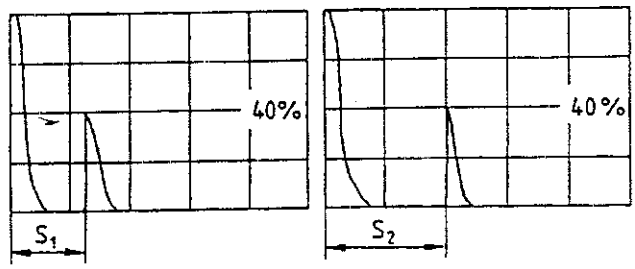
$$\varkappa = \frac{G_{T2} - G_{T1} - V_S}{2(S_2 - S_1)} \text{ (dB/mm)}$$

G_{T1} = . dB
G_{T2} = . dB

Figure B-6: Determination of the sonic wave attenuation for the straight-beam examination



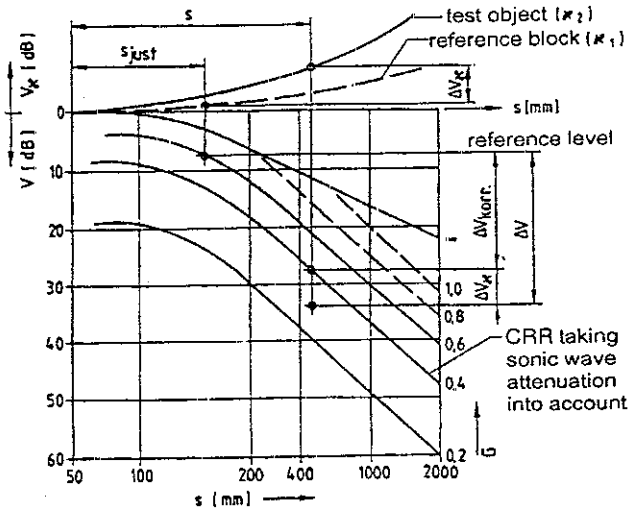
single V sonic path double V sonic path



G_{T1} = . dB G_{T2} = . dB

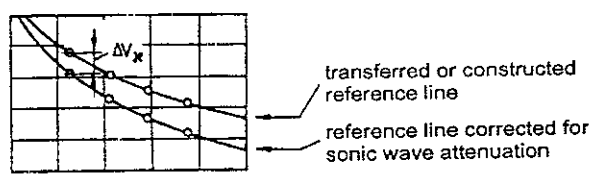
$$\varkappa = \frac{G_{T2} - G_{T1} - V_S}{2(S_2 - S_1)} \text{ (dB/mm)}$$

Figure B-7: Determination of the sonic wave attenuation in the angle beam examination



$\Delta V_{\varkappa} = 2\,(s \cdot \varkappa_2 - s_{adjust} \cdot \varkappa_1)$ [dB]

Figure B-8: Accounting for sonic wave attenuation in the DGS diagram for the case of $\varkappa_2 > \varkappa_1$



$\Delta V_{\varkappa} = 2s\,(\varkappa_2 - \varkappa_1)$ [dB]

Figure B-9: Accounting for sonic wave attenuation by the reference line method for the case of $\varkappa_2 > \varkappa_1$

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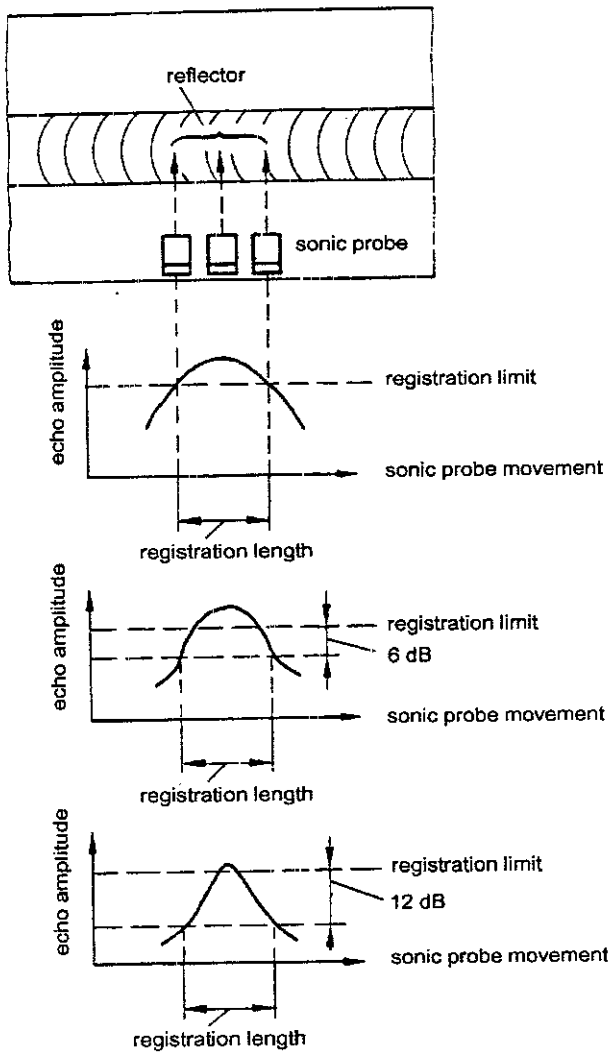

Figure B-10: Determination of the registration length

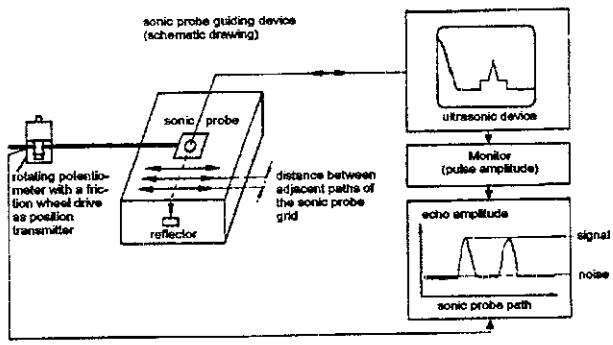

Figure B-11: Measurement device for employing focussing sonic probes for the determining the reflector size

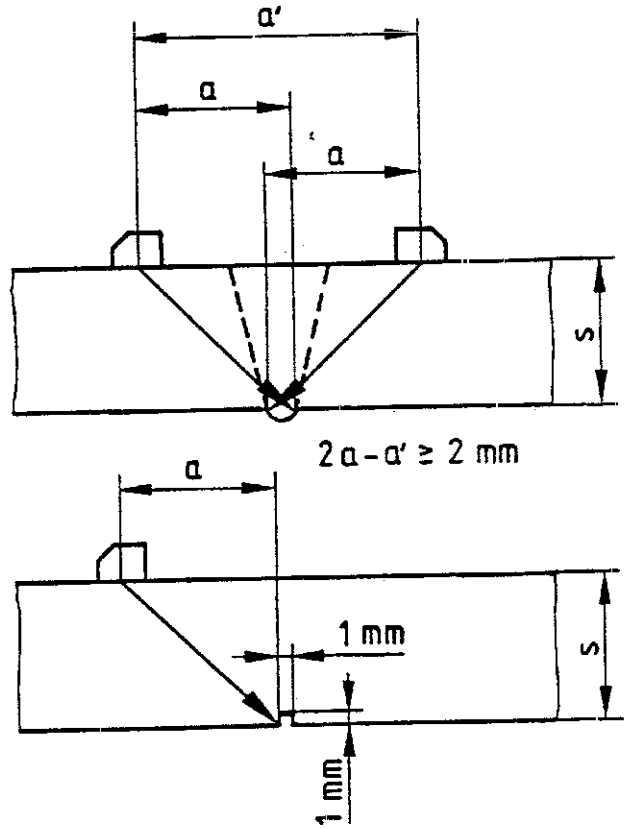

Figure B-12: Demonstration of shape-related indications from the root region of seams welded from only one side

Geometric Class	Type of Transmission	Scope of Application
solid material with a curved surface (e.g. rods)	perpendicular in radial direction	d > 5 N
	angular in axial and circumferential direction	d > 2.5 N for an evaluation up to p/2
concentric surfaces with a single axis curvature (e.g. pipes)	perpendicular in radial direction	d > 5 N
	angular in axial and circumferential direction	d > 2.5 N for an evaluation up to p/2; d_{ref} > 10 N for an evaluation beyond p/2
concentric surfaces with a double axis curvature (e.g. dished sheets, pipe elbows)	perpendicular in thickness direction	d > 10 N
	angular in tangential direction	d > 5 N for an evaluation up to p/2; d_{ref} > 20 N for an evaluation beyond p/2

Table B-1: Application of the DGS method for the single search unit technology

Appendix C

Procedure of Surface Crack Examinations by the Magnetic Particle and the Liquid Penetrant Method

C.1 Scope

This appendix describes the procedures of the magnetic particle examination and the liquid penetrant examination.

C.2 General Requirements

C.2.1 Surface Condition

(1) The surfaces to be examined shall be in a condition that is adequate for the goal of the examination.

(2) They shall be free of scales, weld spatters or other interfering contaminations.

(3) Any grooves or notches that might influence the evaluation of the examination shall be removed.

C.2.2 Visibility Conditions

C.2.2.1 Fluorescent Examination Media

(1) When fluorescent examination media are used the visual examination shall be performed under ultra violet light (UV light) with a wave length maximum in the range of 365 nm ± 10 nm.

(2) The UV light on the test surface shall have a radiant power density of at least 500 µW/cm². This corresponds to a luminous strength of at least 70 lx.

(3) Before starting with the examination, the UV lamps shall have reached their full luminosity.

(4) The eyes of the tester shall have had at least 5 min time to get accustomed to the light conditions.

(5) The examination should be performed in a darkened environment without any interfering influx of light.

C.2.2.2 Nonfluorescent Test Media

(1) During evaluation the test surfaces should be illuminated by daylight or artificial light with a strength of at least 500 lx.

(2) During the visual examination any interfering reflections and influx of light shall be avoided.

C.2.2.3 Evaluation Devices

The use of helping devices (e.g. magnifying glasses, contrast enhancing goggles, mirrors) is allowed during the visual examination.

C.2.3 Post-Examination Cleanup

At the end of the examination the components shall be properly cleaned to remove any examination media residues.

C.3 Magnetic Particle Examination

C.3.1 Magnetization

C.3.1.1 Procedures

(1) The different possibilities for magnetization are specified in DIN 54 130.

(2) If in partial regions the magnetization is carried out with the current flow method or by yoke magnetization, alternating current magnetization shall be employed.

(3) The residual field strength should, basically, not exceed 10^3 A/m (12.5 Oe). If after the examination a welding is to be performed, a demagnetization may be required.

C.3.1.2 Contact Points in the Current Flow Method

(1) If the examination is carried out with the current flow method, melt-off electrodes (e.g. lead-tin alloys) should be used if at all possible. It shall be ensured that in the region of the contact points no overheating of the tested material occurs.

(2) If, nevertheless, overheating has occurred, these regions shall be marked and, after completion of the examination, shall be ground down and subjected to a surface crack examination, preferrably by the magnetic particle examination with yoke magnetization.

C.3.1.3 Direction of Magnetization

Every part of the surface shall be examined under two different directions of magnetization that shall be at an angle of approximately 90° to each other.

C.3.1.4 Field Strength

(1) The tangential field strength at the surface should be at least $2 \cdot 10^3$ A/m (about 25 Oe), but may not exceed $6.5 \cdot 10^3$ A/m (about 80 Oe).

(2) Control measurement shall be performed to ensure that these requirements are met, or, examination conditions shall be determined under which the required values are achieved.

(3) In determining the tangential field strength, the DGZFP Guideline "Checking procedures during the magnetic particle examination" shall be taken into consideration.

Note:
a) The tangential field strength is the tangential component of the magnetic field strength at the surface of the test object.
b) Due to the difficulty in measurement technology, namely that the magnetic flux cannot easily be determined in the component, the tangential field strength is used, however with the reservation that this requirement will be changed at a later time.

C.3.1.5 Magnetization Duration

(1) With regard to application of testing media and magnetization the following values, generally, apply:

a) magnetization and wetting: at least 3 seconds

b) remagnetization: at least 5 seconds

(2) The evaluation shall be performed during the remagnetization phase.

C.3.2 Testing Media

C.3.2.1 Liquid Procedure

(1) The carrier fluid shall be of such nature that no corrosive damage is initiated on the test object even for longer dwell times. The carrier fluid must be able to wet the test surface. Allowable is, e.g., water with corresponding rust protection additives and wetting agents.

(2) The magnetic powder used should be of a fine grained iron oxide. Depending on the application, the powder may be black, fluorescent or colored.

(3) Immediately before wetting the surface, care shall be taken that the magnetic powder is uniformly distributed in the carrier fluid and is kept in suspension.The particle suspension shall be checked before and during the examination with the help of suitable test blocks. When using a Berthold test block, the crossed slits shall be positioned at 45° to the direction of magnetization and shall be wetted during the check run. The magnetic powder concentration is adequate if the crossed slits are clearly and completely visible.

C 3.2 2 Dry Procedure

(1) [Application of] the dry procedure requires the consent of the authorized expert except when it is used for intermediate testing in the hot condition. Attention shall be paid to the fact that the powder used is sufficiently dry.

(2) The equipment for applying the powder shall finely distribute the powder such that no powder heaping occurs. It should be ensured that the powder applied does not cake up under influence of the test object temperature

C 3.2.3 Contrast

(1) To increase the visibility with respect to flaws, suitable measures (e.g fluorescent testing media, or application of a thin paint layer to the surface) shall be taken to achieve a sufficient contrast.

(2) A sufficient contrast is achieved when black magnetic powder is used on a metallic blank [shiny] surface

C.4 Liquid Penetrant Examination

C.4.1 Examination System

(1) Preferably, colored liquid penetrants shall be used. Also allowed is the use of fluorescent liquid penetrants and of fluorescent colored liquid penetrants

(2) The intermediate cleaning agent may be a solvent or water or a combination of both.

(3) Only such liquid developers shall be used that use solvents as a carrier liquid. Dry developers may only be used if they are applied to the test surface by electrostatic means.

(4) The suitability of the examination system (penetrant medium, intermediate cleaner, developer) shall be demonstrated to the authorized expert by performing a sample examination in accordance with DIN 54 152 Part 2

(5) It shall be ensured in accordance with DIN 54 152 that the examination system always meets the characteristics specified under Sec.C 4.1(4).

C 4 2 Procedure

(1) The liquid penetrant examination shall be performed in accordance with DIN 54 152 Part 1 taking the following requirements into consideration.

(2) The penetration time should be no shorter than half an hour.

(3) The evaluation should be performed as soon as possible after surface drying of the developer sets in. An additional evaluation shall be performed no earlier than half an hour after the first evaluation.

(4) Additional points in time for evaluation will be required if the second evaluation shows up crack like indications that were not visible in the first evaluation.

> ***Note:*** *Additional points in time for evaluation may also be considered if the second evaluation shows up essential changes or additional indications.*

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Appendix D

Procedure for Determing the Lateral Expansion

(1) The determination of the lateral expansion of brocken notch bend test specimens requires a measurement of both sides of each of the two brocken specimen ends.

(2) In preparation of the measurement possible spurs on the edges of the break surfaces shall be carefully removed, e.g. with a fine-grade grinding paper, without damaging the upset edges. Brocken specimen ends where the upset edges were damaged by forceful contact with parts of the testing equipment are not suited for determining the lateral expansion.

(3) The two upset edges of each specimen end are then measured with appropriate instruments to an accuracy of 0.01 mm (see **Figure D-1**). From the four measurements SB1 through SB4 the largest values on each side, i.e., the largest value of SB1 and SB3 and the largest value of SB2 and SB4 are determined and added together. This sum is the lateral expansion and shall be recorded to an accuracy of 0.01 mm.

(4) The four individual measurements SB1 through SB4 may be replaced by two measurements, provided, appropriate equipment is employed. Hereby, the lateral expansion is measured for each side simultaneously for both broken specimen ends (cf. measurement principle in **Figure D-2**). With this procedure it is ensured that only the largest expansions are measured on each side and are properly correlated to each other. In this case, likewise, the lateral expansion is again equal to the sum of the two values.

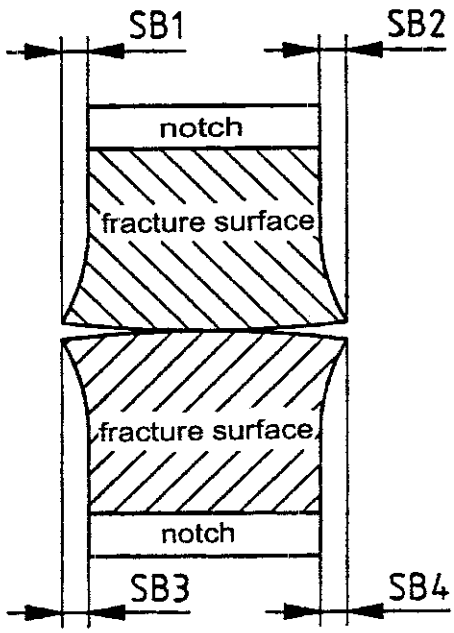

Figure D-1: Determination of the lateral expansion (SB) of brocken notch bend test specimens

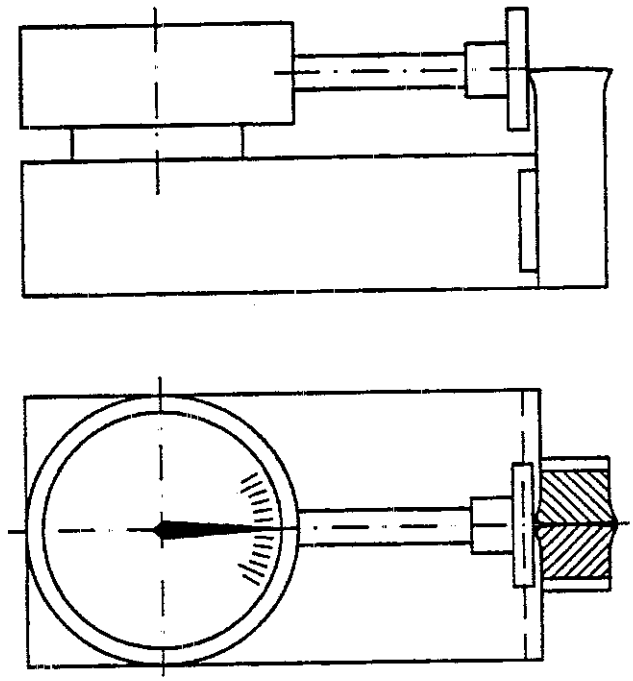

Figure D-2: Measurement principle for a simplified procedure for the determination of the lateral expansion (SB)

Appendix E

Regulations Referred to in this Safety Standard

[Regulations referred to in this safety standard are only valid in the version cited below] Regulations which are referred to within these regulations are valid only in the version that was valid when the later regulations were established or issued

Atomic Energy Act	07/85	Act on the peaceful utilization of atomic energy and the protection against its hazards (Atomic Energy Act) as amended on July 15, 1985 (BGBl I, p 1565)
KTA 1401	12/87	General requirements regarding quality assurance
[KTA 1404	06/89	Documentation during the construction and operation of nuclear power plants]
KTA 1408 1	06/85	Quality assurance of weld filler materials and weld additives for pressure and activity retaining systems in nuclear power plants; Part 1: Suitability testing
KTA 1408 2	06/85	Quality assurance of weld filler materials and weld additives for pressure and activity retaining systems in nuclear power plants; Part 2: Manufacture
KTA 1408 3	06/85	Quality assurance of weld filler materials and weld additives for pressure and activity retaining systems in nuclear power plants; Part 3: Processing
KTA 3401 3	11/86	Reactor containment vessels of steel; Part 3: Manufacture
[KTA 3405	02/79	Integral leakage rate testing of the containment vessel with the absolute pressure method]
EURONORM 103	11/71	Microscopic determination of the ferritic or austenitic grain size of steels [replaced by 103 / DIN 50 601 (08/5), Metallographic examination; Determination of the ferritic or austenitic grain size of steel and ferrous materials]
[DIN 13 Part 13	10/83	ISO metric screw threads; Selected sizes for screws, bolts and nuts from 1 to 55 mm screw thread diameter and limits of sizes]
DIN 267 Part 4	08/83	Fasteners; Technical delivery conditions; Property classes for nuts
DIN 267 Part 11	01/80	Fasteners; Technical delivery conditions (with additions to ISO 3506); Corrosion-resistant stainless steel fasteners
DIN 267 Part 19	10/84	Fasteners; Technical delivery conditions; Surface discontinuities on bolts and screws
DIN 267 Part 20	10/84	Fasteners; Technical delivery conditions; Surface discontinuities on nuts
DIN 267 Part 21	06/81	Fasteners; Technical delivery conditions; Widening test for nuts
DIN/ISO 898 Part 1	04/79	Mechanical properties of fasteners; Part 1: Bolts, screws and studs
DIN/ISO 898 Part 2	03/81	Mechanical Properties of Fasteners; Part 2: Nuts with Specified Proof Load Values
DIN 934	10/87	Hexagon nuts with metric coarse and fine thread pitch; Product grades A and B
[DIN 970		retracted]
DIN 1910 Part 12	09/80	Welding; Metal welding processes; Terms
DIN/ISO 4032	10/87	Hexagon nuts, style 1; Product grades A and B
DIN 4762 Part 1	10/86	Surface roughness; Terms; Surface and its characteristics (identical to ISO 4287/1, edition 1984)
DIN 4768 Part 1	08/74	Determination of surface roughness R_a, R_z, R_{max} using electric contact (stylus) instruments; Basic data
DIN 8572 Part 1	03/81	Determination of diffusible hydrogen in weld metal; Manual arc welding
DIN 8572 Part 2	03/81	Determination of diffusible hydrogen in weld metal; Submerged arc welding
DIN 17 014 Part 1	03/75	Heat treatment of ferrous metals; Terminology
DIN 17 200	03/87	Steels for quenching and tempering; Technical delivery conditions
DIN 17 240	07/76	Heat resisting and highly heat resisting materials for bolts and nuts; Quality specifications
DIN 32 524	03/85	Measurement of preheating temperature, interpass temperature and preheat maintenance temperature during welding
DIN 50 049	08/86	Materials testing certificates
DIN 50 115	02/75	Testing of metallic materials; Notched bar impact bending test
DIN 50 125	03/86	Testing of metallic materials; Tensile test pieces
DIN 50 133	02/85	Testing of metallic materials; Vickers hardness test, HV 0 2 to HV 100

DIN 50 145	05/75	Testing of metallic materials; Tensile test
DIN 50 351	02/85	Testing of metallic materials; Brinell hardness test
DIN 51 220	10/76	Materials testing machines; General requirements
DIN 51 300	11/82	Materials testing machines; Verification of materials testing machines; General
DIN 54 119	08/81	Nondestructive testing; Ultrasonic examination; Terms
DIN 54 120	07/73	Nondestructive testing; Calibration block 1 and its use for the adjustment and control of ultrasonic echo equipment
DIN 54 122	12/73	Nondestructive testing; Calibration block 2 and its use for the adjustment and control of ultrasonic echo equipment
DIN 54 130	04/74	Nondestructive testing; Magnetic leakage flux processes; General
DIN 54 152 Part 1	03/79	Nondestructive testing; Penetrant tests; Procedure
DIN 54 152 Part 2	06/83	Nondestructive testing; Penetrant tests; Testing of testing agents
SEL 072	12/77	Heavy plates subjected to ultrasonic testing; Technical delivery conditions
[SEL 096	03/88	Flat steel products, formed steel and rod steel with a profiled cross section, with improved forming characteristics vertical to the product surface; Technical delivery conditions]
SEP 1805	03/76	Removal and preparation of specimens for the product analysis of steels
SEP 1915	06/77	Ultrasonic testing for longitudinal flaws in tubes of high-temperature steels
[SEP 1918	12/89	Nondestructive testing of weldable ferritic steel tubes]
SEP 1921	12/84	Ultrasonic testing of forgings and forged bar steel with a diameter or edge length larger than approx 100 mm
SEW 088	04/87	Weldable fine-grained structural steels; Guidelines for processing, in particular for fusion welding
[VdTÜV Material Sheets		Material sheets of the corporation of technical surveillance organizations (VdTÜV)]
No 337	06/87	Creep resistant steels 20 NiCrMo 14 5 I and 20 NiCrMo 14 5 II; Material No 1.6772
No 380	12/84	Rolling and forging steel 40 NiCrMo 84 I, II and III for screws, bolts and nuts; Material No 1 6562
No 390	09/89	High-strength steel 26 NiCrMo 14 6 for screws, bolts and nuts; Material No 1 4313
No 427		Fine grained structural steel 15 MnNi 6 3; Material No 16210 Part 1 (03/84), Part 2 (12/81), Part 3 (01/82)]

Reference to Literature

[1] Handbuch für das Eisenhüttenlaboratorium, Bd 2: Die Untersuchung der metallischen Werkstoffe, Düsseldorf 1966;
Bd. 5: Erg -Bd 1, 2 und 3, Düsseldorf
(Manual for the Metalworks Laboratory; Vol. 2: The analysis of metallic materials; Vol. 5: Supplements to vols. 1, 2 and 3)