

Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 1408.1 (2017-11)

Quality Assurance of Weld Filler Metals and Welding
Consumables for Pressure- and Activity-Retaining Systems
in Nuclear Power Plants
Part 1: Qualification Testing
(Qualitätssicherung von Schweißzusätzen und -hilfsstoffen
für druck- und aktivitätsführende Komponenten in Kernkraft-
werken; Teil 1: Eignungsprüfung)

Previous versions of this Safety Standard
were issued 1985-06, 2008-11 and 2015-11

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

Editor:

KTA-Geschaeftsstelle

c/o Bundesamt fuer kerntechnische Entsorgungssicherheit (BfE)

Willy-Brandt-Str. 5 • 38226 Salzgitter • Germany

Telephone +49 (0) 30 18333-1621 • Telefax +49 (0) 30 18333-1625

KTA SAFETY STANDARD

November
2017

Quality Assurance of Weld Filler Metals and Welding Consumables for Pressure- and Activity-Retaining Systems in Nuclear Power Plants; Part 1: Qualification Testing

KTA 1408.1

CONTENTS

Fundamentals	5	6.11 Minimum operating temperature.....	19
1 Scope	5	6.12 Design strength value.....	20
2 Definitions	6	6.13 Corrosion resistance.....	20
3 Requirements regarding the manufacturer's works.....	6	6.14 Special tests	20
3.1 Workshop equipment	6	7 Supplementary tests.....	20
3.2 Receiving, intermediate and final inspections	6	7.1 Extending the range of application	20
3.3 Identification marking of the products.....	6	7.2 Modification of the weld filler metal.....	20
3.4 Testing equipment.....	6	8 Certificates	20
3.5 Initial audit of the manufacturer's works	7	8.1 Preliminary certificate	20
4 Assessment of the suitability of weld filler metals and welding consumables.....	7	8.2 Test report.....	20
4.1 General	7	8.3 Final certificate	20
4.2 Manufacturer's specification.....	7	9 Transfer of qualification test	20
4.3 Extent of the qualification test	7	10 Extension of the validity of the qualification test.....	20
4.4 Investigation of the weld filler metals and welding consumables.....	8	10.1 General.....	20
4.5 Investigations of the all-weld metal	8	10.2 Conditions	20
4.6 Investigations of weld connections.....	14	Annex A: Data sheets for weld filler metals.....	22
4.7 Investigations of weld claddings and hardfacings	18	Annex B: Declaration of identity	26
4.8 Special tests.....	18	Annex C: Extent of the tests to be carried out within the scope of the plant internal quality assurance for the validity extension of the qualification tests of weld filler metals and welding consumables	28
4.9 Requirements regarding mechanical properties of all-weld metal and the weld metal of welded joints.....	18	Annex D: Verification of the welding behaviour of rod electrodes.....	29
5 Workability of weld filler metals	19	Annex E: Testing for susceptibility to hot cracking (ring segment specimen)	30
6 Limitation of the range of application.....	19	Annex F: Additional requirements (values in mass percentage) regarding the chemical com- position of all-weld metal of coated rod electrodes, flux cored wire electrodes and wire flux combinations as well as the chem- ical composition of massive products	32
6.1 General	19	Annex G: Suitability assessment of weld filler metals and welding consumables in the case of small quantities (application-specific individual material appraisal)	33
6.2 Physical dimensions.....	19	Annex H: Regulations referred to in this Safety Standard	34
6.3 Shielding gases and backings.....	19		
6.4 Base metals	19		
6.5 Heat treatment	19		
6.6 Wall thickness, thickness of weld claddings and hardfacings.....	19		
6.7 Type of current and polarity	19		
6.8 Welding positions.....	19		
6.9 Root weldability	19		
6.10 Maximum operating temperature	19		

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

All questions regarding this English translation should please be directed to the KTA office:

KTA-Geschaeftsstelle c/o BfE, Willy-Brandt-Str. 5, D-38226 Salzgitter, Germany or kta-gs@bfe.bund.de

Comments by the editor:

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

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

Translator's note:

In this translation distinction is still made between "weld filler metals" and "consumables", whereas the latest EN ISO standards (see e.g. Annex G) use only the term "welding consumables" for all types of filler metals, electrodes, wires, rods, fluxes, pastes, etc.

Fundamentals

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the objective to specify safety-related requirements, compliance of which provides the necessary precautions in accordance with the state of the art in science and technology against damage arising from the construction and operation of the facility (Sec. 7 para. 2 subpara. 3 Atomic Energy Act - AtG) in order to achieve the fundamental safety functions specified in the Atomic Energy Act and the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants as well as in the Interpretations on the Safety Requirements for Nuclear Power Plants.

(2) The "Safety Requirements for Nuclear Power Plants" require in no. 3.4 "Requirements for the reactor coolant pressure boundary and the pressure-retaining walls of components of the external systems" and no. 3.6 "Requirements for the containment system" the integrity of the pressure retaining walls as well as in requirement no. 5 (3) a documentation showing that the current condition of the safety-relevant measures and equipment fulfils the applicable requirements. Thus, to ensure proper weld connections, it follows that weld filler metals and welding consumables shall be subject to special quality assurance.

(3) When manufacturing, storing and using weld filler metals and welding consumables, it is essential that such properties are obtained and maintained which ensure that the welds meet the requirements over the entire scheduled operating time. This will be achieved by careful

- selection of the initial materials,
- production of the weld filler metals and welding consumables, and
- observation of the prescribed processing conditions.

(4) Qualification tests are used to determine whether the selected weld filler metals and welding consumables meet the requirements of the intended application with respect to their composition and weldability and the properties of the welds produced.

(5) The safety standards of the KTA 1408 series are closely related to the following safety standards:

- KTA 3201.3 Components of Light Water Reactors; Part 3: Manufacture,
- KTA 3211.3 Pressure- and Activity-Retaining Components Outside the Primary Circuit; Part 3: Manufacture
- KTA 3401.3 Steel Containment Vessels; Part 3: Manufacture.

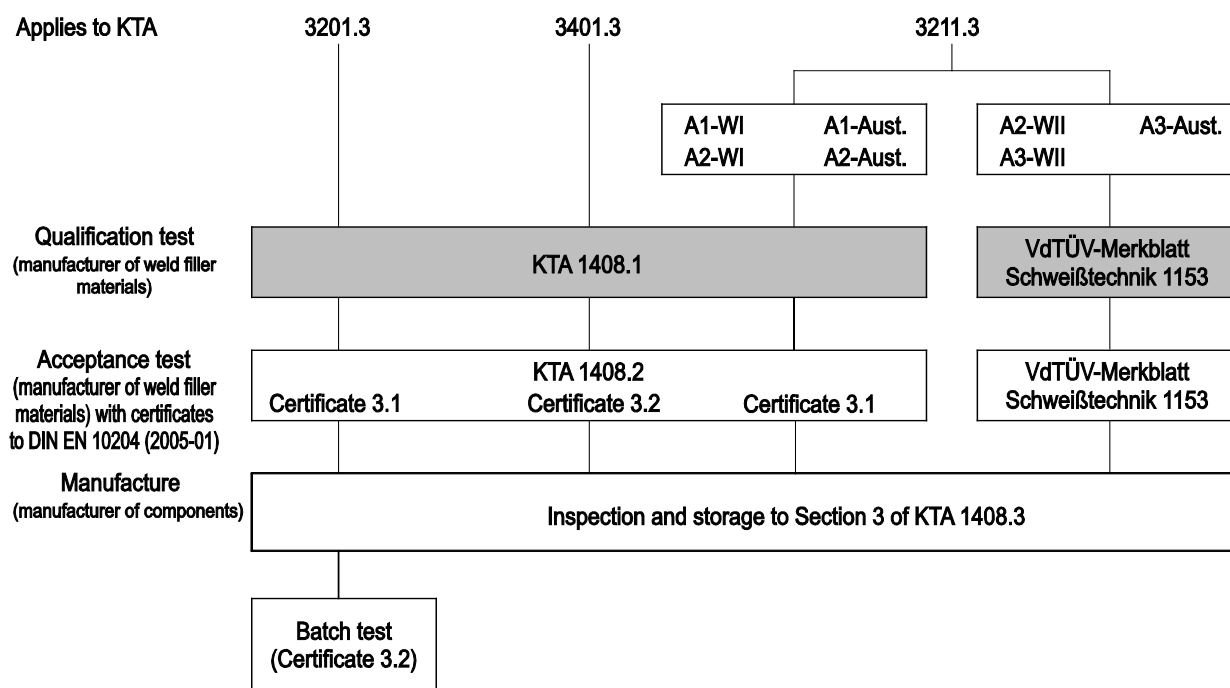
These safety standards specify the requirements for welds which are produced using the weld filler metals and welding consumables dealt with in this safety standard.

1 Scope

(1) This safety standard applies to the qualification testing of weld filler metals and welding consumables (see **Figure 1-1**) which are to be used in the fabrication of product forms, parts and sub-assemblies for pressure-retaining walls of components of stationary nuclear power plants with light water reactors. These include the:

- components of the primary circuit (KTA 3201),
- steel containment vessels (KTA 3401),
- pressure- and activity-retaining components of systems outside the primary circuit (KTA 3211) - only Class 2 components -, excepted are the austenitic steels A2-WII, A3-WII and A3.

(2) In the case of weld filler metals and welding consumables which demonstrably have been used for the manufacture of components in accordance with paragraph 1 prior to the issuance of this safety standard, re-qualification testing is not required. The same applies to weld filler metals and welding consumables which, prior to the preparation of this safety standard, were investigated in special programs of a scope comparable to the following specifications.



A1, A2, A3 : Test groups

W I, W II : Materials groups

Further details on these values can be found in safety standards KTA 3211.1 and KTA 3211.3.

Figure 1-1: Requirements regarding weld filler metals and welding consumables

2 Definitions

(1) Manufacturer

The party who manufactures the consumables totally or performs the final part of production which determines the quality of the consumables.

Those purchasing the above-mentioned products as semi-finished or finished products, but undertaking the full guarantee with regard to the chemical composition, quality and properties of these products and ensuring inspection of the production and products, are also regarded as manufacturers.

(2) Manufacturer's works

The manufacturer's works is defined as the facility where weld filler metals and welding consumables are produced and packed.

(3) Supplier

The party who purchases the welding consumable from a manufacturer and supplies it under his own brand name.

(4) Authorized inspector

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

(5) Welding consumables

Consumables are products which make possible and alleviate the welding process e.g. inert gas, flux or paste.

(6) Weld filler metal

A material added during the welding process and contributing to the formation of a welded joint.

3 Requirements regarding the manufacturer's works

3.1 Workshop equipment

(1) The workshop equipment shall permit a uniform manufacture of the products and a uniform quality of the final product. The manufacturer shall take adequate measures to ensure that mix-ups are excluded in the manufacture and storage of weld filler metals and welding consumables and that the requirements specified for manufacturing are complied with.

(2) Only subcontractors audited by the manufacturer regarding

- a) technical equipment,
- b) personnel,
- c) quality assurance system,
- d) internal and external surveillance,
- e) experience

may be used as suppliers for rolled, drawn or cast initial material.

The purchase specifications for the supplies shall be submitted to the authorized inspector with respect to the chemical composition of the supplies. The authorized inspector shall be notified of any changes of the purchase specifications or of the circle of suppliers of initial materials, with respect to the written status laid down in the final documentation on the qualification test.

(3) Purchase specifications shall exist for all powdered materials for welding rods, flux cored electrodes and flux. The authorized inspector shall be notified of any changes of the materials or formulas, with respect to the written status laid down in the final documentation on the qualification test. The number or designation of the valid recipe shall be disclosed to the authorized inspector who will include it in his report on the qualification test.

(4) The manufacture of weld filler metals and welding consumables shall be performed in accordance with fabrication steps laid down in writing and shall be supervised by the manufacturer.

(5) Suitable drying facilities with adequate temperature control shall be available for the manufacture of coated welding rods, weld flux and flux cored electrodes. The drying conditions shall be laid down in manufacturing specifications, the compliance with which is to be checked by the manufacturer. The authorized inspector shall be notified of any changes of the drying conditions with respect to the status laid down in writing in the final documentation on the qualification test.

3.2 Receiving, intermediate and final inspections

(1) The manufacturer shall have at his disposal a quality assurance unit that is independent of fabrication and that performs the receiving, intermediate and final inspections in accordance with written instructions (see KTA 1408.2). These shall be in accordance with the fabrication system, shall ensure a final product of perfect quality and uniformity and shall ensure that no mix-ups occur.

(2) The quality assurance measures laid down in writing shall be submitted to the authorized inspector. The manager of the quality assurance unit shall be reported by name to the authorized inspector.

3.3 Identification marking of the products

(1) The identification marking of the products shall ensure that no mix-ups of the products occur on their way from the manufacturer's works to the point of application by the welder as a result of wrong or insufficient marking. The welding consumable shall be marked at least with its common trade name. In the case of weld filler metals and welding consumables which passed the qualification testing in accordance with sections 4 to 10 other markings than the trade name which ensure an unambiguous identification shall be included in the weld filler metals data sheet (see **Annex A**). The data sheet shall not include any additional markings.

(2) Welding rods shall be stamped; for lengths exceeding 1 m, the stamp shall be repeated several times. Unless the marking system is specified by standards, it shall be unambiguous with respect to the product range of a manufacturer and shall permit identification of the manufacturer. In the case of materials which do not permit stamping (e.g. cast rods) or where stamping is not possible for other reasons (e.g. if the diameter is 2 mm or less), some other form of unambiguous marking shall be effected (e.g. by tags glued to the material).

(3) Weld filler metals shall be marked in accordance with DIN EN ISO 544, weld flux in accordance with DIN EN ISO 14174.

(4) The imprints on the cover of welding rods shall consist only of colours that will not have detrimental effect on the welding results.

(5) If in the case of weld filler metals and welding consumables which passed the qualification testing in accordance with sections 4 to 10 additional reference to the qualification test in accordance with this safety standard is to be made, the following text shall be used:

"Qualified in accordance with KTA 1408.1".

(6) It is not permitted to use the label "Qualified in accordance with KTA 1408.1" for weld filler metals and welding consumables that were verified to be suited for such specific use by an individual material appraisal in accordance with **Annex G**.

3.4 Testing equipment

The manufacturer's works shall have sufficient testing equipment to perform the receiving, intermediate and final inspection.

tions. The welding and testing equipment required for the continuous monitoring of the mechanical properties and chemical composition shall be available. The other inspection equipment required to ensure uniform quality shall be available at the manufacturer's works.

3.5 Initial audit of the manufacturer's works

The initial audit of the manufacturer's works shall be carried out to meet the requirements of Sections 3.1 to 3.4. The authorized inspector shall establish a report on this audit.

The manufacturer shall make available reference values of chemical composition and mechanical properties for initial materials as well as for finished products.

Note:

The requirements to be met by the manufacturer's works shall be deemed to have been fulfilled if Section 4 of VdTÜV-Merkblatt Schweißtechnik 1153 in conjunction with DIN EN 12074 is complied with.

4 Assessment of the suitability of weld filler metals and welding consumables

4.1 General

(1) The requirements regarding specific characteristics of weld filler metals and welding consumables shall be based on the requirements of the respective applicable classifying standard. Weld filler metals and welding consumables not corresponding to a classification shall be assigned to the classifying standards with respect to their properties (see e.g. **Annex C**). Additional requirements for the chemical composition of all-weld metal of coated rod electrodes, flux cored wire electrodes and wire flux combinations as well as the chemical composition of massive products are specified in **Annex F**.

(2) The authorized inspector shall assess the suitability of weld filler metals and welding consumables on the basis of the specifications and tests required below. The qualification test shall only be carried out on welding consumables of manufacturers whose manufacturing equipment has been checked before by the authorized inspector.

(3) The qualification test shall be carried out at the manufacturer's works for weld filler metals and welding consumables.

4.2 Manufacturer's specification

4.2.1 General

Prior to the beginning of the tests, the authorized inspector shall be informed of the characteristic data, properties and chemical composition specified for the product by the manufacturer, as well as of the intended applicability of qualification testing to the weld filler metals and welding consumables to be tested.

4.2.2 Characteristic data

The characteristic data are:

- type designation in accordance with either the pertinent standards or the type of weld filler metals and welding consumables,
- nature of coating or flux type,
- alloy type of the weld metal,
- code number designating the mechanical properties,
- welding processes and their combinations in accordance with DIN EN ISO 4063,
- welding positions in accordance with DIN EN ISO 6947,
- type of current and polarity,
- marking,

- dimensions,
- welding consumables (e.g. inert gases),
- recommended welding parameters (e.g. range of current and welding rates).

4.2.3 Statement of reference values and properties

- The allowable limits shall be specified for:
 - the analysis of the strip-type and wire electrodes, the core or welding rods, and the metal coating of flux cored electrodes,
 - the typical analysis of the weld metal,
 - quantitative information on the characteristic chemical compounds or elements of coatings or fillings (e.g. TiO_2 , SiO_2) of fluxes and pastes which can be verified by chemical analysis,
 - the properties of the weld metal in the heat treatment conditions concerned.
- Properties for conditions of special applications shall be specified, e.g.:
 - suitability for high or low temperatures,
 - corrosion resistance.

4.2.4 Scope of application

The scope of application of the qualification test shall be specified by the manufacturer such that there is adequate compatibility between the weld metal properties and the service properties of the base metal within the scope. When specifying the scope of application, the KTA safety standards applying to nuclear facilities shall be taken into account. The scope of application shall be described by means of the following information:

- materials,
- heat treatments,
- wall thickness limitations,
- highest and lowest operating temperatures of the parts to be welded together,
- type of current and polarity,
- root weldability,
- welding positions as a function of the dimensions of the weld filler metals,
- design strength values, if any,
- special fields of application.

4.3 Extent of the qualification test

- Investigations shall basically be carried out regarding:
 - the weld filler metals and welding consumables (see Section 4.4),
 - the all-weld metal (see Section 4.5),
 - weld connections and weld claddings (see Sections 4.6 and 4.7), and
 - susceptibility to cracking (see clause 4.6.4.11).
- The above-mentioned investigations relate to the examination of the
 - outer appearance and condition,
 - chemical composition,
 - mechanical properties,
 - satisfactory weldability of the weld filler metals and welding consumables.
- Depending on the application of the welding consumable, supplementary tests shall be performed, for example:
 - corrosion resistance,

- b) determination of the delta ferrite content,
- c) low temperature fracture toughness,
- d) high temperature strength,
- e) long-term behaviour,
- f) cold formability,
- g) hot formability,
- h) determination of hydrogen content.

(4) If weld filler metals and welding consumables are used in such small quantities (with a maximum amount of 500 kg on each occasion) that a qualification test is unsuited due to the disproportionately high expenditure required, an individual material appraisal may be prepared to satisfy the specific application concerned. The procedure to be followed in this case is laid down in **Annex G**. An application-specific qualification test is allowed only if the case of application and the later operating conditions are known. Here it is presumed that the weld filler metal to VdTÜV-Merkblatt Schweißtechnik 1153 in conjunction with DIN EN 14532-1 and DIN EN 14532-2 has been qualification tested.

4.4 Investigation of the weld filler metals and welding consumables

4.4.1 Specimen-taking and examination of the outer appearance and condition

(1) Within qualification testing, the weld filler metals and welding consumables used for the qualification test shall be taken from the manufacturer's stock in the presence of the authorized inspector.

(2) For all weld filler metals and welding consumables, the dimensions which are to be included in the scope of application of the test shall be verified, i.e.

- a) in the case of rod electrodes, these are the core wire, thickness of the coating and length,
- b) in the case of welding rods, these are the rod diameter and length,
- c) in the case of wire electrodes, this is the diameter,
- d) in the case of strip-type electrodes, this is the width and thickness,
- e) in the case of flux cored electrode, these are the diameter and degree of filling.

(3) In the case of fluxes for submerged arc welding or electro-slag welding, the granulation specified in DIN EN ISO 14174 shall be verified. The particle size of other fluxes (e.g. for plasma deposition welding) shall also be checked to verify that the manufacturer's specifications have been satisfied

(4) In addition, all other external features of the weld filler metals and welding consumables should also be documented, for example

- a) the colour of the coating or of the flux,
- b) the bonding strength of the coating, if any, the surface condition and identification marking.

4.4.2 Chemical composition

(1) On the basis of the data on the chemical composition, the authorized inspector shall verify whether the limit values specified by the manufacturer for the analyses are adhered to with respect to

- a) core wire,
- b) welding rod,
- c) strip-type and wire electrodes,
- d) inert gas,
- e) coat of flux cored wire,
- f) coating of the rod electrode,

- g) flux for submerged arc and electro-slag welding,
- h) flux of the flux cored electrode,
- i) flux for plasma arc weld surfacing.

(2) When carrying out the chemical analysis of the core wires, strip-type electrodes and wire electrodes, the alloy constituents and also the impurities (e.g. phosphorus, sulphur, nitrogen and chromium in the case of low-alloy weld filler metals) shall be determined. Special attention shall be paid to metallic coatings such as copper. The proportion of the coating shall be determined when carrying out the analysis of the weld filler metal.

(3) When carrying out the chemical analysis of the coatings or fluxes, random samples should be taken and verified of the constituents governing the properties of the coating or flux, provided a comprehensive reference analysis performed by the manufacturer is available. If the manufacturer provides insufficient reference values, a comprehensive analysis shall be required.

(4) In order to be able to determine the properties of a coating at least the proportions of SiO_2 , Mn and CaF_2 shall be determined. Where certain constituents, such as chromium, nickel or molybdenum are added from the alloy of the coating, they shall be determined as well.

4.5 Investigations of the all-weld metal

4.5.1 General

The properties of the all-weld metal shall be tested. In the case of weld filler metals and welding consumables which are used exclusively for weld cladding and hard surfacing (e.g. austenitic steels, hard surfacing alloys), no tests of the all-weld metal - with the exception of the chemical analysis - need be carried out.

4.5.2 Test coupon forms

(1) Weld metal test coupons shall be prepared in accordance with DIN EN ISO 15792-1. When testing rod, wire and flux cored electrodes as well as welding rods, test coupon forms 1.2 or 1.3 shall be used; when testing wire flux combinations for submerged arc welding, test coupon forms 1.3 or 1.4 shall be used. For the tests of weld filler metals and welding consumables for deposition welding, test coupons shall be prepared in accordance with the corresponding standards.

(2) If the manufacturer specifies a test of the weld filler metal for welding with direct and alternating current or, in the case of direct current, at both poles, the test shall be carried out for all currents or polarities. For this purpose, the full extent of the test shall be carried out for the current having the most unfavourable effects on the welding process - this is, as a rule, the alternating current - or for the less commonly used polarity. For the remaining type of current or polarity, the test coupons shall not only be tested for their chemical compositions but also for their mechanical and technological properties in the unannealed condition or following the specified shortest heat treatment for the largest diameter of the weld filler metal under the scope of application. If the test of the all-weld metal leads to substantial differences in the results for the different types of current or polarities, then, instead of random sampling, the entire test program shall be carried out.

(3) Prior to the beginning of the test, the welding procedure sheet and the test and inspection sequence plan to be prepared by the manufacturer shall be submitted to the authorized inspector. In the procedure sheets, the basic structure of the welds shall be represented by outline drawings. If welding consumables are used they shall be certified by an acceptance test certificate to DIN EN 10204 (see Sec. 8 of KTA 1408.2).

4.5.3 Welding conditions

(1) The following welding conditions shall be complied with:

- a) rod electrodes: see **Table 4.5.3-1**,
- b) wire flux combinations: see **Table 4.5.3-2**,
- c) metal inert gas arc welding with solid wire **Table 4.5.3-3**,
- d) metal inert gas arc welding with flux cored electrodes: see **Table 4.5.3-4**,
- e) tungsten inert gas arc welding: see **Table 4.5.3-5**.

Deviations from the above-mentioned welding conditions shall be specified in the data sheet.

(2) **Tables 4.5.3-1 to 4.5.3-5** apply to ferritic weld filler metals and, where applicable, shall also apply to austenitic, nickel alloy and other weld filler metals. The data shall be laid down by the manufacturer and be examined by the authorized inspector.

(3) The preheat and interpass temperatures shown in **Tables 4.5.3-1 to 4.5.3-5** and **4.6.2-1 to 4.6.2-3** refer to fine-grain steels. For other materials the preheat and interpass temperature shall be fixed and be checked by the authorized inspector. The interpass temperature shall be recorded. The definitions of preheat and interpass temperature shall be taken from DIN EN ISO 13916.

Core rod diameter · length mm	Welding current A	Approximate electrode run-out length mm	Energy per unit length ¹⁾ kJ/cm	Test coupon form to DIN EN ISO 15792-1	Preheat and interpass temperatures °C
2.5 · 250	For the individual dimensions of the rod electrodes, the upper current specified by the manufacturer on the label, reduced by 10%, shall be used as a mean value.	150	5 to 7	1.2	125 to 175
2.5 · 300		170			
2.5 · 350		200			
3.25 · 350		240	7 to 9	1.2	
4 · 350		260	11 to 13	1.3	
4 · 450		340			
5 · 450		400			
6 · 450			470	18 to 22	

¹⁾ The specified energy per unit length is attained with the specified run-out lengths (50 mm stub length).

Table 4.5.3-1: Welding data reference values for the production of all-weld metal test coupons - Rod electrodes -

Wire electrode diameter mm	Welding current A	Welding voltage V	Welding speed cm/min	Energy per unit length kJ/cm	Test coupon form to DIN EN ISO 15792-1	Preheat and interpass temperatures °C
4	approx. 550	flux-specific	approx. 45	21 to 24	1.3 or 1.4	125 to 175

Table 4.5.3-2: Welding data reference values for the production of all-weld metal test coupons - Wire-flux combination -

Wire electrode diameter mm	Welding current A	Welding voltage V	Welding speed cm/min	Energy per unit length kJ/cm	Test coupon form to DIN EN ISO 15792-1	Preheat and interpass temperatures °C
1.2	280 ± 10	gas-dependent	50	8 to 10	1.3	125 to 175
			30	14 to 17		

For other electrode diameters and welding conditions outside the verified range of energy per unit length - in particular in the range of the short arc - the welding data shall be laid down by the manufacturer and be checked by the authorized inspector.

Table 4.5.3-3: Welding data reference values for the production of all-weld metal test coupons - Solid wire electrode -

Wire electrode diameter mm	Welding current A	Welding voltage V	Welding speed cm/min	Energy per unit length kJ/cm	Test coupon form to DIN EN ISO 15792-1	Preheat and interpass temperatures °C
1.2	250 ± 10	25 to 28	50	7.5 to 8.5	1.3	125 to 175
	280 ± 10	26 to 31		14 to 17		
1.6	300 ± 10	26 to 29	30	15.5 to 17.5		

For other electrode diameters and welding conditions outside the verified range of energy per unit length - in particular in the range of the short arc - the welding data shall be laid down by the manufacturer and be checked by the authorized inspector

Table 4.5.3-4: Welding data reference values for the production of all-weld metal test coupons - Flux cored electrode -

Welding rod diameter mm	Welding current A	Welding voltage V	Welding speed cm/min	Energy per unit length kJ/cm	Test coupon form to DIN EN ISO 15792-1	Preheat and interpass temperatures °C
3.0	200 ± 10	approx. 15	approx. 15	approx. 12	1.2	125 to 175

Table 4.5.3-5: Welding data reference values for the production of all-weld metal test coupons - Tungsten inert gas welding -

4.5.4 Heat treatment conditions

(1) If the size of the furnace does not permit the heat treatment of the entire test coupon, the test coupon may be subdivided. The heat treatment of the all-weld metal may not be performed on machined-out test specimens.

(2) If other heat treatments are required than those specified in **Tables 4.5.4-1 to 4.5.4-3**, the requirements of (3) to (8) hereafter apply:

(3) Stress relieving

- a) Welding rods for welding of carbon and low-alloy steels as well as weld metal with similar chemical composition

The holding time shall be 15 hours at the highest stress-relieving temperature for the materials within the intended range of application of the weld filler metal. Cooling shall be effected down to approx. 300 °C in the annealing furnace and then in air.

- b) Filler metals for low-alloy and medium-alloy steels

The holding time shall be 50 hours for all wall thicknesses and 15 hours in the case of a wall thickness limitation to ≤ 80 mm at the highest stress relieving temperature for the materials within the intended range of application of the weld filler metal. Cooling shall be effected down to approx. 300 °C in the annealing furnace and then in air.

(4) Normalizing

The holding time shall be half an hour at the highest normalizing temperature permitted for the materials within the intended range of application of the weld filler metal. Cooling shall be effected in the annealing furnace not to exceed 3 hours down to 300 °C and then in air.

(5) Tempering

The holding time shall be 15 hours at the highest tempering temperature permitted for the materials within the intended range of application of the weld filler metal. Cooling shall be effected down to approx. 300 °C in the annealing furnace and then in air.

(6) Quenching and tempering

Accelerated cooling as specified for the material with subsequent tempering as per (5) shall be effected.

(7) Stabilizing

The heat treatment shall be effected to satisfy AD 2000-Merkblatt HP 7/3. The holding time shall be 15 hours.

(8) Solution annealing

The holding time shall be half an hour at the lowest solution annealing temperature permitted for the materials within the intended range of application of the weld filler metal, e.g. to DIN EN 10088-2, Tables A.1 to A.5. Cooling shall be effected in water. Depending on the range of application of the weld filler metal a shorter or longer holding time as well as other cooling conditions are possible. These conditions shall be taken over into the data sheet for weld filler metals.

4.5.5 Test conditions, form and number of test specimens

4.5.5.1 General

The requirements of DIN EN ISO 15792-1 shall apply to all-weld metal test specimen coupons, the orientation and the form of test specimens. The extent of the test shall be as specified in **Tables 4.5.4-1 to 4.5.4-3**.

4.5.5.2 Tensile tests at room temperature

(1) The tensile test shall be carried out to DIN EN ISO 6892-1. The following values shall be determined:

- in the case of ferritic welding consumables:
the lower yield strength or, if this does not develop, the 0.2 %-proof stress, as well as tensile strength, elongation at fracture, reduction of area,
- in the case of austenitic and nickel alloy welding consumables:
the 0.2 %- and 1.0 %-proof stresses, as well as tensile strength, elongation at fracture, reduction of area.

The proportional specimen to DIN 50125 with a diameter d_0 of 10 mm shall be used.

(2) Three specimens shall be tested for each heat treatment condition and test diameter.

4.5.5.3 Hot tensile tests

(1) The tensile test shall be carried out to DIN EN ISO 6892-2. The following values shall be determined:

- in the case of ferritic welding consumables:
the 0.2 %-proof stress, tensile strength, elongation at fracture, reduction of area,
- in the case of austenitic and nickel alloy welding consumables:
the 0.2 %- and 1.0 %-proof stresses, as well as tensile strength, elongation at fracture, reduction of area.

The proportional specimen to DIN 50125 with a diameter d_0 of 10 mm shall be used.

One specimen shall be tested for each temperature and tested diameter of the weld filler metal.

(2) For one dimension of the respective weld filler metal, hot tensile tests at several temperatures (e.g. between room temperature and the upper test temperature at intervals of about 100 °C) shall be carried out within the range of application of the test such that the characteristic curve is determined. For all other dimensions, it shall be sufficient to choose as test temperature the highest temperature to be guaranteed.

4.5.5.4 Notched bar impact tests

For each test temperature, one set of impact test specimens (3 V-notch test specimens) shall be tested in accordance with DIN EN ISO 9016, where a 2 mm radius striker shall be used. The absorbed energy (KV_2) shall be determined; in the case of ferritic materials, the lateral expansion and the ductile fracture portion to DIN EN ISO 148-1 shall be determined additionally.

- a) The complete KV_2 -T curve shall be determined for ferritic materials, as follows:

The temperatures to be used shall be 33 °C and 80 °C. At least three further temperatures shall be specified such that both upper shelf and lower shelf are covered (90 % and 10 % ductile fracture portion). The extent of testing shall be as specified in **Tables 4.5.4-1 and 4.5.4-2**.

In the case of weld filler metals and welding consumables which are intended for the containment vessel, one of the test temperatures shall be 5 °C.

- b) The partial KV_2 -T curve shall be determined for ferritic materials as follows:

In addition to the 33 °C temperature, at least three other temperatures shall be specified in such a way that the upper shelf and transition temperature range are covered.

- c) In the case of austenitic weld filler metals the requirements of **Tables 4.5.4-3** shall apply.

			Notched bar impact test KV ₂ -T curve			Drop weight test for the determina- tion of the NDT tem- perature	Tensile test		Bend test		Chemical composition of weld metal	Hardness test and ex- amination of micro- structure		Determi- nation of hydrogen	
			complete	limited	ageing		flat tensile speci- men	round tensile specimen	cover pass	root		on the tensile side	Weld metal		Weld connection
Rod elec- trode, flux cored wire elec- trode	Weld metal	Smallest core rod di- ameter (minimum 2.5 mm), flux cored wire diameter 1.2 mm, with 7.5 to 8.5 kJ/cm	U, S _{SV}					U, S _{SV}	U, S _{SV}			X	U, S _{SV}		
		Core rod diameter 4 mm, flux cored wire diameter 1.2 mm	U, S ₃ , S _{SV}	S ₂				U, S ₃ , S _{SV}	U, S ₃ , S _{SV}			X	U, S ₃ , S _{SV}		X ²⁾
		Greatest core rod di- ameter; flux cored wire diameter 1.6 mm	U, S ₃ , S _{SV}	S ₂	U, S ₁			U, S _{SV}	U ³⁾			X	U, S _{SV}		
	Weld con- nection	Position PA	U, S _{SV}			U, S _{SV}	U, S ₃			U, S ₃	U, S ₃			U, S _{SV}	
		Position PF	U, S _{SV}	S ₂		U, S _{SV}	U, S ₃			U, S ₃	U, S ₃			U, S _{SV}	
		Position PE		U						U	U			U	
Wire flux combina- tion	Weld metal	Medium energy per unit length	U, S ₃ , S _{SV}		U, S ₁			U, S ₃ , S _{SV}	U, S ₃ , S _{SV}			X	U, S ₃ , S _{SV}		X ²⁾
	Weld con- nection	High energy per unit length	U, S ₃ , S _{SV} ⁴⁾	S ₂		U, S _{SV}	U, S ₃			U, S ₃	U, S ₃			U, S _{SV}	
		Low energy per unit length ¹⁾	U, S ₃ , S _{SV}	S ₂		U, S _{SV}	U, S ₃			U, S ₃	U, S ₃			U, S _{SV}	
Heat treatment U : If allowable, without heat treatment - otherwise S ₁ S ₁ : 1 h at T _{min} S ₂ : 5 h at 0.5 · (T _{min} + T _{max}) S ₃ : 15 h at T _{max} S _{SV} : Specification by the authorized inspector ¹⁾ Where required, use of a second wire diameter from the same batch. ²⁾ Two production units; different core rod diameters may be tested. ³⁾ The high-temperature strength history in the temperature range that is applied for above 20 °C shall be determined at intervals of 100 °C each. ⁴⁾ An additional set of notched bar impact test specimens from the dendritic area in the bead centre shall be tested at a temperature to be agreed upon with the authorized inspector.															

Table 4.5.4-1: Extent of testing for low-alloy weld filler metals (rod electrodes, flux cored electrodes and wire/flux combination)