Rules For Classification And Construction

Part 1 Seagoing Ships

Volume VI

RULES FOR WELDING

Consolidated Edition 2022

Biro Klasifikasi Indonesia

www.bki.co.id

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Foreword

This Rules is a consolidated edition 2022 of Rules for Welding (Pt.1, Vol.VI).

In this edition there are no new amendments added, only consolidate the 2021 edition, RCN No.1 and RCN No. 2. The summary of previous edition and amendments including the implementation date are indicated in Table below:

No.	Edition/ Rule Change Notice (RCN)	Effective Date	Link
1.	Consolidated Edition 2021	-	
2.	RCN No.1 - May 2021	1st July 2021	
3.	RCN No.2 - November 2021	1st January 2022	

Note: Full previous edition and amendments including its amendment notice is available through link above.

This rules is available to be downloaded at www.bki.co.id. Once downloaded, this Rules will be uncontrolled copy. Please check the latest version on the website.

Further queries or comments concerning this Rules are welcomed through communication to BKI Head Office.

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Section 1 General Rules

A. General

1. Scope

1.1 These Rules apply to all welding work performed in the course of new construction, conversion or repairs carried out on ships and their machinery installations, including steam boilers, pressure vessels and pipelines, for which an application for classification has been submitted to Biro Klasifikasi Indonesia or which have been classified by BKI.

Note:

The terms "welding", "welding work", "welding process" etc. used in these Rules also cover all other thermal and/or mechanized joining processes such as brazing which, because they are deemed as "special processes" under the terms of the quality assurance standards, require pre-qualification which has to be carried out by qualified personnel and constantly monitored. These Rules shall be applied in an analogous manner to these processes. Where no special provisions are made in the following paragraphs, the nature and scope of the quality assurance measures required will be specified by BKI on a case-by-case basis.

1.2 They also apply to all welding work on components, installations or implements for which BKI has issued Rules, Guidelines or other technical directions in which reference is made to these Rules.

1.3 These Rules shall be applied in analogous manner where other Rules, Guidelines or technical directions issued by BKI contain no special instructions with regard to welding work.

2. Application in other fields

These Rules may be applied in analogous manner to welding work carried out on structures and components other than those mentioned under 1., the supervision and inspection of which is the concern of BKI. Where necessary, appropriate arrangements shall be made with BKI.

3. Exceptions to these Rules

Exceptions to these Rules require the consent of BKI Head Office in each individual case.

4. Alterations and additions

BKI reserves the right to alter or add to these Rules from time to time, should this prove necessary on the basis of more recent knowledge or operating experience.

B. Other Rules, Standards and Specifications

1. Other relevant standards

1.1 The standards or other technical directions mentioned in the following sections form an integral part of these Rules and shall also be complied with. The same applies to the working documents, e.g. drawings, welding specifications, etc. approved by BKI.

1.2 Where the following Sections refer to standards in which a date is specified, the current version shall apply. Where no dates are specified, the version of the standards which shall be applicable shall be the one valid at the time that these Rules were issued. The use of later versions of these standards is subject to the consent of BKI.

1.3 Where the following Sections refer to both ISO and EN standards and if, where they are both specified, the standards are not identical, the ISO standards shall take precedence. Where the two standards are identical, either the ISO or the EN standard may be used.

1.4 The application of other Rules, Standards, Regulations or other technical directions is subject to the consent of BKI Head Office in each individual case. BKI may make any such approval conditional upon construction and dimensioning also being subject to these directions.

2. Differences in requirements

If there are differences in requirements between these Rules and the other relevant standards or specifications, the requirements of these Rules shall take precedence, unless otherwise stipulated.

C. Information in Working Documents

1. Drawings, other working documents

1.1 The drawings, and other working documents to be submitted before commencing the fabrication work must contain all the necessary details for the preparation, execution and, where applicable, the inspection of the welds.

This information shall in particular include details of:

- Base materials, shapes and dimensions of product
- Welding processes, welding consumables and auxiliary materials
- Shapes and dimensions of welds
- Preheating and heat input during welding
- Heat treatment after welding
- Subsequent treatment of the welds
- Nature and scope of inspections
- Requirements applicable to the welded joints (e.g. quality grade, weld performance, evaluation category or the like).

1.2 Provided that in the fabrication of ship's structures, the materials, welding processes, welding consumables, auxiliary materials and the shapes and dimensions of welds conform to normal shipbuilding practice, these Rules and the approvals, these details need not be specified.

2. Additional information and documentation

For particular structures (e.g. liquefied gas tanks), materials (e.g. quenched and tempered structural steels and clad plates) or welding processes, the following additional information and documentation shall be provided as necessary:

- Weld preparation, assembly, auxiliary (tack) welds
- Welding positions, welding sequence (drawings)
- Weld build-up, number of passes
- Heat input during welding (heat input per unit length of weld)

This information shall be combined in a welding specification (see Annex D). For test schedules and specifications for non-destructive testing, see Section 10.

D. Materials, Weldability

1. All materials shall be of proven weldability. They shall be chosen in accordance with the intended application and the conditions of service and shall comply with the requirements stated in the Rules for Materials (P.1, Vol. V). Their properties shall be documented to the specified extent by test certificates, e.g. in conformity with ISO 10474 / EN 10204.

Note:

The hull structural steels and rolled products described in the Rules for Materials (Pt.1, Vol. V), for the manufacture of steam boilers, pressure vessel, pipelines and machinery are deemed to be of proven weldability.

2. If, not withstanding 1., materials are to be welded whose properties are not described in the Rules for Materials (Pt.1, Vol. V), the welding shop concerned shall furnish proof of their weldability (e.g. by reference to existing standards) or submit specific material specifications for approval. If there is doubt as to the weldability of a material, the welding shop shall specially demonstrate this in the course of the welding procedure tests.

3. The welding shop shall ensure that only materials which meet the requirements of 1. and 2. Are used for both original and replacement supplies, and shall furnish proof thereof to the Surveyor on request.

E. Welding Consumables and Auxiliary Materials

1. The welding consumables and auxiliary materials shall enable a welded joint to be made which is suited to the base material and the operating conditions. They shall have been tested for product suitability in accordance with Section 5 and approved for the application in question. This provision applies in an analogous manner to brazing metals.

2. Approval shall as a rule have been given by BKI. If, in special cases, e.g. repairs, no welding consumables which have been tested by BKI are available, welding consumables approved by other recognized testing bodies may be used with BKI consent. Relevant proof of this must be submitted to Surveyor.

3. The welding shop's supervisors shall ensure that only tested welding consumables and auxiliary materials which have been approved by BKI are used and shall furnish proof thereof to the Surveyor on request.

F. Quality Assurance, Responsibility

1. Compliance with Rules, Quality inspections

1.1 Shipyards or welding shops are responsible for ensuring that the welding work conforms to these and any supplementary Rules as applicable, the approved working documents, any conditions as may be stated in the approvals, good shipbuilding practice, and also the state of the art technology relating to welding.

1.2 Shipyards or welding shops must ensure, by means of regular in house quality inspections during the production process and at the end of the welding work, that such work has been properly and expertly executed. The responsibilities of the welding supervisors are also covered in ISO 14731. The tests to be performed by BKI Surveyors shall not relieve the welding shop of this responsibility.

1.3 The range and extent of the quality inspections required is determined by the structure in question. In each case, however, it is necessary to ensure that the specified materials, welding consumables and auxiliary materials are used and that weld preparation, assembly, performance of tack and welding work, together with the accuracy to size and completeness of the components and welded joint meet the requirements.

1.4 Following inspection by the welding shop and any repairs which may be necessary, the components must be presented to BKI Surveyor for inspection at appropriate stages of construction, easily accessible and as a rule unpainted. The Surveyor may reject those components which have been inadequately inspected by the welding shop and specify that a component be presented again after a successful inspection by the welding shop and, where necessary repairs.

2. Placing subcontracts

2.1 When placing orders with subcontractors, independent branch companies or suppliers as well as outside companies working in the welding shop who are themselves approved (so-called “contract companies”, see note to paragraph A.1.1 in Section 2) the “prime contractor” must ensure that the provisions stated in 1. are also complied with by the “subcontractor”.

2.2 Where the outside companies working in the welding shop are not themselves approved or where contract labour is used, the welding shop placing the contract shall be responsible for ensuring that the conditions stated in 1. are complied with and that the quality inspection are performed. BKI shall be notified of the placing of subcontracts or the use of contract labour.

3. Deviation from approved working documents, repairs

3.1 If alterations to the design compared with the approved drawings or deviations from approved fabrication procedures become necessary, the welding shop shall promptly obtain the Surveyor's consent thereto. BKI Surveyor shall be notified of any repairs which become necessary during fabrication

3.2 If, due to inadequate or incorrect information in the production documents (e.g. workshop drawings), the quality or functional capability of a component cannot be guaranteed or is doubtful, BKI may require appropriate repairs to be carried out.

3.3 This shall apply in an analogous manner to supplementary or additional components (e.g. reinforcements) even if these are not specified during the examination of the drawing or could not be specified owing to a lack of detail shown in the "class plans" (see Rules for Hull (Pt.1, Vol.II) Sec.1, G.).

4. Marking and identification of materials

4.1 The materials shall be marked in such a way that they can be identified and matched up with the test certificates even during and after fabrication.

4.2 If the marking is likely to be erased during manufacture, the welding shop shall promptly see to it that it is transferred to another part of the product. This can be dispensed with in the case of small parts of minor importance such as ribs or bracings, provided that any confusion of materials can be prevented by operational means.

5. Marking of welds

5.1 In the fabrication of steam boilers and vessels under internal pressure, each weld section shall be marked with the symbol of the welder who executed it. This may be dispensed with if the welding shop supervisory staff keep a record of the names of the welders who execute the individual weld sections.

5.2 In special cases, the Society may also require marking or record–keeping as described in 5.1 for other components or their welded joints.

G. Inspections Tests, Liability

1. Presentation of components

The welding shop shall be obliged to present the components to the Surveyor for the required intermediate and final inspections. Steps shall be taken to ensure unimpeded access to the welds. The welds shall not be treated with coatings or preservatives which make it difficult or impossible to assess the condition of the welds.

2. Supplying of test documentation

For the inspections, all the manufacturer's records and documents concerning the quality assurance measures undertaken by him shall be submitted. These include in particular:

- Drawings (approved if required) and other working documents
- Material test certificates
- Welder's, and welding procedure test certificates
- Test reports and films of the non - destructive tests
- Certificates of hot-forming and heat treatment, where applicable
- Results of production tests, intermediate results if necessary

3. Subsequent defects

3.1 BKI gives no guarantee that the products, welded structures or components tested by its Surveyor to the extent laid down (normally random tests) conform to the requirements in every respect and that their manufacture has been performed correctly and in accordance with the tested procedures.

3.2 Products or welded structures which prove defective in subsequent use or in the operation or processes which exhibit deficiencies in use may be rejected even if an earlier inspection was satisfactory, if it is not possible to remedy the defect or deficiency.

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Section 2 Requirements for Welding Shops, Approval

A. Approval of Welding Shops

1. General

1.1 Shipyards and welding shops, including branches and subcontractors, which perform welding work covered by these Rules shall have been approved for this work by BKI. The preconditions for this approval are that the shops satisfy the requirements under B., have been inspected by BKI in accordance with C. and, where necessary, have carried out welding procedure tests in accordance with D.

Note:

The term welding shop used in the following paragraphs is understood to mean the welding production plant which, due to its space and organizational facilities, can be regarded as an independent unit. Branches and subcontractors shall generally be regarded as independent facilities which have to meet the requirements stated below. In particular, each welding shop shall have available its own permanent in house welding supervisory staff (see B.2.) Outside companies working in welding shops may be approved as independent companies. For details of this and contract labour, see Section 1, F.2.

1.2 Any approval in accordance with 1.1 covers the most essential welding quality requirements in accordance with the standards ISO 3834. For certification under the terms of these standards, the requirements set out in 2.2 and 3.2 shall also be met. These additional requirements shall be regarded as having been met when the welding shop has in place a certified quality assurance system in accordance with the series of standards ISO 9000.

1.3 In individual valid exceptions, e.g. in the case of repairs, BKI may grant approval for welding work to be executed even without approval being granted to the welding shop, subject to a time limit and restricted to a specific structure, if the welding shop pre-conditions have been specified for such work and the quality of the welds performed is demonstrated by relevant tests, e.g. non-destructive and/or production tests.

2. Application for approval

Introductory remark:

Where no special provisions are given in the following paragraphs or, in an individual case, no other arrangements are made, the provisions for "Approval" set out in accordance with these Rules shall also apply in an analogous manner to "Certification" in accordance with ISO 3834.

2.1 Approval shall be applied for in writing to BKI Head Office. The application shall contain the following details, which shall be related to each other as far as possible, (see Description of Welding Shop, Annex B, item 2.), of the scope of the desired approval:

– Nature of the structure and/or components
– Materials and dimensional ranges
– Welding procedures and positions

– Heat treatments (if necessary)
– Weld factor (pressure vessels)

2.2 If a certificate of compliance with the welding quality requirements stipulated in ISO 3834 part 2, part 3 or part 4 is required over and above approval in accordance with these Rules, this shall be expressly noted in the application for approval.

3. Approval documents

3.1 Welding shops applying for approval to carry out welding work shall submit the following documents to BKI Head Office with their application for approval (see Annex A):

– A description of the welding shop: see the form in Annex B
– Copies of the qualification documents of the welding supervisor(s)
– Copies of the valid welder's certificates or a list of the qualified welders (testing standard, testing body, date of testing, test category, date of last retest) signed by the Surveyor.
– Copies of documentation as proof of the qualification of supervisory and test personnel, as appropriate.
– Copies of reports of welding procedure tests performed elsewhere, including the approvals granted, as appropriate.

3.2 For certification in accordance with 2.2, information and documents relating to the elements specified in Annex A to ISO 3834-1 for the respective grade of requirement (ISO 3834 - 2 = comprehensive, ISO 3834-3 = standard, or ISO 3834-4 = elementary quality requirements) shall also be enclosed with the application for approval (e.g. in the form of relevant procedure instructions):

– contract review
– design review
– treatment of subcontractors
– equipment maintenance
– quality inspections
– non-conformances
– calibration
– identification
– traceability

If the welding shop operates a certified quality assurance system conforming to the series of standards ISO 9000, the QA manual and - if specified in Annex A to ISO 3834-1 - documentation relating to the quality assurance measures performed (quality reports) shall be submitted to BKI for inspection in place of the above information and documents.

4. Period of validity of approval, renewal

4.1 An approval granted according to these Rules or certification in accordance with ISO 3834 shall be valid for 4 (four) years subject to periodical inspection on second year. Provided that welding work is constantly performed under BKI supervision during the validity of the approval and that the preconditions on which approval was granted have not changed, approval may be extended on application by the welding shop for further 4 (four) years subject to an appropriate inspection.

4.2 If no welding work has been carried out under BKI supervision for more than a year, an application for renewal of the approval, enclosing updated information as specified in 3., shall be made no later than the end of the 4 (four) years period of validity. Approval may only be renewed if the necessary preconditions continue to apply, which shall be verified by a re-inspection of the welding shop. The approval may then be renewed for a further period of 4 (four) years.

5. Changes, revocation

5.1 If the preconditions under which approval was granted change, e.g. through the use of untested welding procedures, materials and/or welding consumables, or if changes are made to the welding shop supervisory staff, BKI shall be notified voluntarily. As a rule, this necessitates a revision of the approval.

5.2 An approval shall cease to be valid if the preconditions under which it was granted cease to apply. If serious defects are detected in the components or the welds, BKI is entitled to carry out interim reinspection of the production facilities and may, if necessary, revoke the approval.

B. Requirements for Welding Shops

1. Technical equipment

1.1 Welding shops shall have at their disposal suitable workshops, equipment, machinery and jigs on a scale necessary for proper performance of the welding work. This includes, for example, the provision of storage facilities and baking equipment for the welding consumables and auxiliary materials, preheating and heat treatment equipment, testing appliances and equipment, and means of weather protection for carrying out welding work in the open air.

1.2 Equipment and facilities not belonging to the welding shop itself, e.g. testing appliances, may be taken into account when evaluating the capabilities of a welding shop, provided that the preconditions necessary to proper fabrication and testing are satisfied and that such equipment is available without restriction.

2. Welding shop supervisory staff

2.1 Welding shops or branches (see note A.1.) shall have at least one fully qualified welding supervisor, who is responsible for ensuring that the welding work is competently performed. Welding supervisors shall have training and experience corresponding to the scope of the fabrication work and shall provide BKI with the necessary documentary proof thereof.

2.2 The names of the welding supervisor in charge and his deputy shall be notified to BKI, see Annex B "Description of the Welding Shop", 3. If the supervision role is carried out by more than one person, the responsibilities and tasks of each person shall be established and specified. The welding supervisor in charge and his deputy shall be recognized by BKI as part of the approval for the welding shop.

2.3 The following persons shall be appointed as welding supervisors depending on the nature and scope of the work:

– Welding engineers[1] for fabrication of important components of the hull structure and of offshore installations, also of handling equipment, steam boilers, pressure vessels, pressure lines and engine and transmission components

– Welding specialists[2] for fabrication of simpler or less heavily stressed components.

For information relating to the qualification of the welding supervisory staff, their tasks and responsibilities see ISO 14731.

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[1] e.g. professional welding engineers as defined in the guidelines of the European Welding Federation (EWF) or engineers with an equivalent level of knowledge

[2] e.g. welding technicians or welding experts as defined in the EWF guidelines or, if necessary, other persons with suitable knowledge

2.4 The welding supervisor(s) shall be permanently employed by the welding shop. Supervision of the welding work by outside staff is not acceptable.

3. Welders and operators

3.1 Welding shops shall be staffed with qualified welders and, for fully mechanized and automatic welding equipment, adequately trained operators. The required number of qualified welders is determined by the size of the welding shop and the scope of the welding work to be performed under BKI supervision. However, a minimum of two qualified welders are required for each welding process.

3.2 Welders for manual and semi-mechanized welding shall have passed a test in accordance with Section 3 and in conformity with a recognized standard (e.g. ISO 14732, ISO 9606 or ASME Section IX as applicable). The test shall cover the conditions likely to occur in the fabrication work with regard to the process(es), base material, welding consumable and welding position(s). The production of test pieces in a successfully completed welding procedure or production test may be taken as proof of manual skill for testing of welders, see Section 3, G.3.

3.3 Operators of fully mechanized or automatic welding equipment and of welding robots shall have been trained in the use of the equipment. They shall also be capable of setting or programming and operating the equipment in such a way that the required weld quality is achieved. The qualification of such personnel shall be demonstrated in accordance with ISO 14732 on welded test pieces, e.g. in welding procedure or fabrication tests or by means of random tests and operational tests as applicable (please refer to the standards).

4. Test supervisory staff and test personnel

Where the welding shop has its own test supervisory staff and test personnel (see Section 10, C.), documentary proof of their qualification (e.g. certificates conforming to ISO 9712) shall be submitted to BKI.

C. Inspection of Welding Shops

1. Shop inspection

Before starting the fabrication work, it shall be proved to BKI Surveyor in the course of an inspection of the welding shop that the requirements applicable to the technical equipment as stated in B.1 are satisfied. For this purpose the Surveyor shall be given access to all departments and laboratories relevant to fabrication and testing. The fabrication and quality control procedures shall also be described and explained to him if he so requests. For certification according to ISO 3834, compliance with the additional quality requirements stated in the standards shall be demonstrated to the Surveyor (see A.3.2).

2. Submission of documentation

As part of the welding shop inspection procedure, originals of all documents necessary in order to evaluate the fabrication and quality assurance procedures shall be submitted to the Surveyor. These especially include the welding supervisors' qualification documents, welder's certificates, reports on previous welding procedure tests, and results of quality tests and welder's retests. For certification according to ISO 3834, compliance with the additional quality requirements stated in the standards shall be demonstrated to the Surveyor (see A.3.2).

D. Welding Procedure Tests

1. General provisions

1.1 If welding procedure tests are required, their successful performance shall be a further precondition for the approval of a welding shop or for extending its approval. Requirements for the performance of this tests and requirements applicable to test results are given in Section 4 and in Sections 12 to 16.

1.2 Welding procedure tests shall be performed in such a way that the conditions of fabrication can be covered with regard to materials, welding processes, welding consumables and auxiliary materials, wall thicknesses, shapes of welds and heat treatments. The properties of the base materials for the test pieces shall be documented by test certificates.

2. Scope of the welding procedure test

Note:

Please refer to the detailed information given in Section.4.D.

2.1 In general, a welding procedure test is valid only within the limits specified in the approval and is not transferable from the welding shop where it is performed to a different welding shop. BKI may permit exceptions in the case of a nearby branch welding shop which is under the constant supervision of the main welding shop, where the same fabrication conditions prevail and where the same welding processes are used.

2.2 Welding procedure tests performed in a workshop are in general not simultaneously valid for welding in the field. In such cases, the welding procedure test shall be repeated in whole or in part under field conditions as determined by BKI. BKI may waive the repeat testing by prior agreement if the properties of the field welds are documented by production tests.

3. Recognition of other tests

Welding procedure tests performed under the supervision of other testing bodies which are independent of the works may be recognized in full or in part by BKI at the welding shop's request if this is acceptable on the basis of the test results. In such a case, the complete test reports and the approval certificate of the other testing body shall be submitted to BKI for evaluation.

E. Certification of Approvals, Certificates according to ISO 3834

1. BKI issues certificates for the approval of welding shops to carry out welding work and for welding procedure tests if the requirements set out in these rules are satisfied in the tests. These welding shop and welding procedure approvals are valid within the limits stated in the certificates.

2. Where proof has been furnished that the additional requirements listed in A.3.2 according to ISO 3834 have been met, BKI issues a certificate based on this in accordance with this standard.

3. If previously issued approval certificates are replaced or supplemented by more recent ones (see A.5.1) and the details in the more recent approval certificates contradict those of previous approvals, the details in the more recent certificate shall be valid. This applies especially to the range of application, e.g. for a specific welding process.

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Section 3 Welder's Qualification Tests

A. General

1. Scope

1.1 This Section gives requirements for a qualification scheme for welders intended to be engaged in the fusion welding of steels and aluminium as specified in Rules for Materials (Pt.1 Vol.V) Sec. 4.B., 4.L, Sec.5.B, Sec.6.B, Sec.7.B, and Sec.10 for hull structures and piping system of ships.

(IACS UR W32 1.1)

1.2 This qualification scheme does not cover welders engaged in oxy-acetylene welding and welding of pressure vessels.

(IACS UR W32 1.2 & 1.3)

1.3 Welder's qualification tests for particular applications (particular materials or shapes of weld, welding process) which are not covered by the tests and work assignments described below (e.g. for clad plates or offshore pipe junctions) shall be carried out according to a test schedule to be agreed with BKI on a case-by-case basis.

2. Required testing (welding processes)

2.1 Welder's qualification tests are required for all welders who are to perform welding work using manually guided welding appliances (as in manual metal arc welding or semi-mechanized gas-shielded metal arc and/or welding using flux-cored electrodes) and where the quality of the welded joints depends mainly on the manual skill of the welder.

2.2 For welders who perform welding work on steam boiler installations, the relevant National Rules shall also be complied with.

2.3 The welding operator responsible for setting up and/or adjustment of fully mechanized and automatic equipment, such as submerged arc welding, gravity welding, electro-gas welding and MAG welding with auto-carriage, etc., shall be qualified whether he operates the equipment or not. However a welding operator, who solely operates the equipment without responsibility for setting up and/or adjustment, does not need qualification provided that he has experience of the specific welding work concerned and the production welds made by the operators are of the required quality.

The qualification test and approval range of the welding operator are left to the discretion of BKI with reference to ISO 14732:2013.

(IACS UR W32 2.2)

3. Training, manual skill, knowledge

3.1 The training of welders, control of their qualification and maintenance of their skills are the responsibility of welding shop. BKI Surveyor is to verify and be satisfied that the welders are appropriately qualified.

3.2 Welder's qualification tests may only be taken by welders who have received appropriate previous training (both practical and theoretical) and who have had sufficient opportunity to practice the craft.

3.3 Besides the necessary manual skill, the welder shall also possess the professional knowledge enabling him to perform the welding work competently and safely. See the relevant information in the ISO 9606-1 Annex B and ISO 9606-2 Annex C.

4. Lists of welders, symbols

4.1 Welding shops are required to maintain lists or files which furnish information about the number, names (code number) and test scope of the welders and the dates of their initial and repeat tests. These lists shall be submitted to BKI for examination on demand together with the relevant original documentation or, where appropriate, together with the description of the welding shop (see Section 2, A.3.).

4.2 Each welder shall be assigned an unmistakable symbol, which shall be recorded in the testing documentation (certificates, lists, etc.). BKI may in addition - depending on the application - require the components and welds to be marked with the symbol of the welder who performed the work; see also Section 1, F.5.

B. Testing Bodies

1. Initial tests in the welding shop

The initial testing of welders in the welding shop is to be conducted by the welding supervisory staff in the presence of Surveyor. Following submission of the welder performance test forms completed by the welding shop and initialled by the Surveyor (see Annex C), these tests will be confirmed by BKI Head Office either in the form of test certificates.

2. Repeat tests in the welding shop

2.1 Repeat tests taken by welders who have been certified by BKI or by those certified by other recognized testing bodies and recognized by BKI may be conducted independently by the welding engineer recognized by BKI in conjunction with the approval granted to the welding shop. Tests conducted by other welding supervisors shall be carried out in the presence of BKI representative.

2.2 The extension of the validity of a test certified by BKI by a further two years may, however, only be authorized by BKI. For this purpose, a full set of test documentation (welding procedure specification, welder performance test form and test report) shall be submitted to the Surveyor, see E. 3.

3. Tests conducted by other testing bodies

Welder's qualification tests conducted by other testing bodies (e.g. welding training and testing establishments or welding training establishments) which are independent of the welding shop which are recognized by BKI will be recognized by BKI subject to the test categories specified in D. Such recognition is subject to the submission to BKI of a full set of test documentation, as described in 2.2 above.

C. Performance of Welder's Qualification Tests

1. Welding Procedure Specification (WPS or pWPS)

For welding test pieces, a Manufacturer's Welding Procedure Specification (WPS or pWPS) shall be produced by the welding shop - a separate one for each welding task - in accordance with the Annex D. The welding conditions for testing shall match those during fabrication.

2. Test pieces

2.1 Test pieces for butt welds and for fillet welds are to be prepared as shown in Fig. 3.1, Fig. 3.2, Fig. 3.3 and Fig. 3.4 in each qualification test. For pipe circumferences of less than 150 mm, additional test pieces will be required with a maximum of three test pieces.

(IACS UR W32 4.2.1)

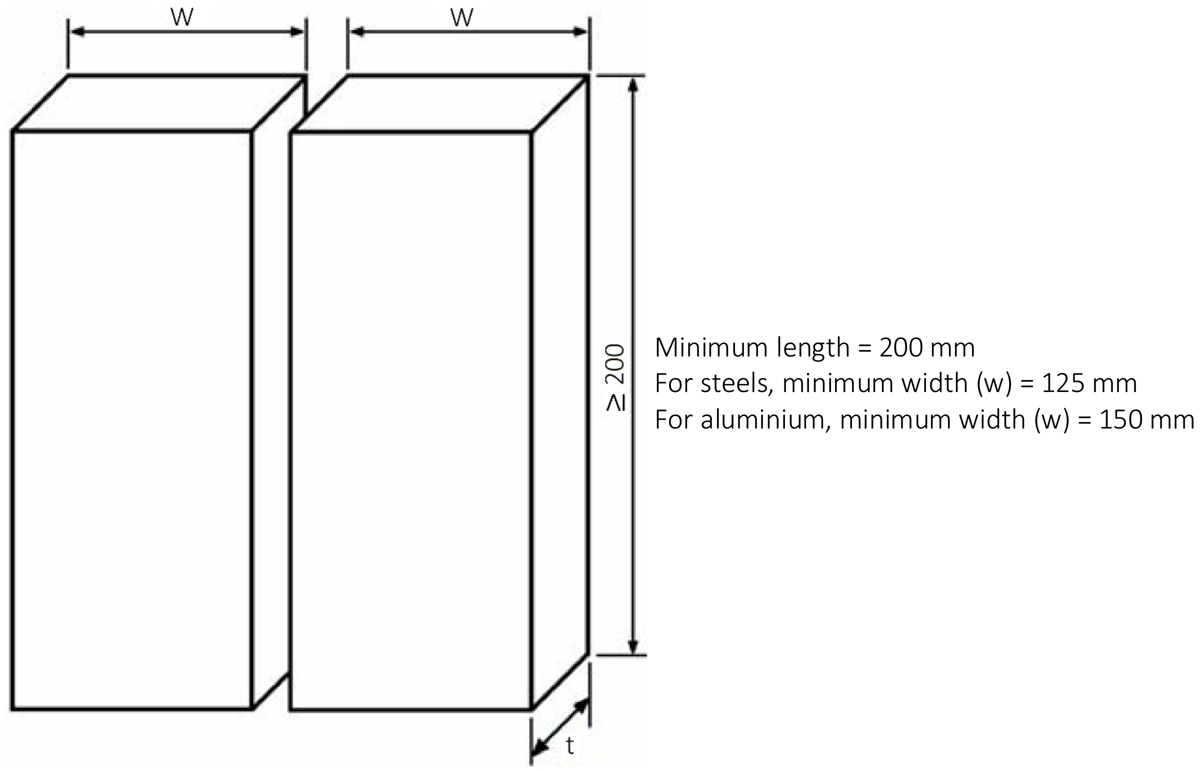
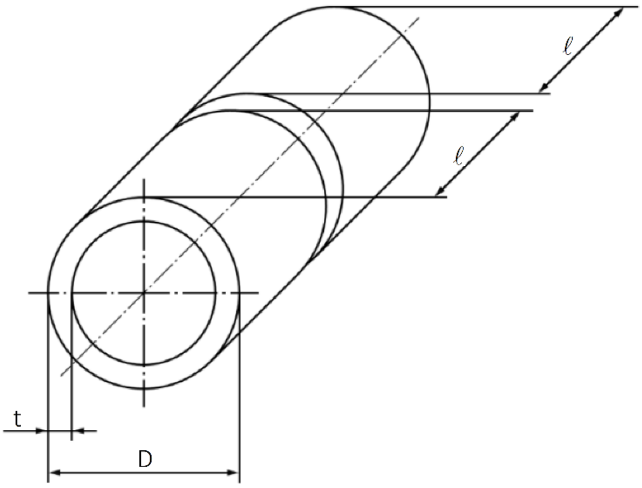
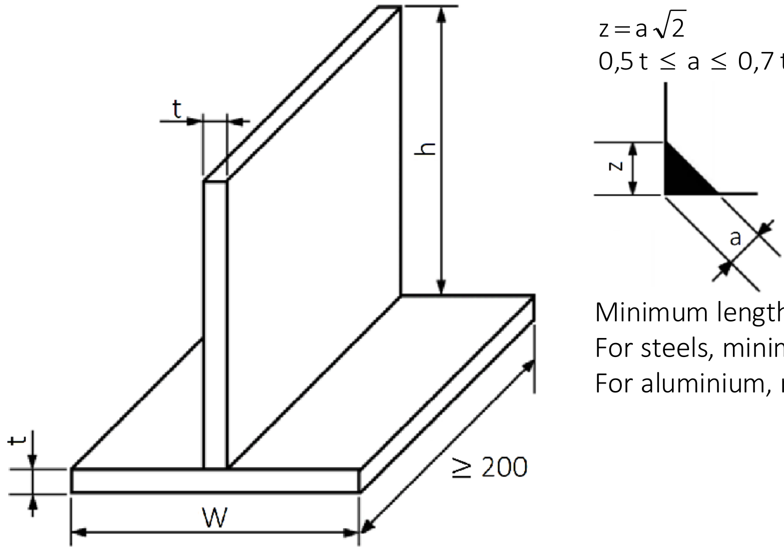


Fig. 3.1 Dimensions of test piece for a butt weld in plate



For steels, minimum length = 125 mm
For aluminium, minimum length = 150 mm

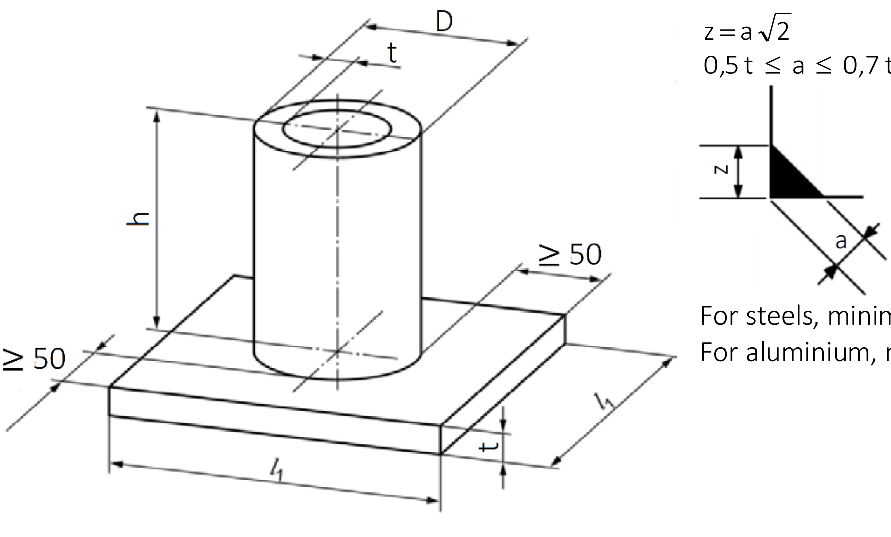
Fig. 3.2 Dimensions of test piece for a butt weld in pipe



$z = a\sqrt{2}$
$0{,}5\,t \leq a \leq 0{,}7\,t$

Minimum length = 200 mm
For steels, minimum width/height = 125 mm
For aluminium, minimum width/height =150 mm

Fig. 3.3 Dimensions of test piece for a fillet weld in plate



$z = a\sqrt{2}$
$0{,}5\,t \leq a \leq 0{,}7\,t$

For steels, minimum height = 125 mm
For aluminium, minimum height = 150 mm

Fig. 3.4 Dimensions of test piece for a fillet weld in pipe

2.2 Test pieces for butt tack welds and for fillet tack welds are to be prepared as shown in Fig. 3.5 and Fig. 3.6.

(IACS UR W32 4.2.2)

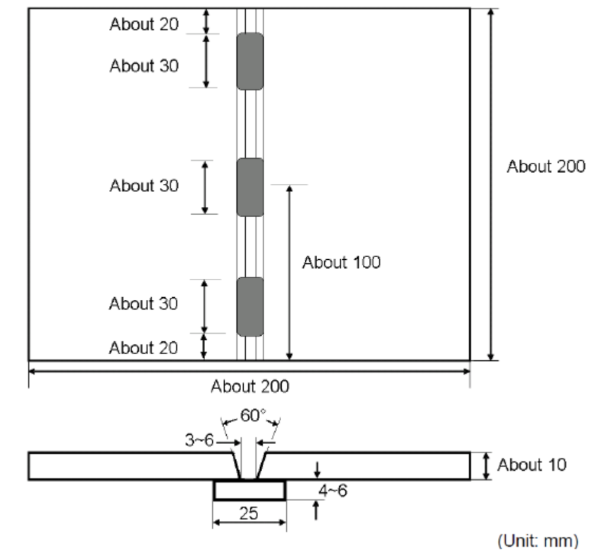


Fig. 3.5 Dimensions and types of test piece for tack butt welds

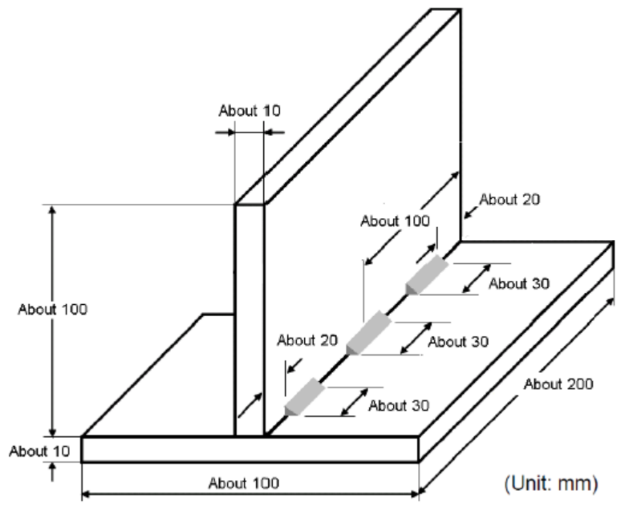


Fig. 3.6 Dimensions and types of test piece for tack fillet welds

2.3 Testing materials and welding consumables shall conform to one of the following requirements or to be of equivalent grade approved by BKI:

a) Testing materials:

- hull structural steels specified in Rules for Material (Pt.1, Vol. V) Sec. 4, B.
- YP47 steels specified in Rules for Material (Pt. 1, Vol. V) Sec. 4, L.
- hull structural forged steels specified in Rules for Material (Pt.1, Vol. V) Sec. 6.
- hull structural cast steels specified in Rules for Material (Pt.1, Vol. V) Sec. 7.
- aluminium alloys for hull construction and marine use specified in Rules for Materials (Pt.1, Vol. V), Sec. 10, B.

b) Welding consumables:

- consumables for hull structural steels and YP47 steels specified in Section 5, B. to E

– consumables for aluminium alloys specified in Section 5, J.

(IACS UR W32 4.2.3)

3. Welding of test pieces,

3.1 The welding of test piece shall follow a WPS or pWPS as a reference. Welding supervisor on yard shall record the welding details and parameters on Welder Performance Qualification Test Form in accordance with the Annex C, which is verified by welding supervisor and BKI Surveyor after the welder qualification test is done. Welding of the test pieces and testing of test specimens shall be witnessed by the Surveyor.

(IACS UR W32 4.1.1)

3.2 During the welding of test piece, these items shall be noticed:

3.2.1 Before welding, the test piece shall be marked with:

– KI specimen stamp (KI)

– for fixed pipe welds, 12 o'clock welding position shall also be marked.

3.2.2 After welding, the test piece shall be marked with:

– code or name of welder

– welding position

– base material grade

3.2.3 The test piece shall have at least one stop and restart in the root run and in the capping run. When more than one process is used, at least one stop and restart shall be carried out for each process, this includes the root run and final run. The stop and restart areas shall be marked for radiography test.

3.2.4 In a condition when a welder is to be qualified for two or more welding processes by welding a single test piece (multi-process joint), the deposited thickness for each welding process used shall be included in the form.

3.2.5 Any post-weld heat treatment required in the WPS or pWPS shall be done except for non-destructive test.

3.2.6 The welder shall be allowed to remove minor imperfections by grinding, except for the capping run for which only the stop and restart may be ground.

4. Examination and Test

4.1 The test pieces specified in 2. shall be examined and tested as follows:

a) For butt welds:

– Visual examination

– Bend test

Note:

Radiographic test or ultrasonic test (for ferritic steels with thickness more than 8 mm) or fracture test may be carried out in lieu of bend test except the gas-shielded welding processes with solid wire or metal cored wire.

b) For fillet welds:

– Visual examination

- Fracture test

Note:

Two macro sections may be taken in lieu of the fracture test.

c) For tack welds

- Visual examination
- Fracture test

Additional tests may be required, at the discretion of BKI.

(IACS UR W32 4.3.1)

4.2 Visual Examination

The welds shall be visually examined prior to the cutting of the test specimen for the bend test and fracture test. The result of the examination is to show the absence of cracks or other serious imperfections.

Imperfections detected are to be assessed in accordance with quality level B in ISO 5817:2014 for steels or ISO 10042:2018 for aluminium and aluminium alloys, except for the following imperfection types for which level C applies:

- excess weld metal
- excess penetration
- excessive convexity
- excessive throat thickness

(IACS UR W32 4.3.2)

4.3 Bend Test

When bending testing is used, the test piece examination length shall be cut into four test specimens of equal width (see Figs. 3.5, 3.6 and 3.9).

Transverse bend test specimens are to be in accordance with Section 11, D.

The test specimens are to be bent through 180 degrees. The mandrel or the inner roller diameter to thickness ratio (D/T) shall be according to Tabel 3.1.

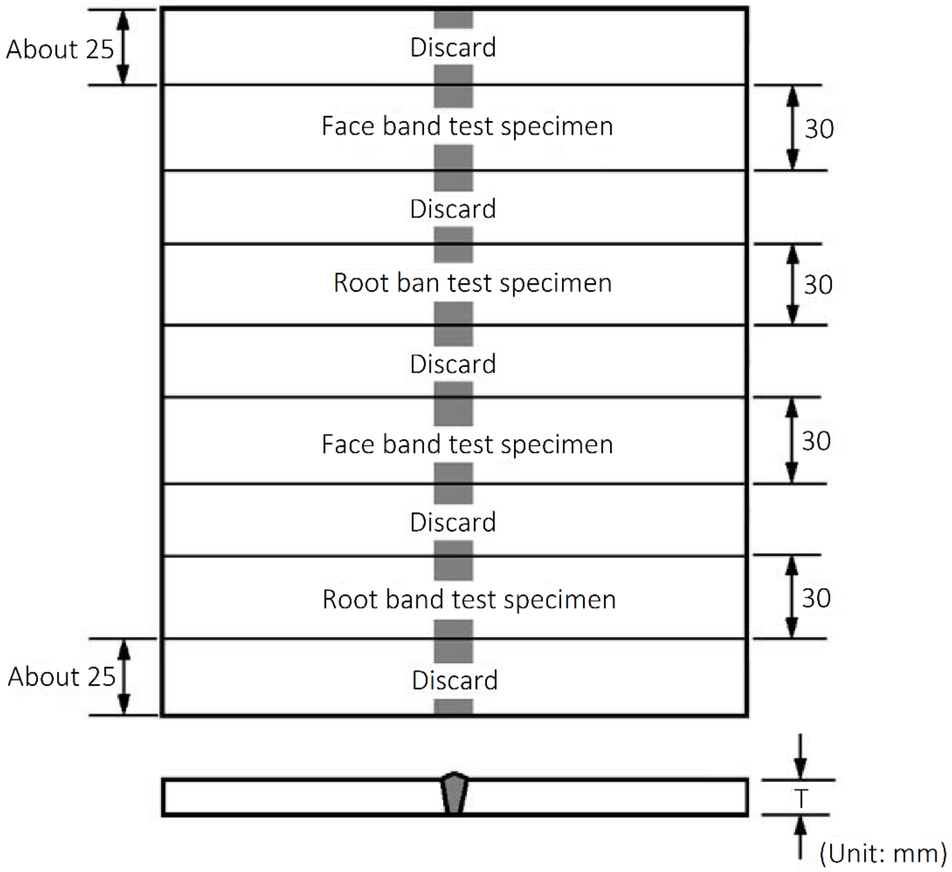


Fig. 3.5 Dimensions and types of test assembly for butt welds (T < 12 mm)

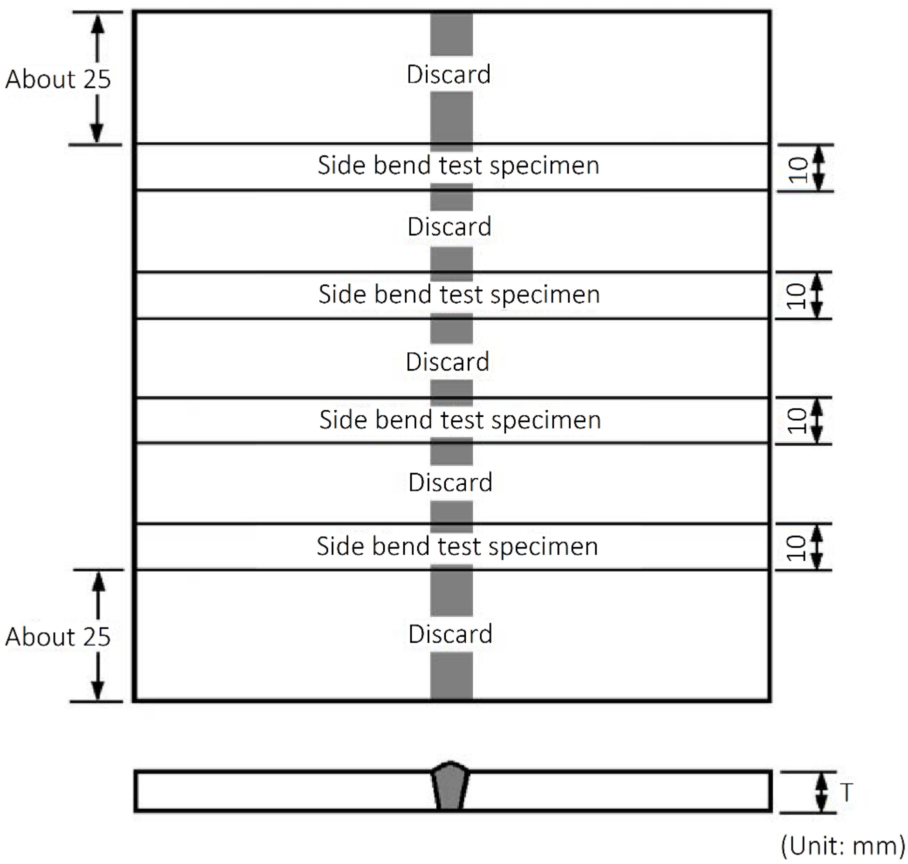


Fig. 3.6 Dimensions and types of test assembly for butt welds (T ≥ 12 mm)

Table 3.1 The mandrel diameter to thickness ratio (D/T)

Base Materials	Mandrel diameter to thickness ratio (D/T)
Normal and higher structural steel	4
YP 47 steels	5
Aluminium alloy grade 5754	3
Aluminium alloy grade 5083, 5086, 5456, 5454, 5059, 5383, 6082, 6061, 6106, 6005	6

Two face bend test and two root bend test specimens are to be tested for initial qualification test, and one face and one root bend test specimens for extension of approval. For thickness 12 mm and over, four side specimens (two side specimens for extension of approval) with 10 mm in thickness may be tested as an alternative.

At least one bend test specimen shall include one stop and restart in the bending part, for root run or for cap run.

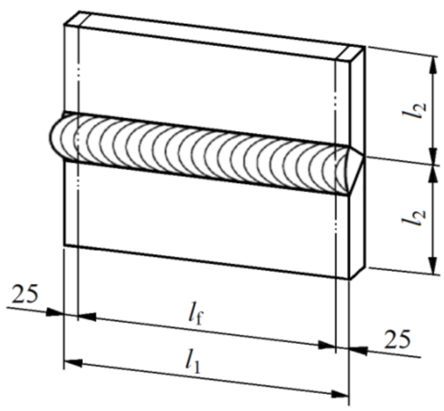
After the test, the test specimens shall not reveal any open defects in any direction greater than 3 mm.

Defects appearing at the corners of a test specimen during testing should be investigated case by case. Defects shall be ignored in the evaluation unless there is evidence that cracking is due to incomplete penetration, slag or other defects. The sum of the greatest defects exceeding 1 mm but less than 3 mm in any one bend specimen shall not exceed 10 mm.

4.4 Radiographic Test

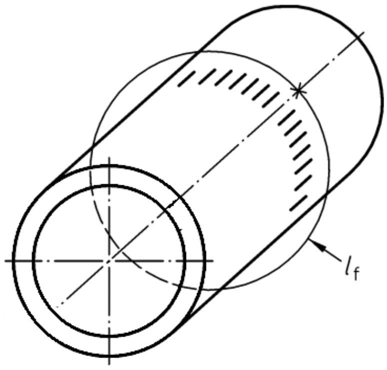
When radiographic testing is used for butt welds, the examination length of the weld (see Fig. 3.7, Fig. 3.8 and Fig. 3.9) in the test piece shall be radiographed in the as-welded condition (no removal of excess weld metal), imperfections detected shall be assessed in accordance with quality level B in ISO 5817:2014 for steels and ISO 10042:2018 for aluminium alloys except for excess weld metal, excessive convexity, excess penetration for which level C applies.

(IACS UR W32 4.3.4)



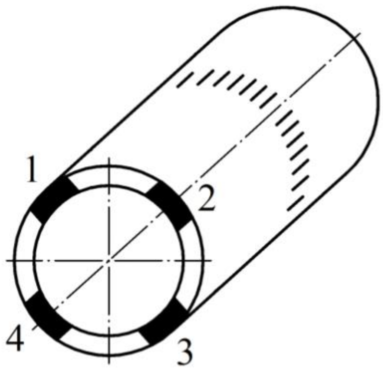
l_1 = length of test piece
l_2 = half width of test piece
l_f = examination length

Fig. 3.7 The examination length of the radiographic test for plate



l_f = examination length

Fig. 3.8 The examination length of the radiographic test for pipe



1 = one root fracture or one root transverse bend or one side bend test specimen
2 = one face fracture or one face transverse bend or one side bend test specimen
3 = one root fracture or one root transverse bend or one side bend test specimen
4 = one face fracture or one face transverse bend or one side bend test specimen

Fig. 3.9 Sectioning of bending or fracture test specimens

4.5 Fracture Test (Butt Welds)

For butt welds in plate and pipe, the test piece examination length (Fig. 3.7 and Fig.3.9 respectively) shall be cut into four test specimens of equal width in accordance with the dimensions given in Table 3.2.

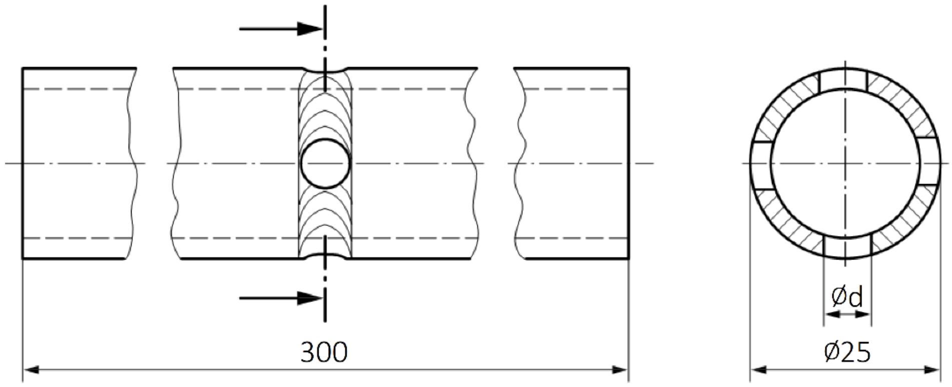
Imperfections detected shall be assessed in accordance with quality level B in ISO 5817:2014 for steels and ISO 10042:2018 for aluminium alloys except for excess weld metal, excessive convexity, excess penetration for which level C applies.

(IACS UR W32 4.3.5)

Table 3.2 Width of fracture test specimens

Product Type		Width of fracture test specimens (mm)
Plate	Pipe [1]	
X	D ≥ 100 mm	≥ 35
–	50 ≤ D < 100 mm	≥ 20
–	25 < D < 50 mm	≥ 10

D = outer diameter
[1] For pipes with outside diameter D ≤ 25 mm, the notch tensile test piece according to Fig. 3.10 is recommended.



Holes are not allowed in start and stop areas.

For t ≥ 1,8 mm: d = 4,5 mm

For t < 1,8 mm: d = 3,5 mm

Fig. 3.10 Example for notch tensile test for pipe test piece outside diameter ≤ 25 mm

4.6 Fracture Test (Fillet Welds)

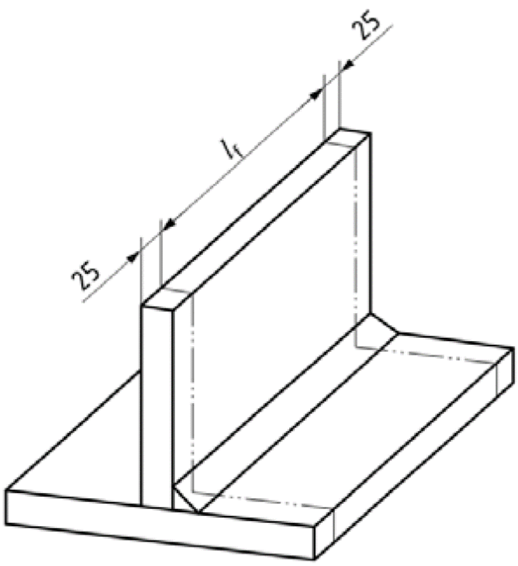
For fillet welds on plate, the test piece examination length (Fig. 3.11) shall be fractured as one complete specimen. If necessary, the test piece can be cut into several test specimens of equal width.

For fillet welds on pipe, the test piece shall be cut into four or more test specimens and fractured (one possibility is shown in Fig. 3.12).

The fracture test is to be performed by folding the upright plate onto the through plate. Evaluation shall concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration.

Imperfections that are detected shall be assessed in accordance with quality level B in ISO 5817:2014 for steels and ISO 10042:2018 for aluminium alloys.

(IACS UR W32 4.3.6)



l_f = examination length

Fig. 3.11 Examination length for fracture testing for a fillet weld in plate

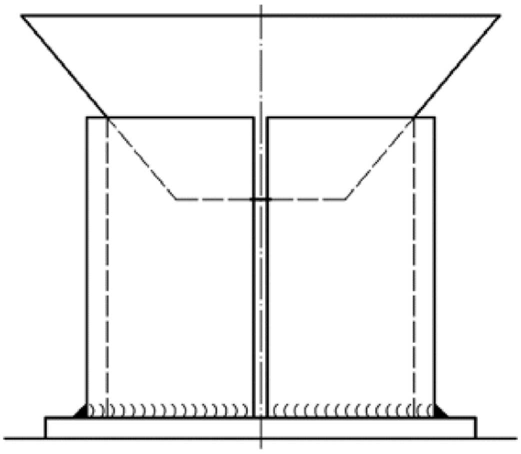


Fig. 3.12 Preparation and fracture testing of test specimens for a fillet weld on pipe

4.7 Macro Examination

When macro examination is used for fillet welds, two test specimens are to be prepared from different cutting positions; at least one macro examination specimen shall be cut at the position of one stop and restart in either root run or cap run. These specimens are to be etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone.

Macro sections shall include about 10 mm of unaffected base metal.

The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal, sufficient root penetration and the absence of defects such as cracks, lack of fusion etc.

5. Retest

5.1 When a welder fails a qualification test, the following shall apply:

5.1.1 In cases where the welder fails to meet the requirements in part of the tests, a retest may be welded immediately, consisting of another test piece of each type of welded joint and position that the welder failed.

In this case, the test is to be done for duplicate test specimens of each failed test.

All retest specimens shall meet all of the specified requirements.

5.1.2 In cases where the welder fails to meet the requirements in all parts of the required tests or in the retest prescribed in 5.1.1, the welder shall undertake further training and practice.

5.1.3 When there is specific reason to question the welder's ability or the period of effectiveness has lapsed, the welder shall be re-qualified in accordance with the tests specified in 2.

5.1.4 Where any test specimen does not comply with dimensional specifications due to poor machining, a replacement test assembly shall be welded and tested.

6. Recording of result

The assessment form provided at Annex C is to be used to record the details and results of the tests (p = passed, np = not passed). Additional sheets shall be used as necessary.

D. Range of Qualification

A welder is to be qualified in relation to the following variables of welding:

- welding process(es);
- product type (plate or pipe);
- type of welded joint;
- material grouping;
- filler material type;
- dimension (material thickness and outside pipe diameter);
- welding position;
- weld detail(s) (material backing, gas backing, flux backing, consumable insert, single side welding, both side welding, single layer, multi-layer).

(IACS UR W32 3.1)

1. Welding processes

The welding processes for welder's qualification are to be classified in Table 3.3.

Table 3.3 Welding processes for welder's qualification

Symbol	Welding process in actual welding works		ISO 4063
M	Manual Welding	Manual metal arc welding (metal arc welding with covered electrode)	111
S	Semi-Automatic Welding / Partly mechanized welding	MIG welding with solid wire electrode	131
		MAG welding with solid wire electrode	135
		MAG welding with flux cored electrode	136
		MAG welding with metal cored electrode	138
T	TIG Welding	TIG welding with solid filler material (wire/rod)	141

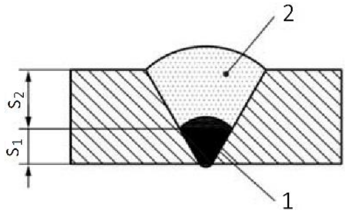
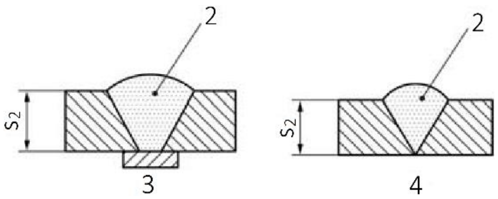
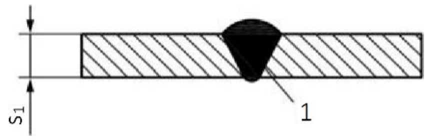
Each testing normally qualifies only for one welding process. A change of welding process requires a new qualification test. Exceptions are as follows:

- a change from MAG welding with solid wire electrode (135) to that with metal cored electrode (138), or vice versa, does not require requalification
- qualifying the welder for dip (short-circuit) transfer mode (131, 135 and 138) shall qualify him for other transfer modes, but not vice versa.

However, it is permitted for a welder to be qualified for two or more welding processes by welding a single test piece (multi-process joint) or by two or more separate qualification tests. The ranges of qualification concerning the deposited thickness for each welding process used and for the multiprocess joint for butt welds are given in Tables 3.4.

(IACS UR W32 3.4)

Table 3.4 - Deposited thickness range of weld metal for single and multi-process joints for butt weld

Welding process used for test piece	Deposited thickness range qualified according to Table 3.10	
	Single process joint	Multi-process joint
 1 = welding process 1 (ss nb) 2 = welding process 2 (ss mb)	for welding process 1 : $t = s_1$ for welding process 2 : $t = s_2$	$t = s_1 + s_2$
 2 = welding process 2 3 = welding with backing (ss mb) 4 = welding with backing (ss nb)	for welding process 1 : $t = s_1$ for welding process 2 : $t = s_2$	for $t = s_1 + s_2$ welding process 1 only for welding of the root area
 1 = welding process 1		

2. Product type

Test piece welds with outside pipe diameter D > 25 mm cover welds in plates.

Test piece welds in plates cover:

- welds in rotating pipes of outside pipe diameter D ≥ 75 mm for welding positions PA, PB, PC, and PD.
- welds in fixed pipe (PH, PF, H-L45) of outside pipe diameter D ≥ 500 mm.

3. Type of welded joint

3.1 Butt welds cover butt welds in any type of groove joint. Butt welds qualify fillet welds but not vice versa. BKI may require a qualification test with fillet welding for welders who are employed to perform fillet welding only.

(IACS UR W32 3.8)

3.2 A welder qualified for butt or fillet welding can be engaged in tack welding for the welding process and position corresponding to those permitted in his certificate.

Alternatively, welders engaged in tack welding only can be qualified on the test assemblies shown in Fig. 3.5 or Fig. 3.6.

(IACS UR W32 3.9)

3.3 Welders engaged in full/partial penetration T welds shall be qualified for butt welds for the welding process and the position corresponding to the joints to be welded.

(IACS UR W32 3.5)

4. Material grouping

The qualification test shall be carried out with filler material from one of the groups listed in Table 3.5.

Table 3.5 – Filler material grouping

Group	Filler material for welding of	Examples of applicable standards
FM1	Non-alloy and fine grain steels	ISO 2560, ISO 14341, ISO 636, ISO 14171, ISO 17632
FM2	High strength steels	ISO 18275, ISO 16834, ISO 26304, ISO 18276
FM3	Creep-resisting steels Cr < 3,75 %	ISO 3580, ISO 21952, ISO 24598, ISO 17634
FM4	Creep-resisting steels 3,75 ≤ Cr ≤ 12 %	ISO 3580, ISO 21952, ISO 24598, ISO 17634
FM5	Stainless and heat-resisting	ISO 3581, ISO 14343, ISO 17633
FM6	Nickel and nickel alloys	ISO 14172, ISO 18274

Welding with a filler material in one group qualifies the welder for welding with all other filler materials within the same group, as well as other groups, listed in Table 3.6.

Table 3.6 – Range of qualification for filler material

Filler material	Range of Qualification					
	FM1	FM2	FM3	FM4	FM5	FM6
FM1	X	X	–	–	–	–
FM2	X	X	–	–	–	–
FM3	X	X	X	–	–	–
FM4	X	X	X	X	–	–
FM5	–	–	–	–	X	–
FM6	–	–	–	–	X	X

X indicates those filler materials for which the welder is qualified.
– indicates those filler materials for which the welder is not qualified.

For aluminium and aluminium alloys, grouping system based on the parent material group where the welding of any one parent material in a group confers qualification on the welder for the welding of all other parent material within the same group as well as other groups according to Table 3.7.

Table 3.7 – Range of qualification for parent material of aluminium and aluminium alloys

Material group[1) of the test piece	Range of qualification					
	21	22	23	24	25	26
21	X	X	–	–	–	–
22	X	X	–	–	–	–
23	X	X	X [2)	–	–	–
24	–	–	–	X	X	–
25	–	–	–	X	X	–
26	–	–	–	X	X	X

X indicates those material groups for which the welder is qualified.
– indicates those material groups for which the welder is not qualified.

1) Material group according to ISO 15608
2) see also 5.

5. Filler material type

For manual metal arc welding, qualification tests are required using basic, acid or rutile covered electrodes.

The ranges of qualification for filler material type are given in Tables 3.8 and 3.9.

Welding with filler material qualifies for welding without filler material, but not vice versa.

(IACS UR W32 3.3)

Table 3.8 Range of qualification for covered electrodes (SMAW)

Welding process	Type of covering used in the test [a)	Range of qualification		
		A, RA, RB, RC, RR, R 03, 13, 14, 19, 20, 24, 27	B 15, 16, 18, 28, 45, 48	C 10, 11
111	A, RA, RB, RC, RR, R 03, 13, 14, 19, 20, 24, 27	X	–	–
	B 15, 16, 18, 28, 45, 48	X	X	–
	C 10, 11	–	–	X

X indicates those filler material types for which the welder is qualified.
– indicates those filler material types for which the welder is not qualified.

a) The type of covering used in the qualification test of welders for root run welding without backing (ss nb) is the type of covering qualified for root run welding in production with no backing (ss nb).

Table 3.9 - Range of qualification for filler material types[1)

Welding process	Filler material types used in test piece	Range of qualification			
		Solid wire (S)	Metal core wire (M)	Flux cored wired (B)	Flux cored wired (R, P, V, W, Y, Z)
131, 135	Solid wire electrode (S)	X	X	–	–
138, 141	Metal cored electrode (M)	X	X	–	–

Table 3.9 - Range of qualification for filler material types[1] *(continued)*

Welding process	Filler material types used in test piece	Range of qualification			
		Solid wire (S)	Metal core wire (M)	Flux cored wired (B)	Flux cored wired (R, P, V, W, Y, Z)
136	Flux cored electrode (B)	–	–	X	X
	Flux cored electrode (R, P,V, W, Y, Z)	–	–	–	X

X indicates those filler material types for which the welder is qualified.
– indicates those filler material types for which the welder is not qualified.

1) The type of flux cored wire used in the qualification test of welders for root run welding without backing (ss, nb) is the type of flux cored wire qualified for root run welding in production with no backing (ss, nb).

For aluminium and aluminium alloy, qualification with AlMg alloy type filler metals qualifies the use of AlSi alloy types but not vice versa.

For welding process 131 an increase of the Helium (He) content of the shielding gas greater than 50% requires qualification test.

6. Dimension

The welder qualification test of butt welds is based on the thickness and outside pipe diameters. The range of qualification for thickness are specified in Tables 3.10 for steels and Tables 3.11 for aluminium and aluminium alloys, whereas the range of qualification for outside pipe diameters is specified in Tables 3.12.

For fillet welds, the range of qualification for thicknesses is specified in Table 3.13.

For test pieces of different outside pipe diameters and thicknesses, the welder is qualified for:

– the thinnest through to the thickest deposited and/or parent metal thickness qualified; and
– the smallest through to the largest diameter qualified.

The qualified thickness range for tack welders is 3 mm and over.

Table 3.10 - Range of qualification of deposited thickness for butt welds of plate/pipe (steels)

Deposited thickness of test piece [mm]	Range of qualification[1] [mm]
t < 3	t to 2t
3 ≤ t < 12	3 to 2t
t ≥ 12 [2) 3)]	≥ 3 [3)]

1) For single process and the same type of filler material, t is equal to parent material thickness.
2) The test piece has to be welded in at least 3 layers
3) For multi-processes, t is the deposited thickness for each process.

Table 3.11 - Range of qualification of material thickness and weld metal thickness (multi process) of test piece for butt welds (aluminium and aluminium alloys)

Material thickness of test piece, t [mm]	Range of qualification [mm]
t ≤ 6	0,5 t to 2 t
t > 6	≥ 6

Table 3.12 - Range of qualification for outside pipe diameter (steels & aluminium and aluminium alloys)

Outside pipe diameter of test piece, D [1)] [mm]	Range of qualification [mm]
D ≤ 25	D to 2 D
D > 25	≥ 0,5 D (min. 25 mm)

1) For non-circular hollow sections, D is the dimension of the smaller side.

Table 3.13 - Range of qualification of material thickness for fillet welds[1)] (steels & aluminium and aluminium alloys)

Material thickness of test piece, t [mm]	Range of qualification [mm]
t < 3	t to 2t or 3, whichever is greater
t ≥ 3	≥ 3

1) See also Table 3.19

7. Welding positions

The range of qualification for each welding position is given in Tables 3.14 and Tables 3.15 for steels and Table 3.16 and Table 3.17 for aluminium and aluminium alloys. Diagrams showing the definitions of welding position used in Tables 3.14 – 3.17 are shown in Annex I.

Welding two pipes with the same outside pipe diameter, one in welding position PH/5G-up and one in welding position PC/2G, also covers the range of qualification of a pipe welded in welding position H-L045/6G-up using upward welding.

Welding two pipes with the same outside pipe diameter, one in welding position PJ/5G-down and one in welding position PC/2G, also covers the range of qualification of a pipe welded in welding position J-L045/6G-down using downward welding.

Outside pipe diameters D ≥ 150 mm can be welded in two welding positions (PH/5G-up or PJ/5G-down 2/3 of circumference, PC/2G 1/3 of circumference) using only one test piece. This test covers all positions for the direction of welding used in the test.

Table 3.14 - Range of qualification for welding positions when testing with butt welding (steels)

Testing position[2)]	Range of qualification[1)]								
	PA Flat	PB Horizontal vertical	PC Horizontal	PD Horizontal overhead	PE Overhead	PF Vertical up	PG Vertical down	PH Up-wards	PJ Down-wards
	1G / 1F	2F	2G / 2F	4F	4G / 4F	3G-up / 3F / 5F	3G v-d / 3F v - d	5G-up / 5F-up	5G v-d / 5F v-d
PA	X	X	–	–	–	–	–	–	–
PC	X	X	X	–	–	–	–	–	–
PE (plate)	X	X	X	X	X	–	–	–	–
PF (plate)	X	X	–	–	–	X	–	–	–
PH (pipe)	X	X	–	X	X	X	–	X	–
PG (plate)	–	–	–	–	–	–	X	–	–
PJ (pipe)	X	X	–	X	X	–	X	–	X
H-L045	X	X	X	X	X	X	–	X	–

Table 3.14 - Range of qualification for welding positions when testing with butt welding (steels) *(continued)*

Testing position[2]	Range of qualification[1]								
	PA Flat	PB Horizontal vertical	PC Horizontal	PD Horizontal overhead	PE Overhead	PF Vertical up	PG Vertical down	PH Up-wards	PJ Down-wards
	1G / 1F	2F	2G / 2F	4F	4G / 4F	3G-up / 3F / 5F	3G v-d / 3F v - d	5G-up / 5F-up	5G v-d / 5F v-d
J-L045	X	X	X	X	X	–	X	–	X

X indicates those welding positions for which the welder is qualified.
– indicates those welding positions for which the welder is not qualified.

[1] Additionally the requirements of 2. shall be observed.
[2] Butt welds in pipes qualify branch joints with an angle ≥ 60°.

Table 3.15 - Range of qualification for welding positions when testing with fillet welding (steels)

Testing position	Range of qualification						
	PA Flat	PB Horizontal vertical	PC Horizontal	PD Horizontal Overhead	PE Overhead	PF Vertical up	PG Vertical down
	1F	2F	2F	4F	4F	3F uphill	3F downhill
PA	X	–	–	–	–	–	–
PB	X	X	–	–	–	–	–
PC	X	X	X	–	–	–	–
PD	X	X	X	X	X	–	–
PE (Plate)	X	X	X	X	X	–	–
PF (Plate)	X	X	–	–	–	X	–
PH (Pipe)	X	X	–	X	X	X	–
PG (Plate)	–	–	–	–	–	–	X
PJ (Pipe)	X	X	–	X	X	–	X

X indicates those welding positions for which the welder is qualified.
– indicates those welding positions for which the welder is not qualified.

Table 3.16 - Range of qualification for welding positions when testing with butt welding (aluminium and aluminium alloys)

Welding position of test piece	Range of qualification[1]									
	PA Flat	PB Hori-zontal vertical	PC Horizont al	PD Hori-zontal overhead	PE Over-head	PF (Plate) Vertical-up	PF (Pipe) Vertical-up	PG (Plate) Vertical-down	PG (Pipe) Vertical-down	H-L045 Upwards
	1G / F	2F	2G / 2F	4F	4G / 4F	3G up / 3F	5G up / 5F	3G v-d / 3F v-d	5G v-d	6G up
PA	X	X	–	–	–	–	–	–	–	–
PC	X	X	X	–	–	–	–	–	–	–
PE (plate)	X	X	X	X	X	X	–	–	–	–
PF (plate)	X	X	–	–	–	X	–	–	–	–
PF (pipe)	X	X	–	X	X	X	X	–	–	–
PG (plate)	–	–	–	–	–	–	–	X	–	–
PG (pipe)	X	X	–	X	X	–	–	X	X	–
H-L045	X	X	X	X	X	X	X	–	–	X

X indicates those welding positions for which the welder is qualified
– indicates those welding positions for which the welder is not qualified

[1] Additionally the requirements of 2. shall be observed.

Table 3.17- Range of qualification for welding positions when testing with fillet welding

(aluminium and aluminium alloys)

Welding position of test piece	Range of qualification [1]								
	PA	PB	PC	PD	PE	PF (Plate)	PF (Pipe)	PG (Plate)	PG (Pipe)
	1F	2F	2F	4F	4F	3F up	5F up	3F v-d	5G v-d
PA	X	X	–	–	–	–	–	–	–
PB	X	X	–	–	–	–	–	–	–
PC (plate)	X	X	X	–	–	–	–	–	–
PD	X	X	X	X	X	X	–	–	–
PE (plate)	X	X	X	X	X	X	–	–	–
PF (plate)	X	X	–	–	–	X	–	–	–
PF (pipe)	X	X	–	X	X	X	X	–	–
PG (plate)	–	–	–	–	–	–	–	X	–
PG (pipe)	X	X	–	X	X	–	–	X	X

X indicates those welding positions for which the welder is qualified
– indicates those welding positions for which the welder is not qualified

[1] Additionally the requirements of 2. shall be observed.

8. Weld details

The weld details for welder's qualification are to be classified as shown in Tables 3.18 in accordance with the qualification test.

Table 3.18 Weld details for welder's qualification

Weld details used in the test piece for the qualification				Weld details qualified
Butt weld	Single sided weld	with material backing	SS MB	SS MB, DS MB, SL, ML
		with gas backing	SS GB	SS MB, SS GB, DS MB, SL, ML
		with no backing	SS NB	SS MB, SS NB, SS GB, DS MB, DS NB, SL, ML
	Double sided weld	with gouging	DS MB	SS MB, DS MB, SL, ML
		without gouging	DS NB	SS MB, DS MB, DS NB, SL, ML
Fillet weld	Single layer weld	–	SL	SL
	Multi-layer weld	–	ML	SL, ML

E. Certification

1. Qualification certificates are normally issued when the welder has passed the qualification test in accordance with these Rules. Each welding shop shall be responsible for the control of the validity of the certificate and the range of the approval.

(IACS UR W32 5.1)

2. The following items shall be specified in the certificate:

a) Range of qualification for material groups, welding processes, filler metal type, types of welded joint, plate thicknesses and welding positions.

b) Expiry date of the validity of the qualification.

c) Name, date of birth, identification and the photograph of the welder.

d) Name of shipbuilder / manufacturer.

3. When a certificate is issued, the relative documents such as test reports and/or revalidation records shall be archived as annexes to the copy of certificate.

4. The status of approvals of each individual qualification is to be demonstrated to BKI when requested.

F. Period of Validity, Repeat Tests

1. Period of validity

1.1 Normally the validity of the welder's approval begins from the issue date of qualification certificate when all the required tests are satisfactory completed.

(IACS UR W32 6.1.1)

1.2 The certificate is to be signed at six-month intervals by the shipyards/manufacturers personnel who is responsible for production weld quality provided that all the following conditions are fulfilled:

a) The welder shall be engaged with reasonable continuity on welding work within the current range of approval. An interruption for a period no longer than six months is permitted

b) The welder's work shall in general be in accordance with the technical conditions under which the approval test is carried out

c) There shall be no specific reason to question the welder's skill and knowledge.

(IACS UR W32 6.1.2)

1.3 If any of these conditions are not fulfilled, BKI is to be informed and the certificate is to be cancelled.

(IACS UR W32 6.1.3)

1.4 The validity of the certificate may be maintained in agreement with BKI as specified in 3. The chosen maintenance option of qualification in accordance with 3.1 a) or b) or c) shall be stated on the certificate at the time of issue.

(IACS UR W32 6.1.4)

2. Repeat tests

2.1 A repeat test relating to an individual welding process is required where a welder who has been tested in more than one welding process has not used the process in question for longer than six months.

2.2 A repeat test is, in any case, necessary where a welder has not performed any welding work as defined in 1.2, for longer than six months.

2.3 BKI may demand a repeat test at any time should reasonable doubts arise as to a welders skill.

3. Revalidation of validity period

3.1 Revalidation shall be carried out by BKI. The skill of the welder shall be periodically verified by one of the following options:

1) The welder shall be re-tested every 3 years.

2) Every 2 years, two welds made during the last six months of the 2 years validity period shall be tested by radiographic or ultrasonic testing or destructive testing and shall be recorded. The weld tested shall reproduce the initial test conditions except for thickness and outside diameter. These tests revalidate the welder's qualifications for an additional 2 years.

3) A welder's qualification for any certificate shall be valid as long as it is signed according to 1.2 subject that all the following conditions are fulfilled. In this option, the fulfilment of all the conditions is to be verified by BKI. The frequency of verification by BKI is to be no longer than 3 years and is to be agreed between BKI and the shipyards/manufacturers.

   A) The welder is working for the same shipyard/manufacturer which is responsible for production weld quality as indicated on his or her qualification certificate.

   B) BKI shall verify that the welder quality management system of the shipyard/manufacturer includes as minimum:

      – A designated person responsible for the coordination of the welder quality management system.
      – List of welders and welding supervisors in shipyard/manufacturer
      – If applicable, list of subcontracted welders
      – Qualification certificate of welders and description of the associated management system
      – Training requirements for welder qualification programme
      – Identification system for welders and WPS used on welds
      – Procedure describing the system in place to monitor each welder performance based on results of welds examination records (e.g. repair rate, etc.) including the criteria permitting the maintenance of the welder qualification without retesting.

   C) The shipyards/manufacturers have to document at least once a year that the welder has produced acceptable welds in accordance with construction quality standards and BKI's requirements in the welding positions, type of welds and backing conditions covered by its certificate. Which documents are required and how to document the evidences should be in agreement between BKI and the shipyards/manufacturers.

(IACS UR W32 6.2.1)

3.2 The welder has to be verified compliance with the conditions of 3.1 above and the maintenance of the welder's qualification certificate is to be signed by the Surveyor.

(IACS UR W32 6.2.2)

3.3 If the conditions under which a revalidation is granted, as specified in 3.1 b) and c) above, are not met a repeat test is to be carried out conforming in scope to the initial test. If a repeat test is carried out with a restricted scope of testing compared with the initial test, the subsequent range of approval is determined by scope of testing of the repeat test.

G. Other Welder's Tests

1. Other rules and standards

1.1 BKI may consent to the performance of welder's qualification tests in accordance with other comparable recognized Rules, Standards or Codes. The work assignments of welders tested in accordance with these tests will be specified in analogous manner to the above Rules, Standards or Codes, depending on the scope of testing. The period of validity is as specified in F.

(IACS UR W32 2.5.1 & 2.5.2)

1.2 Welder's tests conforming to other Rules, Standards or Codes which have been conducted by an independent testing body in analogous manner to B.3. may be recognized by BKI subject to the foregoing provisions. The relevant welding procedure specifications, test reports, test certificates and, upon request, the relevant Rules, Standards or Codes shall be submitted to BKI for this purpose.

2. Exceptions

In justified exceptional circumstances (e.g. repairs), the Surveyor may, subject to a specified time limit and to limitation to a particular structure, authorize the employment of well-trained and experienced welders without the documentary qualifications stipulated above, provided that he has reason to believe that the welders concerned are competent to perform the work envisaged and that the quality of the welds produced by them can be verified by suitable, e.g. non-destructive tests.

3. Welder tests conducted as part of the welding procedure tests

The testing of welders may be included in the welding procedure tests (see Section 4, B.5.3) and their names will then be included in the welding procedure approval. A welder's qualification test certificate conforming to the standards may, however, only be issued provided that all the provisions of the standards, e.g. scope of test and job knowledge testing, have been met and that this is recorded in an assessment form which has been completed accordingly (see Annex C).

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Section 4 Welding Procedure Tests, Production Tests

A. General

1. Welding procedure tests in the user's works

1.1 Welding procedure tests shall be carried out under BKI supervision in the user's works before starting the fabrication work according to the scope described in Sections 12 to 16 for the different areas of application under workshop conditions. Workplace conditions (weather protection, welding equipment, operating jigs, welders, production allowances etc.) and any intended extreme cold-forming operations as well as heat treatments of the materials and/or the welds shall form an integral part of the welding procedure tests.

1.2 Table 4.1 gives a summary of the documentary proof required for recognition of welding processes in the different areas of application. The provisions in the relevant section of Sections 12 to16, however, take precedence.

1.3 Welding procedure tests which have already been carried out under the supervision of other independent testing bodies and certified by them are subject to the provisions of Section 2, D.3. In such cases BKI reserves the right to demand that supplementary production tests be carried out before the start of fabrication or during fabrication.

1.4 In individual, technically justified exceptional circumstances (e.g. repairs), the Surveyor may, subject to a specified time limit and to limitation to a particular structure, authorize the use of particular welding processes without carrying out a welding procedure test beforehand, provided that proof is furnished by means of other suitable tests (e.g. non-destructive weld tests and/or production tests) that the welding process in question is being applied correctly and safely.

2. Preliminary welding procedure test

2.1 A preliminary welding procedure test shall be carried out on the premises of manufacturers of welding equipment or welding consumables or at research institutions if, for special reasons, an immediate welding procedure test in the user's works appears inappropriate.

In this test, the welding parameters and, where applicable, the post-weld heat treatments shall conform to the conditions prevailing in the user's works. In all other respects, the provisions governing welding procedure tests in the user's works apply.

2.2 The preliminary welding procedure test does not relieve the user's works of the obligation to carry out a definitive welding procedure test. On the basis of the preliminary test, a simplified test schedule for the definitive welding procedure test may be accepted.

3. Production tests

3.1 Production tests shall be performed to the extent described in the relevant sections of Sections 12 to16 in the course of fabrication to monitor the quality of the welded joints. Test pieces welded at the same time as the production welds (e.g. in the course of a longitudinal weld of a plate, pipe or vessel shell ring) or sections of production welds may be used for this purpose. Where applicable, the test pieces shall as far as possible be heat-treated together with the component. As a rule, the production tests shall comprise both non-destructive tests and mechanical and technological tests.

3.2 Production tests are also required if a particular welding process has not been used under BKI supervision for a long time or if processes and/or materials to be welded require constant verification of the weld quality. The nature and scope of such production tests shall be established on a case-by-case basis.

3.3 In addition, BKI may require production tests to be carried out if the way in which the welding work is performed gives rise to doubts as to the quality of the welded joints or if individual welding parameters, welding consumables or auxiliary materials have been changed or changes have been made in the welding shop personnel. The scope of such production tests will be established on a case-by-case basis.

3.4 For production tests in conjunction with over weldable shop primers, see Section 6, C.

B. Performance of Welding Procedure and Production Tests

1. Application for approval

1.1 Application for approval of a welding procedure and for the performance of a welding procedure test shall be made to BKI in at least two copies, giving the following details (to be specified in Annex B, "Description of Welding Shop", item 2):

- range of application (components, materials, plate/wall thicknesses, pipe diameter, weld factor where applicable)
- welding process
- welding positions
- welding equipment and parameters
- weld shapes, weld build-up
- welding consumables and auxiliary materials
- joint preparation
- cold- or hot-forming operations prior to welding
- overweldable shop primers
- welding jigs and weather protection
- preheating and heat input during welding
- post-weld heat treatment, other after-treatment
- welders (qualification tests)
- date of test.

Note:

Annex D contains a form to specify the welding procedure (WPS) and recording the test results (WPQR) in conformity with ISO 15609 and ISO 15614.

1.2 Where possible, the application shall enclose a proposal for a test schedule in accordance with the rules set out in the relevant section of Sections 12 to 16 with sketches and dimensions of the test pieces, describing the intended specimens and tests. If the information and parameters stipulated in 1.1 are based on in-house standards or other (welding) specifications, these are also to be enclosed with the application.

2. Scope of testing, requirements, test schedule

2.1 The scope of testing (test pieces, specimens, etc.), tests and requirements for the individual fields of application (shipbuilding, steam boiler and pressure vessel fabrication, pipeline fabrication, etc.) are described in the relevant section of Sections 12 to16 of these Rules, while details of the non-destructive tests are given in Section 10 and details of the mechanical and technological tests in Section 11.

2.2 If a test schedule appropriate to the intended field and range of application has already been drawn up by the applicant in accordance with 1.2 and 2.1 as applicable, this shall be agreed with BKI before starting the tests. Otherwise such a test schedule shall be drawn up by the applicant - with the agreement of BKI - and submitted to BKI Head Office for final authorization.

3. Materials, welding consumables and auxiliary materials

3.1 The materials used in the welding procedure tests shall be unambiguously identifiable on the basis of their marking and certificates. The direction of rolling of the test pieces shall be ascertainable. If not, check specimens shall be prepared and tested.

3.2 The welding consumables and auxiliary materials shall if possible have already been tested and approved by BKI; however, they may be tested and approved at the same time as the welding process. See Section 5, A.1.4. Approvals of this type are generally restricted to the user's works and are valid for a maximum of one year, unless repeat tests are performed in accordance with Section 5, A.3.

3.3 Welding consumables and auxiliary materials used in the welding procedure tests may only be replaced in the subsequent fabrication work by others of the same kind which bear BKI approval if this is expressly stated in welding procedure approval certificate; see also A.3.3.

4. Test pieces, dimensions, direction of rolling, welding positions

4.1 The shape and size of the test pieces shall be compatible with the welding procedure concerned and the number of specimens. The most commonly used test pieces are described in the relevant section of Sections 12 to16. The dimensions of the test pieces may be changed if this does not adversely affect the test and is necessary for evaluating the process. Unless otherwise stipulated in an individual case both butt welded and fillet weld test pieces shall be welded in the specified positions for the fabrication process.

4.2 For vertical welding (e.g. electrogas or electroslag welding) the length of the test piece (length of the weld) shall conform to the production welding jig, while with appliances using a fusible wire-guide electrode, the length of the test piece shall be geared to the length of the wire-guide electrode or the height of the components to be welded, as applicable. Any special features affecting the application of these processes (e.g. welding operations performed through the deck) shall be allowed for in determining the shape of the test piece.

4.3 The plate thicknesses shall be chosen in accordance with the information on the limits of application in Sections 12 to16 in line with the intended range of application. Where possible, two different plate thicknesses should be welded and tested for each range of application. The weld shapes shall be those to be used in subsequent practice in line with the welding process.

4.4 Where the characteristics of the welding process or the dimensions, and hence the number of passes which these entail, are likely to have a considerable effect on the results of the test, the thickness of the test pieces and the number of passes shall be made to conform to the limit thicknesses for the range of application concerned. In the case of vertical downward welding, the thickness of the test piece shall be the upper limit thickness of the range of application, whereas with a variable number of passes depending on the plate thickness (e.g. with single- and multi-pass welding) the scope of the test shall include the various techniques and the thickness of the test pieces shall be chosen accordingly. The same applies in analogous manner to the weld thicknesses.

4.5 Normally, test pieces shall be welded in the positions occurring in subsequent practice. Depending on the welding processes and materials concerned, it may be agreed to restrict the test to certain specified welding positions, e.g. in the case of manual arc welding or semi-mechanized gas-shielded metal arc welding the test may be limited to the positions applicable to the corresponding welder's qualification tests as stated in Section 3. The horizontal-vertical position PC (h-v) is, however, always to be included in the welding procedure test for single-side welding. Where overhead welding PE (o) is included, this may be combined with the downhand position PA (d).

4.6 The direction of rolling of the plates shall be parallel to the direction of welding. The orientation of the rolling direction shall be stated in the test report.

5. Welding of test pieces

5.1 All welding procedure tests shall investigate, in accordance with workshop practice, the effects of prior cold-forming operations, weld preparation as practised in the welding shop and air gap exactness, restraints together with the use, where applicable, of overweldable production coatings (shop primers). Difficult fabrication conditions (e.g. limited accessibility) shall be simulated in the welding procedure test.

5.2 Welding shop facilities, welding equipment, aids to assembly and tack welds used in the test shall conform to those used in actual production. In the downhand and vertical positions, account is to be taken of the maximum anticipated angular deviations from the theoretical welding position (e.g. slope of slipway).

5.3 Where possible, several (at least two) welders or two teams of operators shall participate in a welding procedure test. As part of the welding procedure test, each welder or team of operators, as applicable, shall carry out a new the preparation (tack welding) of the test pieces, the alignment of the welding appliances, and the setting of the current supply and feed rate.

5.4 Preheating, heat input per unit length of weld, interpass temperature, electrode changing and the starting and stopping of welding appliances (starting points/end craters) shall conform to subsequent practice. Rod electrodes are to be used down to the clamping butt.

5.5 In welding procedure tests, depositing a backing run on the root side (cap side), with or without grooving of the root depending on the process, are generally permitted. In single-side welding, the same types of backing shall be used as in the subsequent fabrication work.

5.6 In the case of mechanized welding processes in shipbuilding, an interruption of the welding operation followed by complete cooling of the test piece and restarting of the equipment shall be demonstrated. The machining of the end crater and the preparation of the new starting point shall be carried out in accordance with normal practice. The test results from these weld areas will be evaluated separately.

5.7 Minor welding defects occurring in the course of a welding procedure test may, with the consent of the Surveyor, be repaired or ignored when preparing specimens. In the case of serious defects, the causes shall be established and remedied, after which new test pieces shall be welded.

5.8 The following data shall be recorded when welding the test pieces:

- shape of weld and method of preparation
- weld build-up and number of passes
- welding consumables and auxiliary materials (type, trade name, dimensions, quantities)
- method of root grooving and interpass cleaning/treatment

- preheating, interpass temperatures
- welding equipment and parameters (amperage, voltage, welding speed, heat input per unit length of weld)
- interruptions/disturbances in the welding sequence
- names of welders/operators
- special features applying to the tests (e.g. climatic influences, limited accessibility).

6. Post-weld heat treatment, other kinds of after-treatment

6.1 If post-weld heat treatment of the components (e.g. annealing to relieve stresses) is intended in the subsequent fabrication work, the test pieces are to be subjected to the same post-weld heat treatment. This applies in analogous manner to other types of after-treatment, e.g., TIG after-treatment of the weld interfaces. If approval of the welding process is desired for both the untreated and after treated conditions, the test shall be carried out for both conditions.

6.2 Where possible, post-weld heat treatment of the test pieces should be carried out in the annealing furnaces which are to be used for the fabricated components. The equipping of the annealing furnace with a temperature recorder is mandatory. The time-temperature curve shall be recorded. Other types of after treatment shall be described in the test report. Further information on post-weld heat treatment is given in Section 9.

7. Non-destructive testing

7.1 Prior to sectioning, each butt-welded test piece shall undergo visual and non-destructive testing over the entire length of the weld to detect any external or internal welding defects. Unless otherwise agreed, the test pieces shall be radiographed and those with a thickness of 30 mm or over (10 mm or over in the case of single-side submerged-arc welded test pieces) shall additionally undergo ultrasonic testing.

7.2 Where the base materials or weld metals are liable to crack, surface testing for cracks shall be carried out in addition to the above. If the material is magnetizable, this shall take the form of magnetic particle inspection; otherwise the dye penetrant method shall be used. BKI may require specific testing intervals (e.g. 72 hours) to be adhered to between completion of the welding work and performance of the crack tests.

7.3 Each K-shape or fillet-weld test piece (T-joint or cruciform test piece) shall undergo a visual inspection for external welding defects. Test piece made from a material other than normal-strength hull structural steel or comparable simple structural steels shall in addition be subjected to testing for surface cracks.

7.4 In contrast to the recording limits stated for the production tests, all welding defects and indications detected during non-destructive ultrasonic testing shall be recorded.

8. Sectioning of test pieces, preparation of specimens

8.1 Sectioning of the test pieces shall be carried out as described in relevant Sections 12 to16. The test pieces shall be sectioned mechanically. If thermal cutting methods are employed, a sufficient machining allowance shall be provided and the heat affected zone shall thereafter be machined off.

8.2 The individual specimens shall be marked before sectioning and during machining in a way which enables them to be identified at all times and their orientation in the test piece to be reconstructed.

8.3. From all butt-welded and fillet-welded (cruciform) test pieces for manual and semi-mechanized welding processes, one set of specimens each shall normally be taken and tested. From the test pieces for fully mechanized welding processes, one set of specimens each from the beginning and end of the weld shall be taken and tested. In the case of these latter test pieces, a third set of specimens from the middle of the weld may be additionally demanded in special circumstances, e.g. where long seams are concerned or the welding process has been recently developed. Where single-side submerged-arc welding is performed with flux backing, a third set of specimens shall be subjected to test in every case.

9. Shapes and dimensions of test specimens, mechanical and technological tests

9.1 The shapes and dimensions of the specimens, the preparation and performance of the tests and the determination of the results are subject to the provisions of Section 11. Furthermore, the corresponding provisions in the Rules for Materials (Pt.1, Vol. V) Sec. 1 and 2 shall also be complied with.

9.2 All tests shall be carried out by trained staff using calibrated testing equipment. The testing equipment shall be maintained by its owners in fully functional condition and shall be calibrated at regular intervals by an independent testing body.

9.3 Unless otherwise stipulated or agreed, all mechanical and technological tests shall be performed in the presence of the competent Surveyor. The micrographs shall be submitted to him for evaluation.

C. Evaluation of Test Results, Requirements, Repeat Test Specimens, Test Reports

1. Designation of test results

1.1 To ensure that the description and evaluation of welding processes and positions, test results, etc. are as clear and uniform as possible, use shall be made of the terminology and symbols in the relevant standards (e.g. ISO 857-1, ISO 6947, ISO 6520, ISO 5817, ISO 10042) and, for internal defects, Table 10.1 in Section 10. The position of a defect or fracture may be designated as follows:

- WM = in the weld metal
- FL = in the transition zone (fusion line)
- HAZ = in the heat-affected zone (of the base material)
- BM = in the base material.

2. Requirements, repeat test specimens

2.1 The requirements are specified in the relevant section of Sections 12 to16.

2.2 If, in the tests, individual specimens fail to meet the requirements or the failure of these specimens is due to localized defects in the specimen or deficiencies in the testing equipment, it is sufficient to test two repeat test specimens or sets of repeat specimens in each case, which shall then meet the requirements.

2.3 In the testing of notched bar impact test specimens, unless otherwise specified in a particular case, the average value of three specimens shall meet the stated requirement; none of the individual values may be less than 70% of the required value or the value for more than one specimen is below the required average value. If these conditions are not met, three additional specimens from the same test piece may be tested and the results added to the values originally obtained. The new average value from these six specimens shall then meet the requirements. However, of the six individual values only two may be below the required average value, of which only one individual value may be less than 70% of the prescribed average value. Otherwise the impact test and thus the procedure test has been failed.

2.4 If the requirements are not met by a sizeable number of specimens and/or in several areas of testing, the causes of the failures shall be investigated. When the faults have been cured, new test pieces shall be welded and fully tested.

3. Reports, storage times

3.1 Reports (see Annex D) shall be prepared of all trial welds and tests and submitted to BKI in duplicate, signed by Surveyor and welding supervisor.

3.2 The debris of test pieces, specimens and the test documentation are to be kept until all the tests and inspections are concluded by the confirmation of approval issued by BKI. For the storage time of documents relating non-destructive testing of welds (e.g. radiographs), see Section 10.

D. Limits of Application, Period of Validity

1. Works and sub-works

1.1 Welding procedure approvals are generally non-transferable. BKI may allow exceptions in the case of a nearby branch works where the welding work is carried out under the constant supervision of the main works, provided that the fabrication work is performed under the same conditions and the same specified welding processes are used. BKI may, however, require proof as to whether the welding processes are being applied correctly and the mechanical properties are adequate by means of non-destructive tests and/or simplified production tests.

1.2 Welding procedure tests performed in a workshop are in general not simultaneously valid for welding in the field. In such cases, the welding procedure test shall be repeated in full or in part under field conditions as determined by BKI. BKI may dispense with repeat testing by prior agreement if the qualitative properties of the field welds are demonstrated by production tests.

2. Range of application

2.1 The other materials included in a welding procedure approval on the basis of the testing of a particular material are indicated in the relevant section of Sections 12 to16.

2.2 With regard to plate thicknesses, the provision in the relevant section of Sections 12 to 16 shall be applied. In the case of vertical downward welding (PG/v-d), the thickness of the plate tested shall in each case be regarded as the upper limit of application.

2.3 The welding procedure approval is generally valid for the welding positions tested unless otherwise stated in the relevant section of Sections 12 to 16. Depending on the welding process, particular welding positions may be included; these are stated in the approval document where applicable.

2.4 The welding procedure approval is valid for the welding process and weld build-up tested.

2.5 The welding procedure approval is valid for the heat treatment condition for which the test was performed, e.g. untreated, annealed to relieve stresses, normalized.

2.6 Any minimum or maximum design or operating temperatures taken into account during testing are stated in the procedure approval document. The former is generally 5°C above the test temperature.

3. Period of validity

3.1 A welding procedure approval is generally valid without limit of time or with a time limit - depending upon the range of application; see Table 4.1 and the relevant section of Sections 12 to 16. This is, however, always provided that the conditions under which it was granted do not change significantly.

3.2 The welding procedure approval is tied to the approval of the welding shop to perform welding work and expires when the approval of the welding shop expires. For renewal of the welding shop approval document (see Section 2, A.4.), it shall be demonstrated to BKI that the approved welding processes have not be changed in the current production run and have been used without any significant defects.

3.3 For the production tests necessary in individual fields (e.g. steam boiler, pressure vessel) of application to maintain the validity of a welding procedure approval, please refer to A.3. BKI will check the aforementioned conditions in the course of the three-yearly renewal of the welding shop approval; see Section 2.

3.4 BKI may revoke part or all of a welding procedure approval and require a fresh welding procedure test or fresh production tests if doubts arise as to whether a welding process is being applied correctly or safely or if defects in or damage to the welds made by this process lead to the conclusion that the quality of the welded joints is inadequate.

Table 4.1 Recognition (qualification) of welding processes-summary

Range of application	Welding of hull structures	Welding of steam boilers	Welding of pressure vessels	Welding of pipelines	Welding of machinery components
Components	Hull structures, and equipment parts used in shipbuilding	Pressure bearing parts & parts welded to them	Pressure bearing parts & parts welded to them	Pipe all classes	Bedplates, pedestals, gearbox, casings, wheel bodies, auxiliary deck machinery etc.
Form and principles for acceptance	Acceptance based on welding procedure tests				
Section in these Rules	4 and 12, F.	4 and 13, F.	4 and 14, F.	4 and 15, F.	4 and 16, F.
Relevant standard	ISO 15614-1, ISO 15614-2	ISO 15614-1	ISO 15614-1	ISO 15614-1, ISO 15614-2	ISO 15614-1, ISO 15614-2
General preconditions	– Approved welding shops, – Recognized welding supervisors, – Certified welders conforming to ISO 9606; – Certified materials from approved manufacturers; – Approved welding consumables and auxiliary materials; – Authorized welding procedure specifications (pWPS or WPS) conforming to ISO 15609-1				
Materials	All	All	All	All	All
Plate/wall thickness; pipe diameters	All	All	All	All	All
Welding process	All	All	All	All	All
Welding positions	All	All	All	All	All

Table 4.1 Recognition (qualification) of welding processes-summary

Range of application	Welding of hull structures	Welding of steam boilers	Welding of pressure vessels	Welding of pipelines	Welding of machinery components
Validity	Generally not subject to time limit	1 year	1 year	1 year for pipe classes I & II. For pipe class III generally not subject to time limit	Generally not subject to time limit
Extension based on	Proof according to D.3.2	Production tests or repeat welding procedure test	Production tests or repeat welding procedure test	Proof of quality e.g. NDT or repeat welding procedure test	Proof according to D.3.2

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Section 5 Welding Consumables and Auxiliary Materials

A. General

Requirements of this Section give the conditions of approval and inspection of welding consumables used for hull structural steel according to Rules for Materials (Pt.1, Vol.V), Sec. 4.B as follows:

- Normal strength steels: Grades A, B, D and E ,
- Higher strength steels: Grades A32, D32, E32, A36, D36 and E36,
- Higher strength steels with minimum yield strength 390 N/mm2: Grades A40, D40 and E40,
- Higher strength steels for low temperature application: Grades F32, F36 and F40.

Welding consumables for high strength steels for welded structures are to comply with the requirements of F.

These requirements are not applicable for welding procedure qualification tests at the shipyard.

1. Approval procedure, marking

1.1 All welding consumables and auxiliary materials (welding wires and rods, covered electrodes, flux cored wires, (flux cored-) wire-gas or wire-flux combinations, etc.) which are to be used within the range of approval of the Rules for Welding or other Rules, regulations, etc. issued by BKI shall be tested and approved by BKI for that purpose in accordance with the following provisions. The same also applies an analogous manner to brazing materials, the tests and requirements for which will be specified on a case-by case basis.

1.2 Approval is normally granted on the basis of specimen welds and tests carried out on the weld metal and the weld joints on the manufacturer's premises under BKI's supervision with each individual product (individual manufacturer's brand) in accordance with 1.1, for which approval was applied for. For details of transfers of approvals, see 2.

1.3 An inspection of the manufacturer’s production facilities (production workshops, stores etc.) and especially the internal quality assurance measures applied shall be carried out in the course of normal production in conjunction with the approval tests.

Note:

1. The quality requirements relating to the manufacture, supply and marketing of welding consumables and the processes applied are described in ISO 14344. Unless other or contrary provisions relating to this are stipulated in the following paragraphs, the quality requirements stated in this standard may be used as a basis for the inspection of the manufacturer's facilities.

2. IACS Rec.17 can be used for the Acceptance of Manufacturer's Quality Assurance Systems for Welding Consumables as a guidance.

1.4 For the approval of welding consumables and auxiliary materials in conjunction with a (preliminary) welding procedure test, see also Section 4, B.3.2. The user shall have consented to the approval (on behalf of the manufacturer). In such cases the testing of the pure weld metal shall also be included in the scope of the welding procedure tests. Testing of specimens taken from the welded joint is not regarded as testing of the pure weld metal.

1.5 Where approval is applied exclusively for auxiliary materials such as ceramic backing strips (i.e. not in conjunction with welding consumables), their properties shall be tested, and where appropriate their effect on the quality of the welded joints established on the basis of the relevant product standards or the manufacturer's specifications in accordance with a test schedule to be specified in each individual case.

1.6 If welding consumables and auxiliary materials are to be approved in exceptional cases on the basis of approval tests conducted elsewhere by other bodies recognized by BKI (e.g. other classification societies or Technical Supervisory Authorities) the complete test reports shall be submitted (initial test not older than 5 years and, if applicable, the last 3 annual repeat tests) and - if nothing else has been stipulated by BKI - tests at least corresponding to the compulsory (annual) repeat tests shall be performed.

1.7 In isolated, urgent cases, consent may exceptionally be given for the use of welding consumables and auxiliary materials which have been approved by other recognized classification societies or neutral testing authorities (e.g. Technical Supervisory Authorities), though such consent shall be subject to a time limit and shall be restricted to a particular structure. In the case of larger projects, the manufacturer shall simultaneously apply for approval.

1.8 Applications for approval according to Annex A shall be submitted in one copy to BKI, giving the following information and accompanied by the most recent catalogues resp. technical data sheets with the properties guaranteed by the manufacturer (especially chemical composition, strength and toughness values):

– Manufacturer's name and manufacturing works (name of licensor, where appropriate)
– Nature of the welding consumables and auxiliary materials
– Manufacturer's brand (licensor's designation, where applicable)
– Dimensions for which approval is applied for (diameters, lengths)
– Grades for which application is made, including additional symbols
– Proposed range of application, including for example base materials, welding processes, welding positions for which approval is sought, heat treatment condition and any special operating conditions (e.g. low temperatures)
– Instructions for use (welding current, polarity, baking, heat treatment, etc.)
– Classification to ISO, AWS, EN, or other standards
– Marking, packaging.
– Any previous approvals (e.g. from other classification societies)
– Proposed testing laboratory and date of test.

The statements of conformity ("Affidavits") specified in 2.2 shall also be enclosed with any application for transfer of approval. The form provided in Annex E may be used to list the information specified above.

Note:

The Classification to ISO, AWS, EN, or other standards is performed by the manufacturer and is included in the approval certificate and in the list of welding consumables and auxiliary materials approved by BKI. Where possible classification is performed to AWS standards, but where these are not well-known classification shall be to other rules which have the widest possible circulation. For space reasons, however, only the designation of the standard is generally given in the list (not the title of the relevant standard). Classification is not normally covered by the tests and therefore is not part of the approval granted by BKI; see 4. If BKI is also required to check and confirm the classification in accordance with the standards, a separate application should be made to this effect.

1.9 The applicant is generally the manufacturer of the welding consumables and auxiliary materials. The manufacturer is the firm which carries out the final quality-influencing stage of the manufacturing process (e.g. coiling in the case of wire electrodes).

1.10 In the case of applicants with several production facilities which have separate organizations and are in separate locations, approval of the welding consumables and auxiliary materials will generally be granted for the plant that manufactured them. If production is relocated, already existing approvals may be transferred to the new plant. The conditions relating to the transfer of approvals specified in 2. shall apply in an analogous manner hereto.

When a filler product is manufactured in several plant of the same company, the complete series of approval tests should be carried out in one of the works only. In the other plant, a reduced test programme at least equivalent to annual tests is permitted if the manufacturer can certify that the materials used and the fabrication process are identical with those used in the main works. This requirement is applicable to all manufacturers of filler products under license (sister firms). However, should there be any doubt, complete test-series may be required.

Note:

Wire flux combination for submerged arc welding. If a unique powder flux is combined with different wires coming from several factories belonging to the same firm, it may be admitted to perform only one test-series if the different wires are conformable to the same technical specification, after approval of BKI.

1.11 If the applicant is not the manufacturer of the welding consumables and auxiliary materials, he shall give BKI the names of his suppliers. Any change of supplier shall be promptly notified to BKI and generally necessitates a fresh approval test.

1.12 If welding consumables of the same composition are manufactured by several suppliers and marketed by the applicant under a brand name, the in-house records and the printing on the packaging (e.g. fabrication number) shall clearly identify the manufacturer in question beyond all doubt. The relevant code system used shall be notified to BKI.

1.13 On the successful conclusion of the specimen welds and tests, BKI Head Office will issue an approval certificate. BKI also maintains and publishes a "List of Type Approved Products".

1.14 The manufacturer's plant, methods of production and quality control of welding consumables are to be such as to ensure reasonable uniformity in manufacture. With the approval, the manufacturer assumes responsibility for ensuring that during fabrication, the composition and properties of the products conform at all times to those of the tested welding consumables and auxiliary materials; see also Section 1, F.1., and under 3.2.

1.15 Manufacturers are obliged to state in their catalogues at least those items of information from the approval certificate which appear in the "List of Type Approved Products".

1.16 Besides the brand name, identifying marks and the manufacturer's details concerning the nature and use of the welding consumable or auxiliary material, the printing on the packaging or the adhesive label or the tag attached to reels, coils of wire, etc. shall at least indicate BKI's full quality grade and any additional symbols shall be visible. The details given in the current approval list published by BKI in accordance with 1.13 shall, however, take precedence in each case.

1.17 Where possible, each individual covered electrode, welding wire, etc. shall be permanently and distinctively identified by color-coding, stamping or impressed marking. The marking shall match that on the packaging

2. Transfers of approval

2.1 On application, an "original approval" once granted may be transferred to welding consumables and auxiliary materials manufactured in the same works but bearing a different brand designation or to welding consumables and auxiliary materials with the same or a different brand designation and produced by other manufacturers (including subsidiary companies) under license. An approval which has already been based on a transfer of approval cannot be transferred.

2.2 For this purpose, manufacturing and marketing companies as well as licensors and licensees shall confirm that the welding consumables are identical in composition, manufacture and the welding properties and quality factors on which approval was based ("Affidavits"), and they shall constantly supervise that this identity is preserved in accordance with 1.14. Marketing companies are also required to confirm that other welding consumables and auxiliary materials (from other manufacturers) are not marketed under the same brand name; see 1.9 to 1.12 and the note to 3.3.

2.3 Transfer of approval is normally conditional upon a previous test corresponding in scope to the prescribed (annual) repeat test. However, a test differing from this in scope and timing may be agreed. A test may be waived where the transfer relates to welding consumables and auxiliary materials manufactured in the same works provided that the prescribed (annual) repeat tests were performed on the manufacturer's premises in the period stipulated.

2.4 The company (marketing company, licensee) in whose name the approval certificate has been issued is responsible for the prescribed (annual) repeat tests. Where welding consumables and auxiliary materials are produced in the same works, repeat tests need not be duplicated, but where welding consumables of the same composition are manufactured by several suppliers (see 1.12) repeat tests are required for all suppliers.

2.5 Changes to welding consumables and auxiliary materials or their brand designations, the relocation of manufacturing facilities, or changes in the relationship existing between companies (e.g. in the case of transfers of approval) shall be brought to BKI's attention by each of the companies concerned. The provisions of 1. are to be applied in analogous manner.

3. Period of validity and repeat tests

3.1 Provided that the prescribed (annual) repeat tests are performed, approvals of welding consumables and auxiliary materials remain valid indefinitely until revoked. The production techniques and associated quality control procedures at all establishments approved for the manufacture of welding consumables are to be subjected to an annual re-appraisal. On these occasions, samples of the approved consumable are to be selected by the Surveyor and subjected to the tests detailed in subsequent sub-sections.

These are to be completed and reported within the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

If welding consumables and auxiliary materials do not undergo the prescribed annual repeat tests, the approval shall lapse and they shall be removed from the list of type approved products. Equivalent alternative documentary proof may be recognized by BKI by prior special agreement.

Note:

BKI may accept regular in-house tests performed as part of a recognized quality assurance system as equivalent alternative proof provided that this system meets the recommendations Guidelines for the Acceptance of Manufacturer's Quality Assurance Systems for Welding Consumables which have been jointly drawn up by the IACS classification societies and that satisfactory quality assurance test records are submitted to BKI for inspection at not more than yearly intervals. BKI may also perform interim tests on a random basis in order to satisfy itself that the specified procedure is being followed and that the prescribed requirements are being met.

3.2 The continued validity of the approval is further conditional not only upon the brand designation being retained, but also upon the composition and properties of the starting and end products remaining unchanged in the intervening period, as well as upon the constant monitoring of these products by the manufacturer in accordance with 1.14 and upon the maintenance of verifiable records of this monitoring. BKI may demand sight of these records at any time, may inspect the current production and may also, in case of doubt, call for interim sampling or testing, as appropriate.

3.3 Transfers of approval are generally valid for a year at a time from the date of issue of the certificate, but at the most up to the (annual) repeat test at the premises of the manufacturer (licensor) which follows the issuing of the transfer certificate. Transfers of approval may be extended for a further year at a time on application by the marketing company (licensee) if both the manufacturer (licensor) and the marketing company (licensee) submit appropriate confirmations of identity (affidavits) in accordance with Section 2.

Note:

BKI may waive the requirement for the submission of annual confirmations of identity (Affidavits) if, in conjunction with the first transfer of approval, the manufacturer (licensor) and marketing company (licensee) both expressly declare that they agree to BKI continuing to certify the annual repeat test(s), (until revoked), i.e. extending the approval(s).

3.4 A transfer of approval to brand designations used for marketing in accordance with 2.1 shall cease to be valid when the approval of the corresponding manufacturer's product expires. A transfer of approval for a product made under license by another manufacturer may in such cases, on application, continue to be valid, provided that the prescribed (annual) repeat tests continue to be conducted by the licensed manufacturer.

3.5 Repeat tests shall be performed under BKI supervision and shall be of the scope described for the various welding consumables and auxiliary materials. Unless otherwise agreed, the tests shall be performed at yearly intervals. They relate to period of one year calculated from the date of the approval and are to be concluded by the end of this period at the latest. If no welding consumable or auxiliary material is manufactured within this period, i.e. is sold "ex stock" from a production run that BKI has already inspected, BKI may, on application, defer the repeat test. BKI issues collective certificates covering these repeat tests.

Note:

If the scheduled repeat test is missed, the subsequent repeat test shall apply retrospectively to the period in which it should have been performed and may be subject to a time limit. The manufacturer is then required to perform subsequent repeat tests at shorter intervals to ensure that on average the prescribed annual test period is once again achieved. Approval is revoked if repeat testing is not performed in two consecutive years.

3.6 Repeat tests for welding consumables and auxiliary materials which have been approved for use in both untreated condition and for one or more heat-treated conditions (see 7.4) shall be carried out according to the prescribed scope for use in untreated condition and for use in each of the heat treated conditions in question.

3.7 Welding consumables and auxiliary materials which have been tested and approved in conjunction with welding procedure tests conducted on the user's premises (see Section 4, B.3.2) or in conjunction with a preliminary welding procedure test (see Section 4, A.2.) shall be subjected to annual repeat tests in line with these provisions, which shall be carried out on the premises of either the manufacturer or the user. In the case of welding consumables and auxiliary materials for special welding processes or materials, the scope of the tests applicable will be determined on a case-by-case basis.

4. Classification and designation (quality grades, added symbols)

4.1 Basic groups and grades

Filler metals are mainly divided into three groups regarding their strength properties as classified below:

- Normal strength filler metals for welding normal strength hull structural steels,
- Higher strength filler metals for welding normal and higher strength hull structural steels with minimum yield strength up to 355 N/mm^2,
- Higher strength filler metals for welding normal and higher strength hull structural steels with minimum yield strength up to 390 N/mm^2.

Each of the three groups is based on corresponding tensile strength requirements.

Welding consumables and auxiliary materials for the welding of hull structural steels (including the corresponding grades of steel forgings and castings) and of comparable structural steels are subject to classification, designation and approval as follows:

- According to their nature (e.g. covered electrode, flux-cored or flux-coated wire electrode, wire-gas combination or wire-flux combination)
- According to quality grades 1, 2, 3 and 4 or higher, depending on their notch impact energy and test temperature (see B. to E.)
- With the added symbol Y or Y40 (= yield controlled) for welding of higher-strength hull structural steels and Y47 for welding of YP47 steel
- With the added symbol H15, H10 or H5 for controlled hydrogen content of the weld metal (applies only to quality grades 2, 3 and 4 or higher)
- With the added symbol S (= semi-automatic) for semi-mechanized welding
- With the added symbol T (= two run technique) for welding in one pass on each side, M designating a multi run technique, or TM which covers both (and is applicable only to welding consumables and auxiliary materials for fully mechanized welding)
- With the added symbol V (= vertical welding process) for electrogas or electroslag welding.

Each higher quality grade includes the one (or those) below. Approval for higher-strength hull structural steels (added symbol Y or Y40) generally encompasses approval for normal-strength hull structural steels; see Table 12.1 in Section 12, E. For welding processes where a high base material content may influence the properties of the weld metal (e.g. in submerged-arc welding using the two-run technique or in electrogas or electroslag welding), BKI may require testing of both categories of material. Approval for semi-mechanized welding (added symbol S) subsumes approval for fully mechanized multi-run welding (added symbol M) in flat positions.

4.2 Welding consumables and auxiliary materials for the welding of high-strength structural steels with minimum yield strengths in excess of 390 N/mm^2 are subject to classification, designation and approval in analogous manner to 4.1, with the following differences:

- With the quality rating 3 or higher, depending on their notch impact energy and test temperature (see F.)
- With the added symbol Y and an appended code number designating the minimum yield strength of the weld metal (e.g. Y46 for a minimum yield strength of 460 N/mm^2).

Each higher quality grade includes the one (or those) below. Approval for steels having the minimum yield strength designated by the code number subsumes approval for steels of similar type having the next two lower yield strengths (e.g. approval for a steel with the symbol Y50 subsumes approval for steels with the symbols Y46 and Y42). In the case of steels with minimum yield strengths of 550 N/mm^2 and above (symbols Y55, Y62 and Y69), the approval only subsumes the steel with the next lower yield strength. In special cases, welding consumables and auxiliary materials are approved only for specific materials.

4.3 Depending on their nature and condition (type of alloy), welding consumables and auxiliary materials for welding of steels tough at subzero temperatures are classed as equivalent to those for high-strength structural steels (see F.), for austenitic stainless steels (see I.), or for nickel and nickel alloys (see L.) and are subject to classification, designation and approval as follows:

- For approvals in accordance with F., according to a quality grade which depends on their notch impact energy and test temperature and, where applicable, with the added symbol Y and the code number for the minimum yield strength (see 4.2)

  or

- For approvals in accordance with I., according to a quality grade consisting of the abbreviated material number of the material or material category for which approval was granted (see 4.5), also stating the test temperature used for the approval test

  or

- For approvals in accordance with L., according to a quality grade corresponding to the code designation shown in the standard applicable to the welding consumable (see 4.8), also stating the test temperature used for the approval test.

The inclusions and exclusions of the category of welding consumables and auxiliary materials according to which approval was granted apply, unless otherwise stated in the approval certificates.

4.4 Welding consumables and auxiliary materials for welding of high-temperature steels are subject to classification, designation and approval as follows:

- According to a quality grade corresponding to the code designation for the material or material category for which the approval was granted (see H.).

The materials included in the respective approvals are shown in Table 5.19.

4.5 Austenitic welding consumables and auxiliary materials for welding of stainless and nonmagnetic steels and nickel alloy steels tough at sub-zero temperatures are subject to classification, designation and approval as follows:

- For welded joints in (austenitic) stainless steels, according to a quality grade consisting of the abbreviated material number of the base material to be welded with the product (e.g. quality grade 4571 for the welding of steel with the material number 1.4571 X6CrNiMoTi17-12-2)
- For welded joints in (austenitic) non-magnetic stainless steels, according to a quality grade consisting of the abbreviated material number of the welding consumable itself (e.g. quality grade 3954 for the welding of steel with the material number 1.3964 X2CrNiMnMoNNb21-16-5-3)
- For welded joints between these steels and unalloyed or low-alloy (hull) structural steels, for intermediate weld runs in clad plates and build-up welding, according to a quality grade consisting of the abbreviated material number of the welding consumable itself (e.g. quality grade 4370 for the welding consumable with the material number 1.4370 Xl5CrNiMn-18-8)

– For welding of nickel alloy steels tough at sub-zero temperatures, according to a quality grade consisting of the abbreviated material number of the base material to be welded with the product in question (e.g. quality grade 5662 for welding of steel with the material number 1.5662 X8Ni9).

The steels also covered by the approval and information on the types of application are shown in I. (Tables 5.22 to 5.25). In special cases, e.g. where the inclusions and exclusions differ, the relevant information is given in the approval certificates.

4.6 Welding consumables and auxiliary materials for welding of aluminium alloys are subject to classification, designation and approval according to a quality grade corresponding to the code designation according to the standard (ISO 18273), e.g. quality grade R-AlMg 4,5 Mn. For other aluminium alloys covered by the respective approval, see J., Table 5.27.

4.7 Welding consumables and auxiliary materials for welding of copper and copper alloys are subject to classification, designation and approval according to a quality grade corresponding to the code designation according to the standard (ISO 24373), e.g. quality grade CuNi30Fe. For other base materials covered by the respective approval, see K., Table 5.30.

4.8 Welding consumables and auxiliary materials for welding of nickel and nickel alloys are subject to classification, designation and approval according to a quality grade corresponding to the code designation for the welding consumable according to the standard (ISO 18274), e.g. quality grade NiCu30MnTi. For other base materials covered by the respective approvals, see L., Table 5.32.

4.9 The code numbers and letters indicated in Table 5.1 are used to identify the approved welding positions. In special cases, the approved welding positions are specified individually; for example, an approval applicable only to the vertical-down PG (v-d) position or individual welding positions are also specified or excluded as applicable. For the limitations relating to the use of vertical-down welding, see Section 12, H.6.

Table 5.1 Welding positions

Code No.	Welding positions, code letters[1]	
1	All welding positions	PA (d), PB (h), PC (h-v), PD (h-o), PE (o), PF (v-u), PG (v-d)
2	All except the vertical-down position	PA (d), PB (h), PC (h-v), PD (h-o), PE (o), PF (v-u)
3	Butt welds in the down-hand position, fillet welds in the down-hand and horizontal positions	PA (d), PB (h)
4	Butt welds in the down-hand position and fillet welds in the down-hand position	PA (d)
5	Vertical down-positions and those as for code no. 3	PA (d), PB (h), PG (v-d)

[1] Description of welding positions, see Annex I.

4.10 The code letters indicated in Table 5.2 are to be used to designate the type of current approved for use with the relevant welding consumables and auxiliary materials.

Table 5.2 Type of current and polarity

Code letter and symbol	Type of current and polarity
DC +	Direct current, + polarity
DC -	Direct current, - polarity
DC ±	Direct current, + and - polarity
AC	Alternating current

5. Alterations, upgrading and downgrading

5.1 Any alteration proposed by the manufacturer to the approved consumable which may result in a change in the chemical composition and the mechanical properties of the deposited metal, must be immediately notified to BKI. Additional test may be necessary.

(IACS UR W17 2.5)

5.2 The upgrading of approved welding consumables and auxiliary materials into a higher quality grade shall be applied for by the manufacturer and may suitably be effected on the occasion of the prescribed (annual) repeat tests. Upgrading requires that in addition to the repeat tests, notched bar impact test specimens shall be taken from all the butt-welded test pieces (welded joints) prescribed for the (original) approval test in the various positions and shall be subjected to test. Radiographic examination of the butt-welded test pieces is recommended.

5.3 Downgrading into an appropriately lower quality grade results when the outcome of the prescribed (annual) repeat tests fails to fulfil the requirements, even if the retest specimens are included. Where the earlier test results and the evaluation of all the new test findings point to the likelihood that the failure of the specimens was due to defects in the material or the welding, the repeat test may be repeated at short notice. If the requirements are still not met, the quality grade will be reduced. In such a case, a renewed upgrading may take place after three months at the earliest (i.e. after thorough revision and improvement of the product) and only after testing as described in 5. 2.

5.4 The extension of an existing approval covering the welding of normal-strength hull structural steels to the welding of higher-strength hull structural steels (e.g. from grade 2 to grade 2Y or from grade 3Y to grade 3Y40) requires the performance of a complete new approval test using higher strength hull structural steel in question as the base material. This requirement applies in analogous manner to other materials as well.

5.5 Extension of an existing approval to include the added symbol H15 or the modification of the symbol H15 to H10 or H5 is permissible provided that the weld metal can be proved to contain the stipulated lower quantity of hydrogen by a test in accordance with B.4. Corresponding tests performed elsewhere may be recognized as furnishing the necessary proof, provided that they were carried out not more than three years previously.

6. Physical characteristics, welding performance and packaging

6.1 All welding consumables and auxiliary materials shall have physical characteristics compatible with the proposed application and conforming to the relevant standards and shall display a satisfactory general welding performance. The packaging shall be such as to prevent excessive moisture absorption and damage to the contents provided that the materials are properly handled and stored. Verification of these characteristics and testing of the packaging form an integral part of the approval tests and repeat tests.

6.2 In the case of rod electrodes, the coating shall encase the core rod concentrically and with uniform thickness. When the electrodes are correctly used, no projecting crater rim may be formed at one side of the coating during welding. The coating shall not display any marked irregularities or surface defects. It shall adhere firmly to the core rod and be capable of storage within the specified limit conditions. Subject to proper handling and use, the coating shall not rupture or break away from the core rod. The clamping butt and the arcing end shall be free from coating material.

6.3 Welding wires (wire electrodes and welding rods) shall have a smooth surface and shall be free from surface defects, rust or other contamination which might impair the satisfactory execution of the welding operation (e.g. by impeding the current flow). Although welding wires may be provided with metal coatings, these shall not adversely affect their welding performance or the properties of the weld. Coiled welding wires shall be free from buckling and shall unwind smoothly.

6.4 Welding fluxes and shielding gases shall possess a degree of purity conforming to the relevant standards together with the lowest possible moisture content. Welding fluxes should be granular in consistency and free-flowing to facilitate their smooth passage through the flux supply system. The granulometry of the flux should be uniform and constant from one package to another. Regarding the identity testing of gases and the inspection of shielding gas mixing devices on the user's premises, see C.1.5.

6.5 Other auxiliary materials such as nitrogen hydrogen mixtures and powder or ceramic weld pool supports (backings) should as far as possible be metallurgically neutral and have no effect on the characteristics of the weld. Where such an effect cannot be ruled out (e.g. with powder supports which deplete or add to the alloying constituents), the materials shall be included in the scope of the relevant approval or repeat tests, or shall be tested as part of the (preliminary) welding procedure tests; see Section 4, A.2 and B.3.2.

6.6 Welding consumables - where appropriate in conjunction with the corresponding auxiliary materials shall in all positions and even at the limit values of the welding current display a satisfactory and constant welding performance without excessive spatter. The coating of rod electrodes shall not flake off during welding, nor may coated wire electrodes burst open. Should the arc be accidentally interrupted during welding, the slag shall not impede the speedy restoration of the arc. Cooled slag shall be capable of being removed from the weld without undue difficulty. The external characteristics of the weld and its internal features (as revealed by radiography) shall meet the subsequent requirements of fabrication (see Section 10, G.).

7. Performance of approval tests

7.1 Unless otherwise stated below, approval tests shall be conducted in accordance with Section 4. The conditions under which the specimen welds are made (welding parameters, number of runs, weld build-up, etc.) shall conform to the manufacturer's recommendations and to normal shipbuilding practice and be placed on record. Covered electrodes shall be consumed down to a residual length of approx. 50 mm. The heat input (energy input per unit length of weld E) applied during welding shall be determined by the following formula and shall also be placed on record:

Energy input per unit length:

$$E = \frac{U[\text{volt}] \cdot I[\text{amps}] \cdot \text{Welding time}[\text{min}] \cdot 6}{\text{Length of weld }[\text{mm}] \cdot 100} \left[\frac{\text{kJ}}{\text{mm}}\right]$$

U = electrical voltage [Volts]

I = electrical current [Ampere]

7.2 The base materials used for approval tests shall be of the chemical composition and strength category for which the welding consumables and auxiliary materials are to be approved. The chemical composition including the content of grain refining elements is to be reported. Table 5.3 shows base materials shall be used in the approval test.

Table 5.3 Base materials to be used for individual quality grade

Quality grade	Base materials shall be used in the approval test [1) 2)]
1	A
2	A, B, D
3	A, B, D, E
2Y [2)]	A32, A36, D32, D36
3Y [2)]	A32, A36, D32, D36, E32, E36
4Y [2)]	A32, A36, D32, D36, E32, E36, F32, F36
2Y40	A40, D40
3Y40	A40, D40, E40
4Y40	A40, D40, E40, F40
5Y40	A40, D40, E40, F40
3Y47	YP47

[1)] Other comparable structural steel possessing the same minimum tensile strength may be used.

[2)] Where higher strength steel with minimum yield strength 315 N/mm^2 is used for grade 2Y, 3Y and 4Y electrodes, the actual tensile strength of the steel is to be not less than 490 N/mm^2.

For testing the pure weld metal, normal-strength hull structural steels or comparable structural steels may generally be used. For welding consumables with a very divergent chemical composition, the side walls of the test piece may, if necessary, be provided with a buffer (e.g. in the case of stainless steels) and a backing strip of the same composition as the plate may be used. For the special features applicable to submerged-arc welding, see D.3.2 and D.3.5.

When a welded joint is performed, the edges of the plates are to be bevelled either by mechanical machining or by oxygen cutting; in the later case, a de-scaling of the bevelled edges is necessary.

7.3 Where welding consumables and auxiliary materials are to be approved for welding with both direct current (DC) and alternating current (AC), the test shall be conducted with alternating current (AC). In special cases, verification of the welding characteristics using direct current may be demanded as an alternative or in addition (e.g. for covered electrodes used for gravity welding with direct and alternating current, and for certain welding processes).

7.4 Post-weld heat treatment of the test pieces or specimens is not allowed where products are to be approved for the untreated condition alone; see also the preliminary remarks relating to B. Excepted from this rule is the heat treatment of tensile specimens to reduce their hydrogen content as described below in relation to the various welding consumables and auxiliary materials. Where welding consumables and auxiliary materials are also to be approved for the heat-treated condition, the prescribed additional test pieces shall be prepared (see H.1.3) and heat-treated accordingly. Follow-up heat treatment of the specimens once they have been removed from the test pieces is not allowed.

7.5 In special cases, further tests (e.g. hardness measurements, examination of macro- or micrographic specimens to check weld penetration and structural characteristics, etc.) or the testing of notched bar impact test specimens at temperatures lower than those specified may be stipulated in addition to the test pieces and specimens called for in the following paragraphs. In the case of welding consumables and auxiliary materials for austenitic stainless steels, proof is required of resistance to intergranular corrosion and for solid austenitic steels resistance to hot cracks shall also be demonstrated.

7.6 Should individual test results fail to meet the requirements, a double quantity of test pieces and specimens of the same kind shall be freshly prepared and subjected to testing. Base materials, welding consumables and auxiliary materials originating from the same delivery as those used for the first test shall be used for this purpose. If the new test pieces are made with the same procedure (particularly the number of runs) as the original test pieces, only the duplicate re-test specimens needs to be prepared and tested. Otherwise, all test specimens should be prepared as for re-testing. Should the specimens again fail, approval will not be granted until the reasons have been clarified and a complete new test has been conducted (see also 5.3). For the repetition of notched bar impact tests, see the following provisions relating to the various welding consumables and auxiliary materials.

B. Covered Electrodes for Manual Metal-Arc Welding of Hull Structural Steels

Preliminary remarks:

In normal shipbuilding practice, components are in general not subjected to post-weld heat treatment (e.g. annealing to relieve stresses). Consequently, the welding consumables and auxiliary materials to be used for ship constructions are generally tested and approved for the untreated, i.e. as-welded, condition.

Should post-weld heat treatment nevertheless be intended or required in special cases, only welding consumables and auxiliary materials with properties and quality grades which have been proved to be adequate in the respective heat-treated condition shall be used. The nature and scope of the necessary verifications shall be determined on a case-by-case basis.

In the case of welding consumables for hull structural steels, the test temperature for the base material in question (see Section 12, Table 12.1 as well as the Rules for Hull (Pt.1, Vol. II) Sec. 2) may be assumed to be the minimum load temperature (design temperature). A temperature of 300°C is generally considered to be the maximum load temperature.

1. General

1.1 The following provisions apply to covered electrodes for manual metal-arc welding of hull structural steels, including the corresponding grades of steel forgings and castings, and of comparable structural steels. Covered electrodes for semi mechanized gravity welding and spring-loaded welding processes are treated in the same way as those for manual metal arc welding.

1.2 Depending on the results of the Charpy V-notch impact tests, electrodes are divided into the following grades:

– For normal strength steel: Grades 1, 2 and 3
– For higher strength steel with minimum yield strength up to 355 N/mm^2: Grades 2Y and 3Y and 4Y (Grade 1Y not applicable for manual welding)
– For higher strength steels with minimum yield strength up to 390 N/mm^2: Grades 2Y 40, 3Y40, 4Y40 and
– For YP47 steel: Grade 3Y47

In special cases, e.g. when the electrodes are also used for steels tough at sub-zero temperatures, approval may be granted with a higher quality grade, as with welding consumables and auxiliary materials for high-strength structural steels (see F. and Table 5.15). Regarding added symbols, inclusions and exclusions, see A.4.1.

2. Deposited Metal Tests

2.1 Preparation of Deposited Metal Test Assemblies

For testing the deposited weld metal, 2 (two) test pieces of the type shown in Fig. 5.1 are to be prepared in the down hand (PA(d)) welding position.

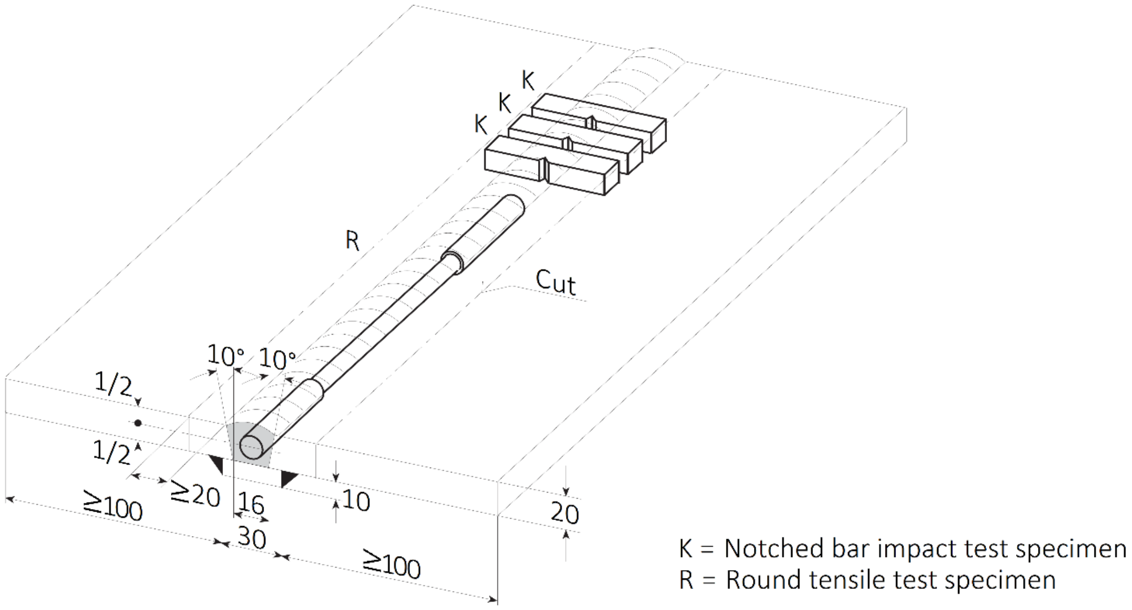


Fig. 5.1 Weld metal test piece

One of the test pieces is to be welded with 4 mm diameter rod electrodes, the other with covered electrodes of the maximum diameter produced, up to a limit of 8 mm. Where the electrodes produced are of one diameter only or do not exceed 4 mm in diameter, one test piece is sufficient.

In accordance with the rod electrodes used and normal welding practice, the weld metal shall be laid down in layers comprising single or multiple runs. The layers shall be welded in alternate directions, and the individual runs shall be 2 – 4 mm thick. Prior to the welding of each new layer, the test piece shall be cooled in still air to 250°C or below, but on no account to below 100°C. The temperature shall be measured at the surface of the center of the weld. After welding, the test assemblies are not to be subjected to any heat treatment.

2.2 The chemical composition of the deposited weld metal shall be determined by the manufacturer using recognized methods of analysis and shall be certified by him. The analysis shall encompass all the important alloying constituents and impurities (e.g. phosphorus and sulphur). The results of the analysis shall not exceed the limits specified in the standards. In special cases, narrower tolerances for the constituents may be stipulated.

2.3 Following the recommended radiographic examination, one round tensile test specimen as shown in Fig. 5.2 and three ISO V-notch impact test specimens conforming to Fig. 5.3 shall be machined from each weld metal test piece. The longitudinal axis of the round tensile specimen shall be located in the center of the weld at the mid–thickness of the weld in deposited metal test assemblies or the mid thickness of the 2nd run in the two-run welded test pieces.

The upper lateral surface of the impact test specimens shall be located:

– at mid thickness of the weld in the deposit metal and butt weld test assemblies with multi-run technique
– on the 2nd run side, 2 mm maximum below the surface in the two-run welded test pieces

To remove the hydrogen from the weld metal, the round tensile specimens may be subjected to a temperature not exceeding 250°C for not longer than 16 hours prior to the tensile test.

In the notched bar impact test, the temperature of the specimens for quality grades 2, 2Y, 2Y40, 3, 3Y, 3Y40, 4Y, 4Y40, 5Y40 and 3Y47 shall not deviate from the prescribed test temperature by more than ± 2°C.

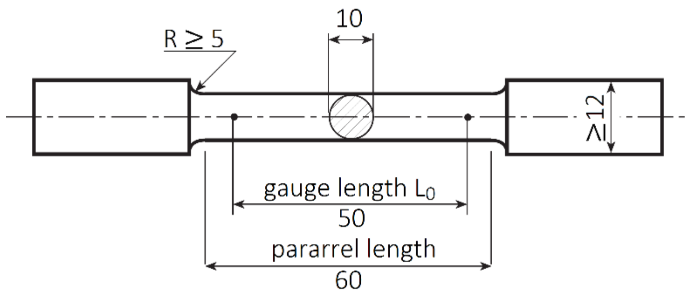


Fig. 5.2 Round tensile test specimen

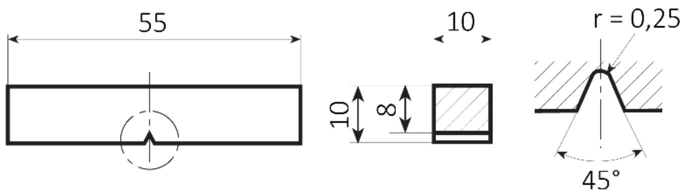


Fig. 5.3 ISO V- notch impact test specimen

2.4 The mechanical properties of the weld metal shall meet the requirements stated in Table 5.4. If the tensile strength exceeds the upper limit, approval of the electrode will be granted only after careful consideration of its other technological properties and the chemical analysis of the weld metal. The mean value for the notch impact energy shall meet the requirements of the following sections; an individual value may be below the required mean value but not less than 70% of this value.

Table 5.4 Required properties of the weld metal (covered electrodes)

Quality grade [1)]	Minimum yield strength [N/mm²]	Tensile strength [N/mm²]	Minimum Elongation ($L_0 = 5\ d_0$) [%]	Minimum notch impact energy [2)] [J]	Test temperature [°C]
1	305	400 - 560	22	47 (33)	+20
2					0
3					- 20
2Y	375	490 - 660	22	47 (33)	0
3Y					- 20
4Y					- 40

Table 5.4 Required properties of the weld metal (covered electrodes) *(continue)*

Quality grade [1]	Minimum yield strength [N/mm²]	Tensile strength [N/mm²]	Minimum Elongation ($L_0 = 5\ d_0$) [%]	Minimum notch impact energy [2] [J]	Test temperature [°C]
2Y40 3Y40 4Y40 5Y40	400	510 [3] - 690	22	47 (33)	0 - 20 - 40 - 60
3Y47	460	570 - 720	19	53 (37)	- 20

1) For possible higher quality grade, see 1.2.
2) Mean value of three specimens; ( ) for minimum individual values; for this and retests, see 2.4 and 2.5.
3) A tensile strength of 500 N/mm² is acceptable if adequate values are achieved in the welded joint.

2.5 For the carrying out of retests, see A.7.6; the requirements for the notch impact energy test are as follows:

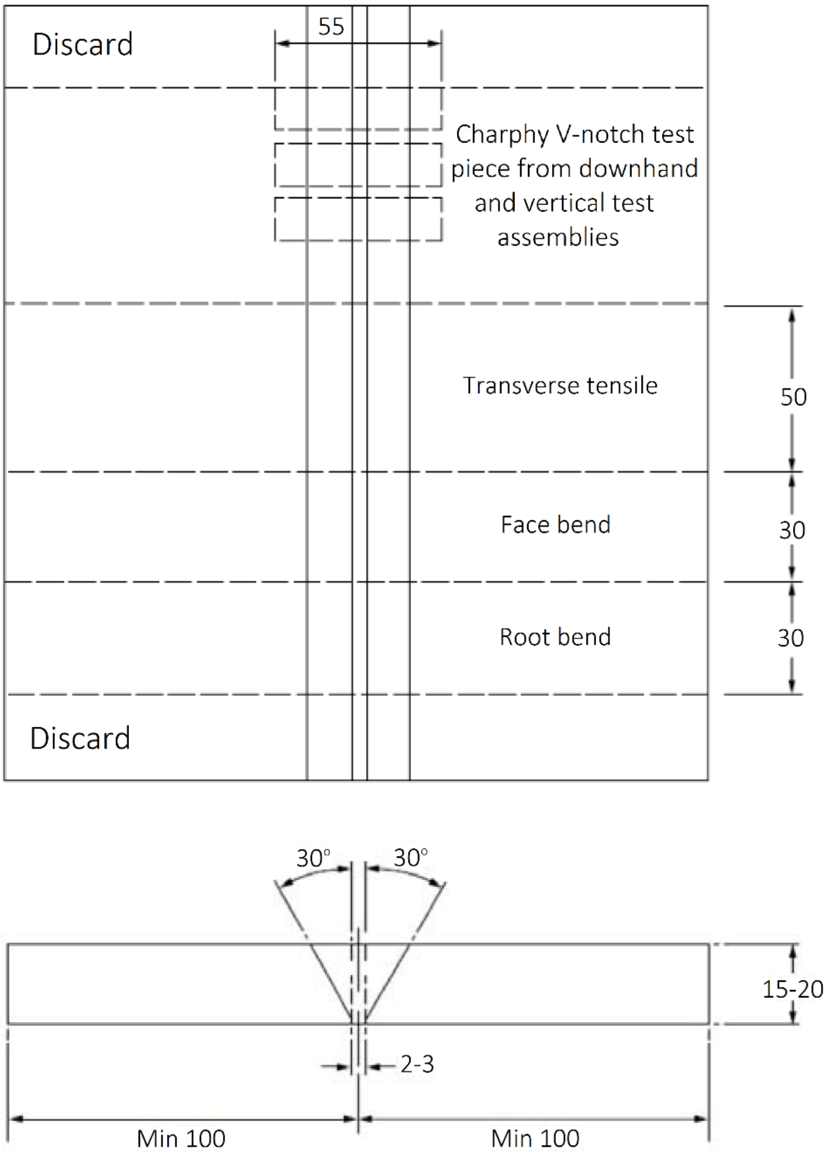
If the required notch impact energy values are not attained, but not more than two of the individual values are below the required mean value and not more than one of them is less than 70% of the required value, three more impact test specimens may be taken from the same or an identical weld metal test piece and tested. The results obtained are to be added to the first results and the resulting new mean value shall then meet the requirements. In addition, no more than two of the six individual values in all may be below the required mean value and of these, not more than one may be less than 70% of the required value.

2.6 Further repeat tests require the consent of BKI in each individual case; see also A.7.6. Such tests, however, shall without exception comprise the welding of a new test piece and the testing of all the specimens originally required, even if some of them gave satisfactory results in the first test.

3. Testing on welded joints

3.1 Tests on weld joint are generally performed on butt-welded test piece in accordance with Fig. 5.4 and Table 5.5. Where rod electrodes are to be approval only for fillet welding (e.g. for gravity welding), fillet welded test pieces as shown in Fig. 5.7 instead of butt-welded test pieces shall be welded and subjected to test. In special cases, BKI may call for fillet -welded as well as butt-welded test pieces, e.g. for vertical down welding.

3.2 Butt-welded test pieces in accordance with Fig. 5.4 shall be welded in the positions and with the electrode diameters shown in Table 5.4 according to the welding positions covered by the approval application (see A.4.9 and Table 5.1). For the base material to be used, see A.7.2; their chemical composition is to be recorded.



All dimensions in mm unless otherwise indicated

Fig. 5.4 Butt-weld test piece

Table 5.5 Butt-weld test pieces, welding positions and electrode diameters

Position(s) applied for approval	Butt-weld test pieces required ...				
	... in position (s)		... with electrode diameter (s) 1)		
	No.	Position5)	Root pass	Fill and cover passes	Back pass
(1) 3) All positions incl. vertical-down	1	PA (d)	4	5 to 8 2)	4
	1	PF (v-u)	3,25	4 or 5	4
	1	PE (o)	3,25	4 or 5	4
	1	PG (v-d)	acc. to manufacture's instruction		
(2) 3) All positions except vertical-down	1	PA (d)	4	5 to 8 2)	4
	1	PF (v-u)	3,25	4 or 5	4
	1	PE (o)	3,25	4 or 5	4

Table 5.5 Butt-weld test pieces, welding positions and electrode diameters *(continue)*

Position(s) applied for approval	Butt-weld test pieces required ...				
	... in position (s)		... with electrode diameter (s) [1]		
	No.	Position[5]	Root pass	Fill and cover passes	Back pass
(3) [3] Down hand positions and vertical-up	1	PA (d)	4	5 to 8 [2]	4
	1	PF (v-u)	3,25	4 or 5	4
(4) Down hand positions only	1	PA (d)	4	5 to 8 [2]	4
	1	PA (d)	4	5 to 8 [4]	4
Horizontal-vertical (2G) position only	1	PC (h-v)	4 or 5	5	4
(x) Other individual positions	1	(x)	as specified above		

[1] Electrode diameters in [mm].

[2] Filler passes with 5 or 6 mm size; last two runs including the cover pass with the largest diameter electrodes produced, up to a maximum of 8 mm.

[3] Includes the horizontal-vertical PC (h-v) position.

[4] Second pass with 5 or 6 mm size; all other filler and cover passes to be made with the largest diameter electrodes produced, up to a maximum of 8 mm.

[5] See Annex I.

The two parts of the test piece are to be juxtaposed with sufficient allowance for angular shrinkage. Prior to the welding of each new pass, the test piece shall be cooled in still air to 250°C or below, but on no account below 100°C. The temperature is to be measured at the surface of the centre of the weld. The back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. After welding, the test assemblies are not to be subjected to any heat treatment.

3.3 Following the recommended radiographic examination, one flat tensile test specimen in accordance with Fig. 5.5, two 30 mm wide transverse bend test specimens (one with the cover pass and one with the backing pass in tension) and three notched bar impact test specimens (ISO V-notch specimens conforming to Fig. 5.3) are to be machined from each butt-welded test piece.

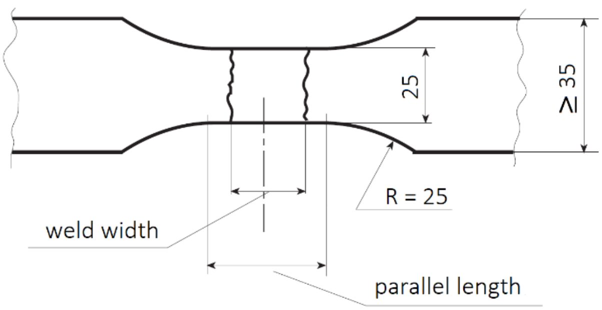


Fig. 5.5 Flat tensile test specimen

The parallel length of the flat tensile test specimens shall be equal three times the plate thickness or the weld width plus twice the plate thickness, whichever is the greater. On the tension side, the edges of the transverse bend test specimens may be rounded to a radius of not more than 2 mm. The position of the impact test specimens shall conform to Fig. 5.6. The weld reinforcement shall be machined flush with the surface of the plate on both sides of all specimens.

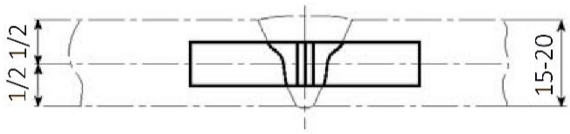


Fig. 5.6 Position of impact test specimens

3.4 The mechanical properties of the welded joints shall meet the requirements stated in Table 5.6. For the performance of the tests and the carrying out of retests, see 2.4 and 2.5. The position of the fracture shall be recorded. Bend test specimens displaying incipient cracks shall be broken open for assessment of the fracture. BKI may stipulate that the bend tests or supplementary bend tests be performed within a set time limit in order to ascertain possible effects of hydrogen.

3.5 Fillet-weld test pieces as shown in Fig. 5.7 shall, if necessary according to 3.1, be prepared in each of the welding positions applied for approval (see 3.2). For the base materials to be used, see A.7.2. The first fillet weld is to be made with the largest, the second with the smallest electrode diameter recommended by the manufacturer for the particular welding position and throat thickness concerned. Unless otherwise stipulated or agreed, each fillet weld shall be made in a single pass. Electrodes of the maximum length produced are to be used. The amperages used shall be recorded.

The length "L" of the test piece shall be such as to permit the melt-off of at least one complete electrode length - namely, the longest produced - with a throat thickness appropriate to the electrode diameter.

Table 5.6 Required properties of welded joints (covered electrodes)

Quality grade [1]	Tensile strength [N/mm^2]	Minimum notch impact energy [J] [2]			Bending Test Ratio (D/t)	Minimum bending angle
		Positions		Test temperature [°C]		
		PA (d), PC (h-v), PE (o)	PF (vu), PG (v-d)			
1	≥ 400	47 (33)	34 (24)	+ 20	3	120° before the first incipient crack, minor pore exposures up to a maximum length of 3 mm allowed.
2				0		
3				– 20		
2Y	≥ 490	47 (33)	34 (24)	0		
3Y				– 20		
4Y				– 40		
2Y40	≥ 510	47 (33)	39 (27)	0		
3Y40				– 20		
4Y40				– 40		
5Y40				– 60		
3Y47	≥ 570	53 (37)	53 (37)	– 40	4	

[1] For possible higher quality grades, see 1.2.
[2] Mean value of three specimens; ( ) for minimum individual values; for this and retests, see 2.4 and 2.5.

3.6 Following visual inspection and assessment, the fillet-weld test pieces shall be sectioned in the manner shown in Fig. 5.7, and the macro graphic specimens marked with "M" shall be prepared for evaluation of the weld penetration and measurement of the hardness in accordance with Fig. 5.8. Wherever possible, Vickers hardness measurements (ISO 6507-1, HV 10) should be performed.

3.7 The hardness of the weld metal obtained with welding consumables and auxiliary materials for higher-strength hull structural steels with minimum yield strengths up to 355 N/mm^2 (added symbol Y) shall not be less than 150 HV and the corresponding hardness for higher-strength hull structural steels with a minimum yield strength of 390 N/mm^2 (added symbol Y40) shall not be less than 160 HV. The test report shall also record the hardness values measured in the heat-affected zone and the base material. Equivalent values for other methods of measurement shall be agreed.

After machining off one of the fillet welds, the two remaining pieces of each fillet-weld test piece shall be broken open on alternate sides and the fracture shall be assessed. The specimen shall be free from any major defects such as large pores and slag lines in the root, incomplete penetration, lack of fusion at the side walls, cracks, etc., see also, Section 12, G.10.3.4.

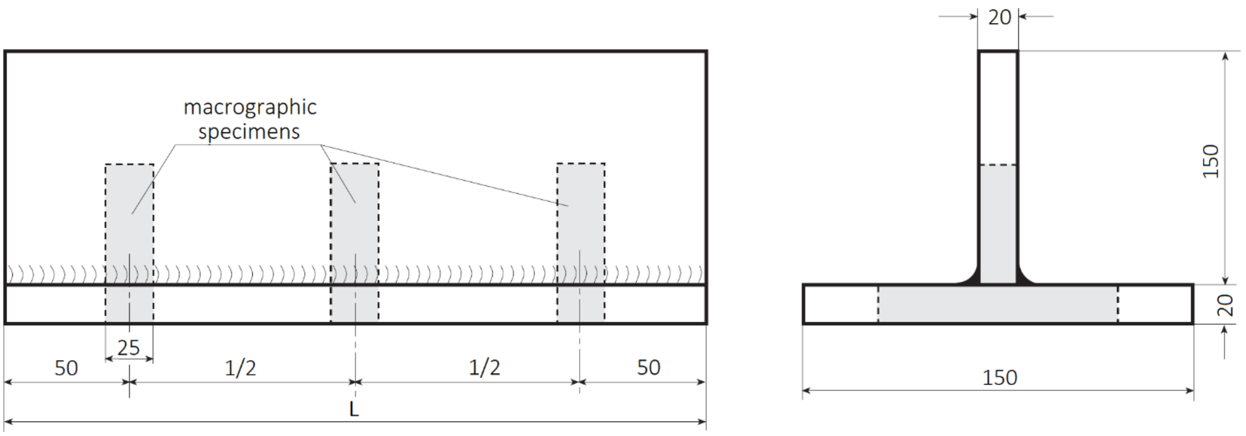


Fig. 5.7 Fillet-weld test piece

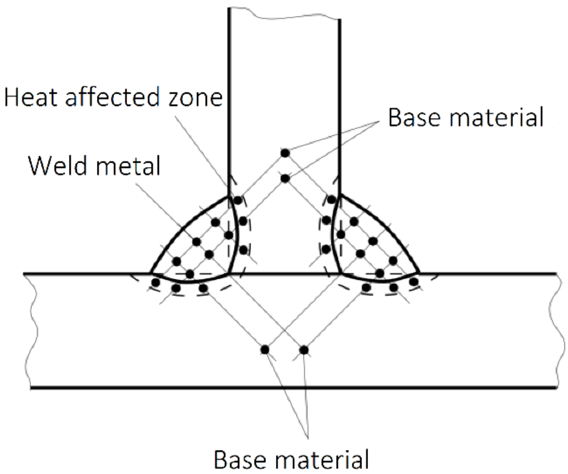


Fig. 5.8 Hardness measurements

4. Hydrogen test

4.1 The hydrogen test to determine the diffusible hydrogen content of the weld metal should, where possible, be conducted according to the mercury method or thermal conductivity detector method prescribed in ISO 3690 or, with BKI's consent, according to other comparable methods. For an interim period and with BKI's consent, the glycerine method described in 4.4 may continue to be used as an alternative for the added symbols H15 and H10. Depending on the added symbols H15, H10 or H5 to be appended to the quality grade specified in the approval (see A.4.1), the hydrogen content of the weld metal shall not exceed the limits indicated in Table 5.7.

4.2 In the mercury method, the quantity of hydrogen related to the fused weld metal H_F shall be determined and recorded in addition to the quantity of diffusible hydrogen related to the deposited weld metal H_D (see ISO 3690).

Table 5.7 Permissible hydrogen content of weld metal

Added symbol	Permissible hydrogen content of welding material 1)		
	Mercury method	Glycerine method	Thermal conductivity detector method
H15	15 cm^3 / 100 g	10 cm^3 / 100 g	15 cm^3 / 100 g
H10	10 cm^3 / 100 g	5 cm^3 / 100 g	10 cm^3 / 100 g
H5	5 cm^3 / 100 g	2)	5 cm^3 / 100 g

1) Mean value of four specimens, related to deposited weld metal.
2) Not to be used.

4.3 Four weld assemblies are to be prepared. The temperature of the specimens and minimum holding time are to be complied with following Table 5.8, according to the measuring method respectively.

Table 5.8. Standard test temperature and holding time for mercury method

Measuring method		Test temperature (°C)	Minimum holding time (h)
Thermal conductivity detector method 1)	Gas chromatography	45	72
		150	6

1) The use of hot carrier gas extraction method may be considered subject to verification of testing procedure to confirm that collection and measurement of the hydrogen occurs continuously until all of the diffusible hydrogen is quantified

4.4 Where the glycerine method of testing for hydrogen is used, the following procedure shall be adopted:

4.4.1 Four sample bars of normalized steel[1] measuring 125 × 25 × 12 mm shall be thoroughly cleaned and weighed to the nearest 0,1 g. A single bead of weld, approximately 100 mm long, is to be laid down on one of the 125 × 25 mm faces of each sample bar, on each occasion using a new 4 mm diameter rod electrode. 120 to 150 mm of the electrode length shall be consumed in the process.

4.4.2 The welding operation shall be performed with a current of approximately 150 A and the shortest possible arc. Where the welding process is mechanized, the electrode diameter and the amperage shall be so chosen that the thermal input corresponds to that of manual arc welding. Prior to welding, the consumables may be baked in the normal manner prescribed by the manufacturer.

4.4.3 Within 30 seconds of the completion of the welding of each specimen the slag is to be removed and the specimen quenched in water at approximately 20°C. After 30 seconds in the water, the specimen is to be cleaned and dried, and then placed in an apparatus suitable for the collection of hydrogen by displacement of glycerine. The glycerine is to be kept at a temperature of 45°C during the test. All four

[1] Wherever possible, the steel should not contain more than the following components: 0,15% C, 0,10% Si, 1,0% Mn, 0,03% P, 0,03% S.

specimens are to be welded and placed in individual hydrogen collecting apparatus within a period of time which will limit any variation in hydrogen content due to variation in exposure to moisture absorption following any drying treatment. This should not exceed 30 minutes.

4.4.4 During the test, the temperature of the glycerine is to be held at 45°C. The sample bars are to be left immersed in the glycerine for 48 hours, after which they are to be taken out and cleaned with water and alcohol. After drying, the sample bars shall again be weighed to the nearest 0,1 g to determine the quantity of deposited weld metal.

4.4.5 The volume of gas collected in the test vessel is to be measured to the nearest 0,05 cm^3 and corrected for a temperature of 0°C and a pressure of 760 mm of mercury. The mean volume of the diffusible hydrogen measured in relation to the deposited weld metal for the four sample bars may not exceed the values indicated in Table 5.7.

5. Hot-cracking test

5.1 Where BKI requires that a hot cracking test be performed, two plates shall for that purpose be welded together in the manner shown in Fig. 5.9. The end face of the web plate shall be cut straight and at right angles and shall fit snugly against the flat upper surface of the bottom plate. Any unevenness is to be removed. The base plate shall be stiffened by three transverse web plates.

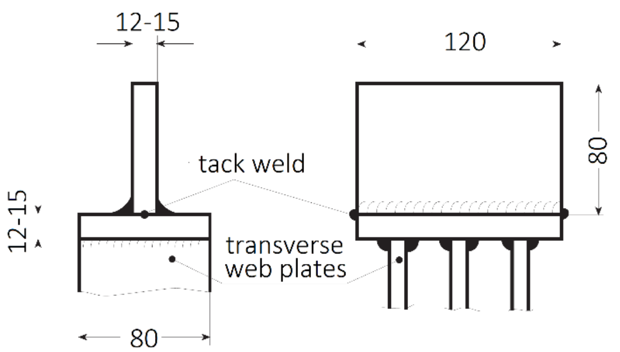


Fig. 5.9 Test piece for hot cracking

5.2 The first fillet weld is to be laid down in a single pass in the down hand PA(d) position. During this operation, the current shall be at the upper limit of the range prescribed for the electrode. The second fillet weld on the opposite side shall be laid down immediately after the first, also in the down hand PA (d) position and starting at the end of the test piece where the first fillet weld terminated. Both fillet welds are to be laid down at a uniform speed without weaving of the electrode.

5.3 For the welding of the complete length of each fillet weld (120 mm), the electrode lengths indicated in Table 5.9 are to be molten off. After welding, the slag shall at once be removed from the fillet welds.

Table 5.9 Molten off lengths of electrodes

Electrode core wire diameter [mm]	Molten-off lengths	
	1st fillet weld [mm]	2nd fillet weld [mm]
4	200	150
5	150	100
6	100	75

5.4 Half an hour after welding, at the earliest, i.e. when the test piece has cooled completely through its entire thickness, the fillet welds are to be examined for cracks with a magnifying glass or by a crack-detecting technique.

The first fillet weld shall then be removed by machining and the second fillet weld shall be fractured by collapsing the plates (with the root in tension). The fractured seam shall then be examined for hot cracks. When subjected to testing for hot cracks, the fillet welds may not reveal any superficial or internal cracks of any kind. Only end crater cracks may be tolerated.

6. Annual repeat tests

6.1 For rod electrodes for hull structural steels, the annual repeat test called for in A.3.1 requires the preparation of two weld metal test pieces in accordance with 2.1. The test specimens prescribed in 2.3 shall be taken from these. For the tests to be applied and the required properties, see 2.4 and Table 5.3.

6.2 In special cases BKI may stipulate more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

C. (Flux-cored) Wire-Gas Combinations and Flux-Cored Wire Electrodes for Welding of Hull Structural Steels

1. General

1.1 The following provisions apply to (flux-cored) wire-gas combinations and flux-cored or flux-coated wire electrodes (for use with or without a shielding gas) for semi-mechanized welding of hull structural steels, of corresponding grades of steel forgings and castings and of comparable structural steels. Wire-gas combinations for manual tungsten-inert-gas (TIG) welding shall be treated analogously to those for semi-mechanized welding. For wire-gas combinations and flux-cored or flux-coated wire electrodes for fully mechanized welding and mesh-wound wire electrodes, see D.1.1.

1.2 Depending on the results of impact tests, wires and wire-gas combinations are divided into the following grades:

- For normal strength steel: Grades 1, 2 and 3;
- For higher strength steels with minimum yield strength up to 355 N/mm^2: Grades 1Y, 2Y, 3Y and 4Y.
- For higher strength steels with minimum yield strength up to 390 N/mm^2: Grades 2Y40, 3Y40, 4Y40 and 5Y40.
- For YP47 steel :Grade 3Y47

A suffix "S" will be added after the grade mark to indicate approval for semi-automatic multi-run welding. For inclusions and exclusions, see A.4.

1.3 Approval is essentially linked to a specific (commercial) brand of wire - where appropriate, in conjunction with a shielding gas conforming to a standard (e.g. to ISO 14175) or defined in terms of its composition and purity. An approval relates exclusively to the wire produced by a particular manufacturer and used for the approval tests. BKI is to be notified of the manufacturer and the brand and standard designations of the wire used for the approval test. The marketing of other wires (wires produced by other manufacturers) under the (commercial) brand name stated in the approval certificate is permitted only after a renewed approval test using the other wire.

1.4 Approval may be granted for a (commercial) brand of wire in conjunction with a specific (commercial) brand of shielding gas produced by a particular manufacturer or in conjunction with a shielding gas covered by ISO 14175 and defined by its group and code number (e.g. M 21) in accordance with Table 5.10.

1.5 Where a (commercial) brand of (flux-cored) wire is approved in conjunction with a standardized shielding gas in accordance with 1.4, the wire in question may be used with other standardized gases of the same type, provided that these gases are included in the "List of Type Approved Products" (see A.1.13) on the basis of an initial verification of identity performed on the manufacturer's premises followed by annual repeat tests of composition and purity. Branch works, cylinder filling stations, etc. shall also be covered by these tests. For gas mixing installations (including those on the user's premises) adequate documentary proof shall be submitted to BKI.

1.6 If in exceptional cases, e.g. where the gas producer makes application for approval for a (flux-cored) wire-gas combination, approval is required to be granted for a specific standard wire in conjunction with a (commercial) brand of gas produced by a particular manufacturer, the brand of wire used in the test will also be noted in the approval confirmation document. The use of other, equivalent (commercial) brands of (flux-cored) wire or standard wire as part of such an approval is only permitted if the particular wire in question has already been tested and approved elsewhere with a gas of the appropriate composition and is included on the "List of Type approved Products" (see A.1.13)

Table 5.10 Classification of shielding gases according to ISO 14175

Symbol		Components [% vol.]					
Main Group	Sub-group	Oxidizing		Inert		Reducing	Low reactivity
		CO_2	O_2	Ar	~~He~~	H_2	N_2
M1	1	≥ 0,5 to 5		balance 1)		≥ 0,5 to 5	
	2	≥ 0,5 to 5		balance 1)			
	3		≥ 0,5 to 3	balance 1)			
	4	≥ 0,5 to 5	≥ 0,5 to 3	balance 1)			
M2	0	> 5 to 15		balance 1)			
	1	> 15 to 25		balance 1)			
	2		> 3 to 10	balance 1)			
	3	≥ 0,5 to 5	> 3 to 10	balance 1)			
	4	> 5 to 15	≥ 0,5 to 3	balance 1)			
	5	> 5 to 15	> 3 to 10	balance 1)			
	6	> 15 to 25	≥ 0,5 to 3	balance 1)			
	7	> 15 up to 25	> 3 to 10	balance 1)			
M3	1	> 25 up to 50		balance 1)			
	2		> 10 up to 15	balance 1)			
	3	> 25 up to 50	> 2 up to 10	balance 1)			
	4	> 5 up to 25	> 10 up to 15	balance 1)			
	5	> 25 up to 50	> 10 up to 15	balance 1)			
C	1	100					
	2	balance	≥ 0,5 to 30				

1) For the purpose of this classification, argon may be substituted partially or completely by helium.

2. Testing the weld metal

2.1 For testing the deposited weld metal, two test pieces are to be prepared in the down hand PA (d) welding position in accordance with B.2.1 and Fig. 5.1. One of the test pieces is to be welded with wire of 1,2 mm diameter or the smallest diameter produced for use in shipbuilding. The other is to be welded with wire of 2,4 mm diameter or the largest diameter produced. Where wire of only one diameter is produced, a single test piece is sufficient. The test pieces are to be welded in a manner analogous to that prescribed in B.2.1 (see also ISO 14341) in such a way that the thickness of the individual passes is at least 2 mm but not more than 6 mm.

2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in B.2.2. The results of the analysis shall not exceed the limiting values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

2.3 The test specimens defined in B.2.3 and Figs. 5.2 and 5.3 shall be machined from the weld metal test pieces and subjected to test.

2.4 The test results shall meet the requirements stated in D.2.4 and resp. Table 5.13.

3. Testing on welded joints

3.1 As in the case of covered electrodes for manual arc welding (see B.3.1), tests on the welded joint are generally carried out on butt-welded test pieces in accordance with Fig. 5.4 and Table 5.5 and in certain cases on fillet-weld test pieces in accordance with B.3.5 and Fig. 5.7.

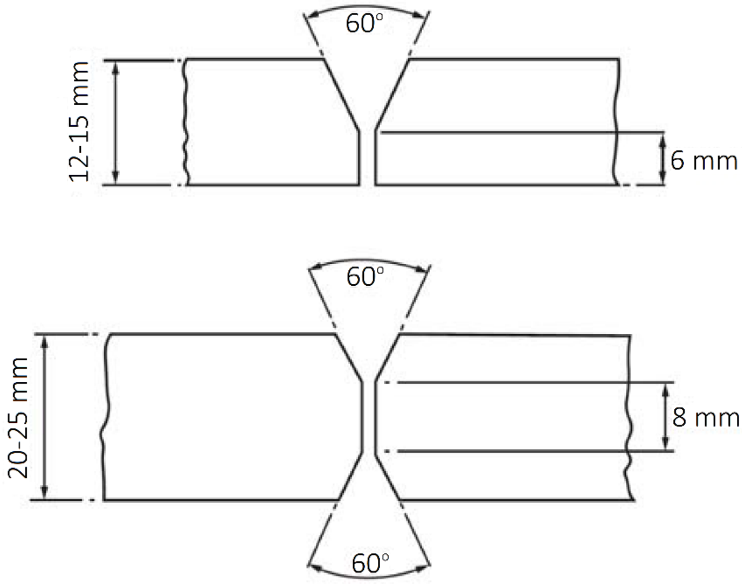
3.2 Depending on the welding positions applied for approval (see A.4.9), the butt-weld test pieces are to be welded in the positions indicated in Table 5.5, but with the wire diameters shown in Table 5.11. For the base materials to be used, see A.7.2. The test pieces shall be welded in a manner analogous to that prescribed in B.3.2.

Table 5.11 Butt-weld test pieces, wire diameters

Welding Position	Root pass	Filler and cover passes, back pass
Down-hand PA (d) [1]	1,2 mm or smallest diameter produced	2,4 mm or largest diameter produced
Other positions	1,2 mm or maximum diameter recommended by the manufacturer for the position concerned	

[1] Where approval is required only for the PA (d) position, a second test piece shall be welded in this position with the various wire diameters recommended by the manufacturer.

3.3 For automatic two-run welding, two butt weld test pieces is to be prepared in accordance with Fig. 5.10. If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.



All dimensions in mm unless otherwise indicated

Fig. 5.10 Recommended edge preparation for two run butt weld test assemblies

Small deviations in the edge preparation may be allowed, if requested by the manufacturer. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information. Deviations or variations will be expected to form part of the manufacturer's standard recommended procedure for this technique and thickness range.

The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

3.4 Following the recommended radiographic examination, test specimens in accordance with B.3.3 and Figs. 5.3 to 5.6 shall be machined from the butt weld test pieces and subjected to test.

3.5 The test results shall meet the requirements stated in B.3.4 and Table 5.6.

3.6 If necessary according to B.3.1, fillet-weld test pieces in accordance with Fig. 5.7 shall be welded in each of the welding positions applied for approval (see A.4.9). For the base materials to be used, see A.7.2. The test pieces shall be welded in a manner analogous to that prescribed in B.3.5.

3.7 The fillet-weld test pieces are to be sectioned and tested in a manner analogous to that prescribed in B.3.6 and B.3.7.

4. Hydrogen test

4.1 (Flux-cored) wire-gas combinations and flux-cored or flux-coated wires whose composition (core material) or structure (e.g. folded flux-cored or flux-coated wire) may result in moisture up take and consequently a higher concentration of hydrogen in the weld metal shall be subjected to a hydrogen test, unless otherwise agreed. In the case of solid wire-gas combinations, a hydrogen test is normally unnecessary.

4.2 For the performance of the hydrogen test and the requirements to be met, see B.4; unless otherwise stipulated in a particular case, a wire electrode 1,2 mm in diameter shall be used for this purpose. The welding parameters shall comply with the manufacturer’s recommendations.

5. Hot cracking test

5.1 Where BKI calls for a hot cracking test (see B.5.1), a test piece conforming to Fig. 5.9 with 250 mm in length shall be welded.

5.2 The wire diameters, weld thicknesses and weld lengths shall conform to Table 5.12. In all other respects, the provisions of B.5.2 - B.5.4 shall be applied in analogous manner.

Table 5.12 Wire diameters and weld dimensions

Wire diameter [mm]	1st fillet weld		2nd fillet weld	
	a-dimension [mm]	Weld length [mm]	a-dimension [mm]	Weld length [mm]
1,2	9	250	7	250
1,6	9		7	

6. Annual repeat tests

6.1 (Flux-cored) wire-gas combinations and flux-cored or flux-coated wires approved for semi-mechanized welding or both semi-mechanized and fully mechanized multi run welding, the annual repeat test in accordance with A.3.1 shall entail the welding, with wire diameters within the range approved, of one deposit metal test assembly, from which shall be taken the test specimens called for in 2.3 and 3.3. For the tests to be applied and the requirements to be met, see 2.4.

6.2 In special cases, BKI may require a more extensive repeat test (see A.3.2, A.7.4 and A.7.5).

D. Wire-Flux Combinations for Submerged-Arc Welding of Hull Structural Steels

1. General

1.1 The following provisions apply to wire-flux combinations for two run and multi run technique of submerged-arc (SAW) welding of hull structural steels, of the corresponding grades of steel forgings and castings, and of comparable structural steels. Approvals granted in accordance with these provisions are valid for standard single-wire welding. Approval also covering tandem or multi-wire welding and single-side welding using (flux-) backings necessitates the performance of a (preliminary) welding procedure test. Wire-gas combinations and flux cored wires used only for fully mechanized welding and mesh-wound wire electrodes shall be analogously tested and approved in accordance with these Rules.

1.2 Where there is a requirement to use multiwire flux combinations of a certain, stipulated composition and structure, BKI may require additional test pieces or tests to be performed over and above the standard test described below. The test pieces submitted for these tests shall be of this combination and structure. The composition and structure will then be particularly noted in the approval confirmation.

1.3 Depending on the results of impact tests, wire-flux combinations are divided into the following grades:

- For normal strength steel: Grades 1, 2 or 3.
- For higher strength steels with minimum yield strength up to 355 N/mm^2: Grades 1Y, 2Y, 3Y or 4Y.
- For higher strength steels with minimum yield strength up to 390 N/mm^2: Grades 2Y40, 3Y40, 4Y40 or 5Y40.
- For YP47 steel: Grade 3Y47.

Wire-flux combinations for welding in a single pass on each side (two-run technique) are designated by the added symbol "T". Those used for multi-run welding receive the added symbol "M", and those used for both welding techniques the added symbol "TM". The base materials used for approval tests shall be as shown in Table 5.3. For inclusions and exclusions, see A.4.

1.4 Approval is essentially linked to a specific (commercial) brand of flux in conjunction with a (commercial) brand of wire produced by a particular manufacturer, or in conjunction with a standardized wire (e.g. to ISO 14171) or a wire otherwise identified by its chemical composition and other characteristics. BKI is to be notified of the manufacturer and the brand or standard designation of the wire used for the approval test.

1.5 Where approval is granted with a standardized wire, the type of flux concerned (the commercial brand) may also be used with other standardized wires of the same type (wires produced by other manufacturers who have been checked by BKI in accordance with A.1.2), provided that these wires are included in the "List of Type Approved Products" (see A.1.13) on the basis of an initial verification of identity followed by annual repeat tests of the chemical composition and other qualitative characteristics. The marketing of wires produced by different manufacturers under a single brand designation approved by BKI is not permitted.

1.6 Wire flux combination for submerged arc welding. If a unique powder flux is combined with different wires coming from several factories belonging to the same firm, it may be admitted to perform only one test-series if the different wires are conformable to the same technical specification, after approval of BKI.

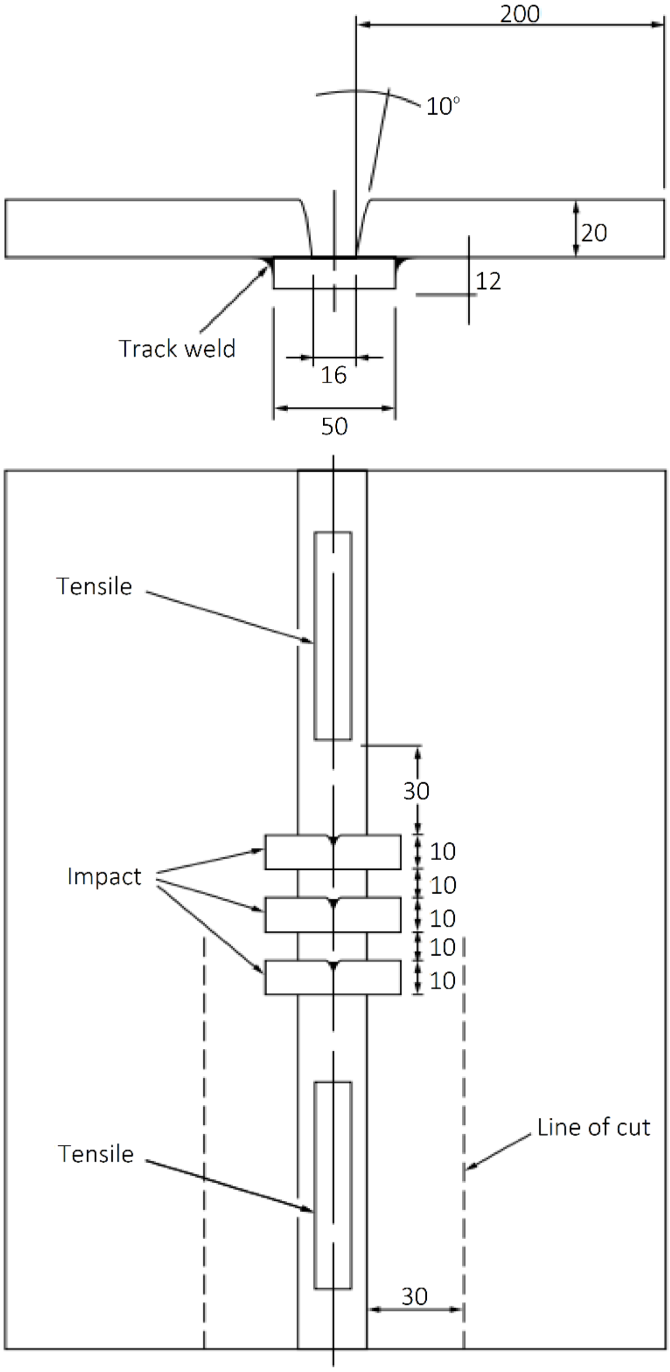
2. Testing the weld metal

2.1 Testing of the deposited weld metal is required in the case of an approval relating to multi-run technique (added symbol M), two-run and multi-run technique (added symbol TM), or exclusively to the welding of (double) fillet welds. When a wire-flux combination is offered to approval for use with the two-run technique only, no deposited metal test assemblies have to be made. For this purpose, a weld metal test piece as shown in Fig. 5.11 is to be welded in the down hand PA (d) position using wires at least 4 mm in diameter.

The welding parameters should be as used for ordinary multi-run welding, and individual runs should be laid down in alternate directions. Before each new run, the test piece should be cooled in still air to 250°C or below, but on no account below 100°C. The temperature is to be measured at the surface of the centre of the weld. The thickness of the individual runs should be at least equal to the diameter of the welding wire used and shall not be less than 4 mm.

2.2 The chemical composition of the weld metal shall be determined and certified in a manner analogous to that prescribed in B.2.2. The results of the analysis shall not exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

2.3 Following the recommended radiographic examination, round tensile test specimens (two specimens for M and one specimen for TM) conforming to Fig. 5.2 and three ISO V-notch impact test specimens conforming to Fig. 5.3 shall be machined from the weld metal test piece as shown in Fig. 5.11. For the preparation and heat treatment of the test specimens, see B.2.3.



All dimensions in mm unless otherwise indicated

Fig. 5.11 Weld metal test piece for submerged-arc welding

2.4 The mechanical properties of the weld metal shall meet the requirements indicated in Table 5.13. The provisions of B.2.4 and 2.5 apply in analogous manner to the maintenance of the test temperature, the performance of the notched bar impact tests and the carrying out of retests.

Table 5.13 Required properties of the weld metal in submerged-arc welding

Quality grade	Yield strength [N/mm²] min.	Tensile strength [N/mm²]	Elongation (at Lo = 5d) [%] min.	Impact energy[1)] [J] min.	Test temperature [°C]
1	305	400 – 560	22	34 (24)	20
2					0
3					−20
1Y	375	490 – 660	22	34 (24)	20
2Y					0
3Y					−20
4Y					−40
2Y40	400	510 – 690	22	39 (27)	0
3Y40					−20
4Y40					−40
5Y40					−60
3Y47	460	570 - 720	19	53 (37)	-20

[1)] Mean value of three specimens; ( ) minimum individual values; for this and retests, see B.2.4 and 2.5 and well as D.2.4.

3. Testing on welded joints

3.1 Tests on the welded joint are generally performed on butt-weld test pieces as shown in Fig. 5.12 for multi-run technique (added symbol M) and/or Fig. 5.13 for the two-run technique (added symbol T). Where an application relates only to approval for welding in a single run on each side (T), testing of the deposited weld metal in accordance with 2. may be dispensed with.

Where approval is to cover wire-flux combinations used exclusively for fillet welds, the butt-weld test pieces shall be replaced by a fillet-weld test piece analogous to Fig. 5.7 but with dimensions suitable for submerged-arc welding. After inspection for surface cracks, this shall be sectioned and tested in a manner analogous to that described in B.3.6 and B.3.7. BKI may also call for fillet-weld test pieces in addition to butt-weld ones.

3.2 For multi-run technique (added symbol M), a butt-weld test piece conforming to Fig. 5.12 shall be welded in the down hand PA (d) position by welding together two plates (20 to 25 mm thick), each not less than 150 mm in width and sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single vee joint, the included angle between the fusion faces being 60° and the root face being 4 mm. Where a wire-flux combination is also to be approved for other positions (e.g. for welding in the horizontal vertical position), test pieces shall also be welded in these positions. For the base materials to be used, see A.7.2, although grade A hull structural steel shall as a rule be used for approvals with quality grades 1 and 2.

The two portions of the test piece shall be juxtaposed with sufficient allowance for angular shrinkage. The weld shall be executed by the multi-run technique using wires of at least 4 mm diameter and the same parameters and method as for the submerged-arc weld metal test piece described in 2.1. Before the back pass is laid down, the root is to be grooved at the back of the weld, if possible by machining. After welding the test assembly is not to be subject to any heat treatment.

3.3 Following the recommended radiographic examination, the test specimen to be prepared from the butt-weld test piece are given in Table 5.14 and shown in Fig. 5.12.

Table 5.14 General table giving the mechanical tests on butt-weld test piece with submerged-arc welding for wire/flux approval

M (multi-run technique)	T (two-run technique)		TM (two-run and multi-run technique)		
Butt-weld test piece	Butt-weld test piece (minimum thickness)	Butt-weld test piece (maximum thickness)	butt-weld test piece Multi-run technique	butt-weld test piece (Minimum thickness)	butt-weld test piece (Maximum thickness)
2 FT 4 TB 3 CV -	2 FT 2 TB 3 CV -	2 FT 2 TB 3 CV 1 RT	2 FT 4 FB 3 CV -	2 FT 2 TB 3 CV -	2 FT 2 TB 3 CV 1 RT

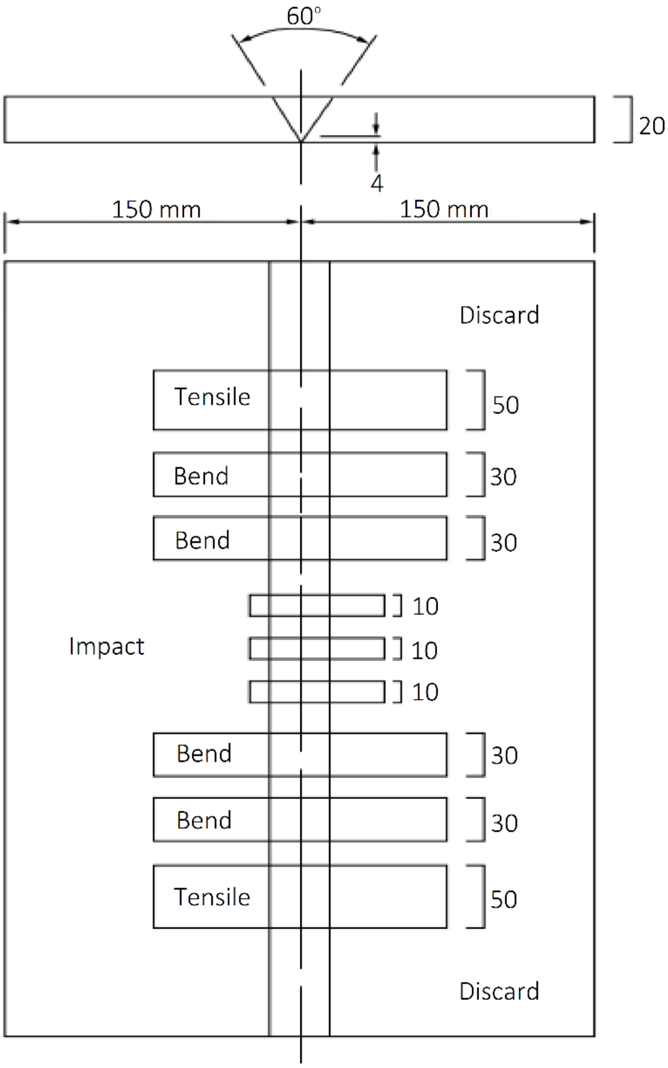
Symbol definition:
FT : flat tensile test specimens conforming to Fig.5.6
TB : transverse bend test specimens
CV : charpy-V impact test in the axis of the weld conforming to Fig.5.3
RT : round tensile test specimens conforming to Fig.5.2

3.4 The mechanical properties shall meet the requirements stated in Table 5.15. The provisions of B.2.4 and B.2.5 as well as B.3.4 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperatures for the notched bar impact tests and the information on retest specimens.

Table 5.15 Required properties of submerged-arc welded joints

Quality grade	Tensile strength [N/mm²]	Minimum notch impact energy [J] [1]	Minimum notch impact energy Test temperature [°C]	Bending Test Ratio (D/t)	Minimum bending angle
1	≥ 400	34 (24)	20	3	120° before the first incipient crack, minor pore exposures up to a maximum length of 3 mm allowed
2			0		
3			−20		
1Y	≥ 490	34 (24)	0		
2Y			20		
3Y			−20		
4Y			−40		
2Y40	≥ 510	39 (27)	0		
3Y40			−20		
4Y40			−40		
5Y40			−60		
3Y47	≥ 570	53 (37)	−20	4	

[1] Mean value of three specimens; ( ) minimum individual values; for this and retests see B.2.4 and 2.5 as well as D.3.4 and 3.7



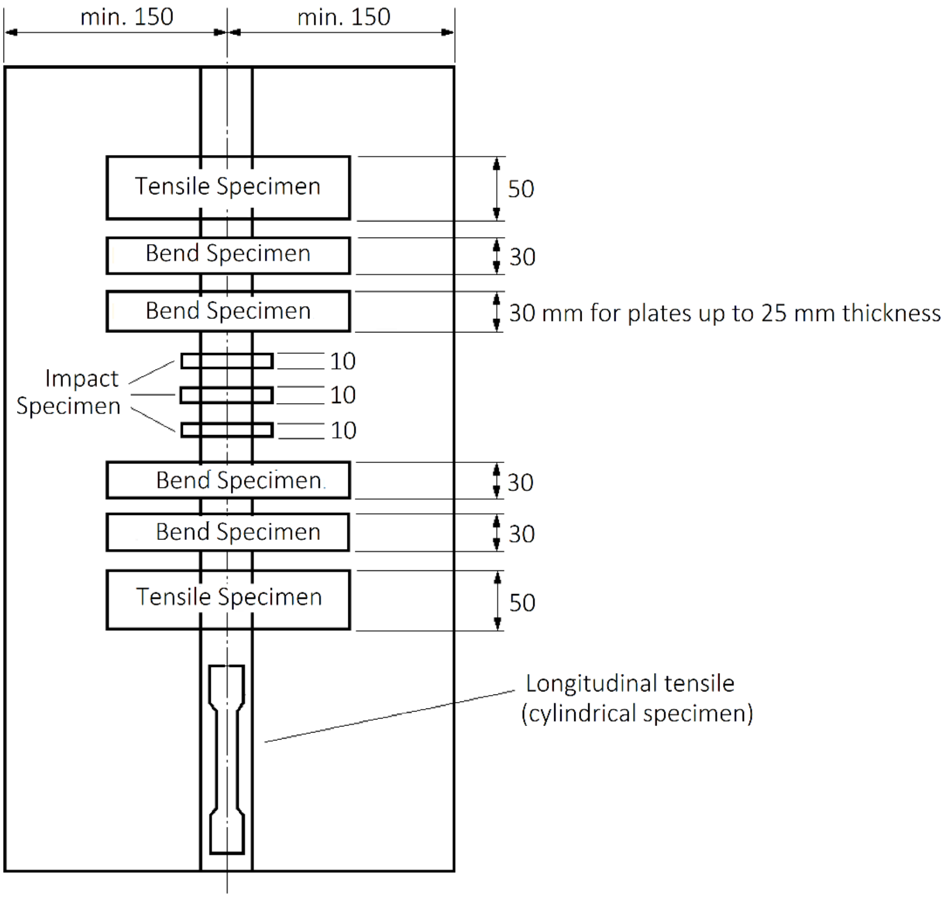
All dimensions in mm unless otherwise indicated

Fig. 5.12 Multi-run butt weld test piece for submerged-arc welding

3.5 For welding one run on each side (two-run technique added symbol T), two butt-weld test pieces as shown in Fig. 5.13 are to be welded in the down hand PA (d) position using the base materials, plate thicknesses, weld shapes and wire diameters shown in Table 5.16. Where approval is requested for welding of both normal strength and higher strength steel two assemblies are to be prepared using higher strength steel. The chemical composition of the base materials used shall be stated in the test report.

The butt-weld test pieces shall be produced by laying down one run on each side. The welding current parameters and the feed rates shall be those recommended by the manufacturer for application. After laying down the first run, flux and slag are to be removed and the test piece allowed to cool down to 100°C in still air. The temperature is to be measured at the surface of the center of the weld. The root should be grooved prior to laying down the second run only if this is expressly prescribed by the manufacturer for the future application.

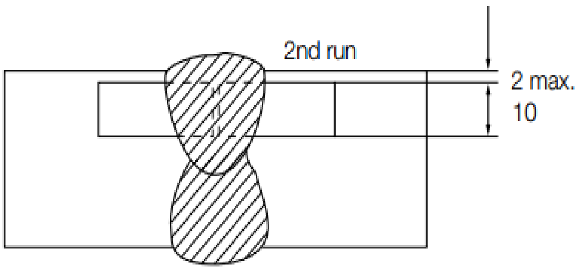
3.6 Following the recommended radiographic inspection, the test specimens indicated in Table 5.14 and shown in Fig. 5.13 are to be prepared from each butt weld test-piece.



All dimensions in mm otherwise indicated

Fig. 5.13 "T" submerged-arc butt-weld test piece for one run on each side (two-run technique)

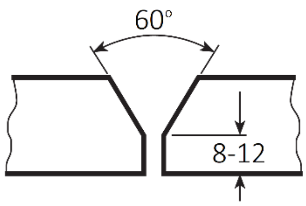
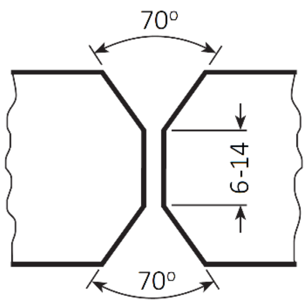
3.7 The mechanical properties shall meet the requirements stated in Table 5.15. The provisions of B.2.4 and B.2.5 as well as B.3.4 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperatures for the notched bar impact tests and the information on retest specimens.



All dimensions in mm otherwise indicated

Fig. 5.14 "T" butt-weld test piece; location of notched bar impact test specimens

Table 5.16 "T" submerged-arc butt-weld test pieces; base materials, plate thicknesses, weld shapes and wire diameters

Quality grades	Base material [1)]	Thickness of test piece t [2)] [mm]	Recommended weld preparation [3)]	Maximum wire diameter [mm]
1 1Y	A A 32, A 36	12 – 15		5
1 1Y	A A 32, A 36	20 – 25		6
2 2Y 2Y40	A, B, D A 32, A 36, D 32, D 36 A 40, D 40			
3 3Y 3Y40	A, B, D, E A 32 to E 36 A 40, to E 40			
4Y 4Y40 5Y40 3Y47	A 32 to F 36 A 40 to F 40 A 40 to F 40 YP47			
2 2Y 2Y40	A, B, D A 32, A 36, D 32, D 36 A 40, D 40	30 – 35		7
3 3Y 3Y40	A, B, D, E A 32 to E 36 A 40 to E 40			
4Y 4Y40 5Y40 3Y47	A 32 to F 36 A 40 to F 40 A 40 to F 40 YP47			

1) A32, D32, E32, F32 only with a tensile strength of at least 490 N/mm^2.

2) For approval with quality grades 1 and 1Y : t = 12 - 15 and 20 - 25 mm,
For approval with quality grades 2 to 5Y40 : t = 20 - 25 and 30 - 35 mm.
A limitation of the approval to the lower and medium thickness range (up to the maximum welded plate thickness) may be agreed to, and the test pieces shall then be welded from plates of thickness t = 12 - 15 mm and 20 - 25 mm irrespective of the quality grade.

3) Minor deviations in the weld preparation are admissible. The root gap should not exceed 1 mm.

4. Hydrogen test

4.1 Where a hydrogen test is stipulated for a wire-flux combination (or for the flux component), this shall be performed analogously to B.4, although with the altered dimensions for the specimens and the clamping device according to ISO 3690-2.

4.2 Alternatively, the hydrogen test may, for an interim period, continue to be conducted according to the glycerine method described in B.4.3. Here too, however, the dimensions of the specimens and the clamping device shall conform to ISO 3690-2.

5. Annual repeat tests

5.1 For multi-run technique (M), the annual repeat test shall entail testing of the deposited weld metal in accordance with 2. (submerged-arc weld metal test piece as shown in Fig. 5.11). However, only one round tensile test specimen and three notched bar impact test specimens need to be tested on these occasions.

5.2 For two-run technique (T), a T butt-weld test piece as shown in Fig. 5.13 with 20-25 mm in thickness plate shall be prepared and tested in accordance with 3.6 and 3.7. However, only one round tensile test specimen, one flat tensile test specimen, two transverse bend test specimens and three notched bar impact test specimens need to be tested on these occasions.

5.3 For two-run and multi-run technique (TM), the weld metal test piece prescribed in 5.1 and the T butt-welded test piece in accordance with. 5.2 shall be welded and tested. The round tensile test specimen called for in 5.2 may, however, be dispensed with.

5.4 Wire-flux combinations used exclusively for fillet welding (see 2.1 and 3.1) are to be repeat tested in accordance with 5.1.

5.5 For tandem and multi-wire technique and for single-side welding using (flux) backings, annual repeat tests analogous to those provided for above shall be conducted with the welding method concerned (see 1.1 and A.3.7).

5.6 Where a wire-flux combination is approved for welding both normal strength and higher strength steel, the latter steel is to be used for the preparation of the butt weld assembly required by 5.2.

5.7 In special cases, BKI may require more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

E. Welding Consumables and Auxiliary Materials for Electrogas and Electroslag Welding of Hull Structural Steels

1. General

1.1 The following provisions apply to wire-gas combinations, flux-cored or flux-coated wires and wire-flux combinations for fully mechanized electrogas (EG) and electroslag (ES) welding (in the vertical-up position) of hull structural steels, of corresponding grades of steel forgings and castings, and of comparable structural steels. Where consumable nozzle electrodes are used, these are to be included in the test.

1.2 The welding consumables and auxiliary materials referred to in 1.1 and used for normal-strength hull structural steels are approved according to quality grades 1V, 2V and 3V depending on the notch impact energy values achieved during the approval tests. Quality grades 1YV, 2YV, 3YV and 4YV or, where applicable, 2Y40V, 3Y40V, 4Y40V and 5Y40V are awarded to such welding consumables and auxiliary materials used for higher-strength hull structural steels. Quality grades 3Y47V is awarded to welding consumables and auxiliary materials used for YP47 steel. For inclusions and exclusions, see A.4.

2. Testing on welded joints

2.1 The testing of welding consumables and auxiliary materials covered by 1.1 and used for electrogas and electroslag welding is performed exclusively on welded joints in a manner analogous to that prescribed in D.3.5 - D.3.7 for wire-flux combinations, using butt-weld test pieces conforming to Fig. 5.15.

2.2 Butt-welded test pieces conforming to Fig. 5.15 are to be welded analogously to Table 5.16 using base materials of known composition (to be recorded) and two thicknesses of plate, one of them with plates 20 - 25 mm thick, the other with plates 35 - 40 mm thick or more. The weld preparation, the wire diameter and the welding parameters shall conform to the manufacturer's recommendations for subsequent practice and are to be recorded. The length of the test pieces shall be suited to the welding appliances used and, where appropriate, to the length of the consumable nozzle electrodes.

2.3 Following the recommended radiographic examination, the following shall be removed from each butt-welded test piece according to Fig. 5.15: two flat tensile test specimens to Fig. 5.5, two side bend test specimens (specimen width 10 mm), two round tensile test specimens to Fig. 5.2, three notched bar impact test specimens (ISO V-notch impact test specimens according to Fig. 5.3) each from the center and side of the weld metal, and two macro graphic specimen. When the weld reinforcement has been machined off, the edges of the side bend test specimens may be rounded on the tension side to a radius not greater than 1 mm. The location of the notched bar impact test specimens shall conform to Fig. 5.16. The provisions of B.2.3 and B.3.3 apply in analogous manner.

2.4 The mechanical properties of the welded joint shall meet the requirements indicated in Table 5.15. The provisions of B.2.4 and 2.5 as well as B.3.4 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperature for the notched bar impact test and the carrying out of retests.

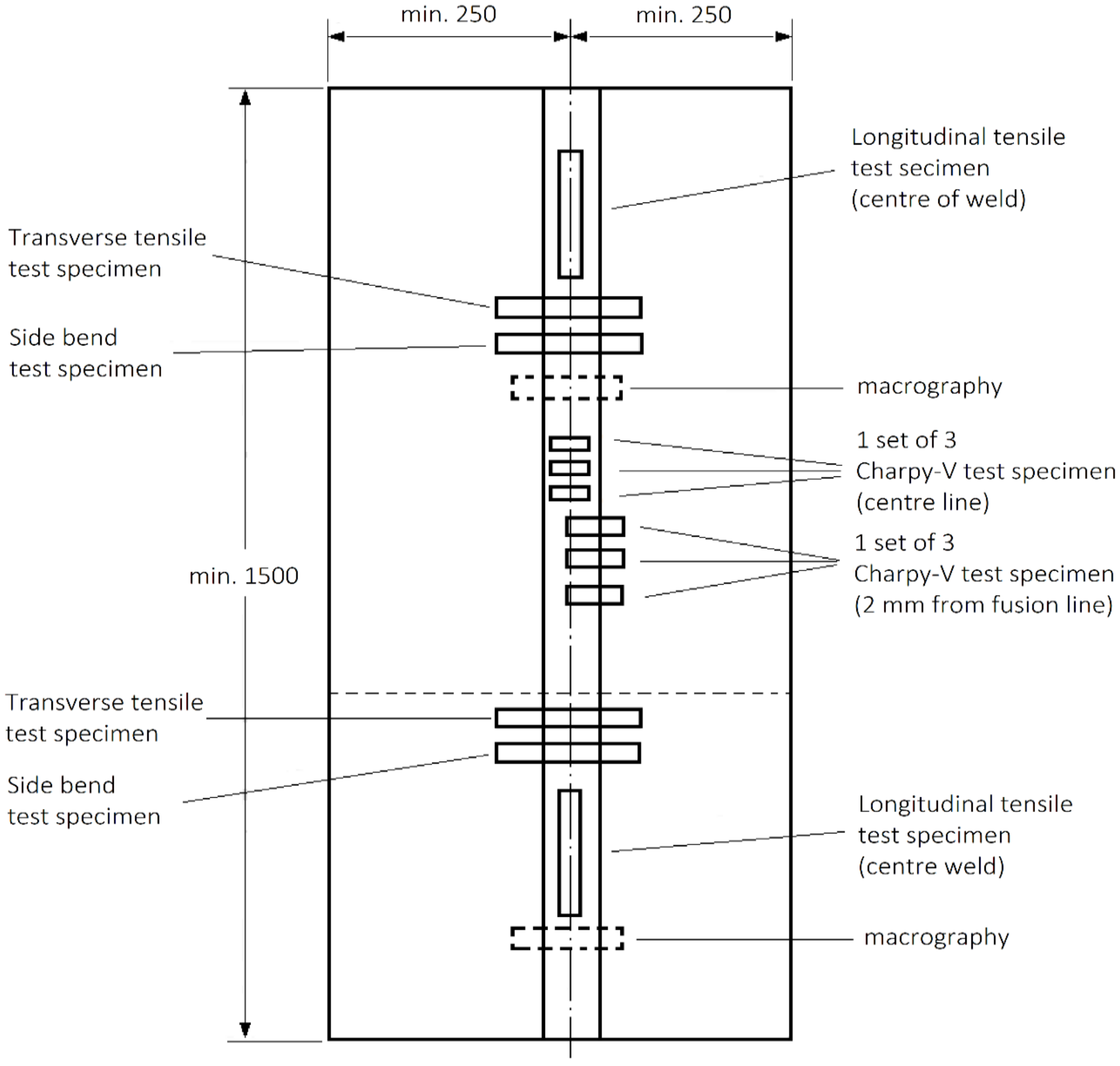
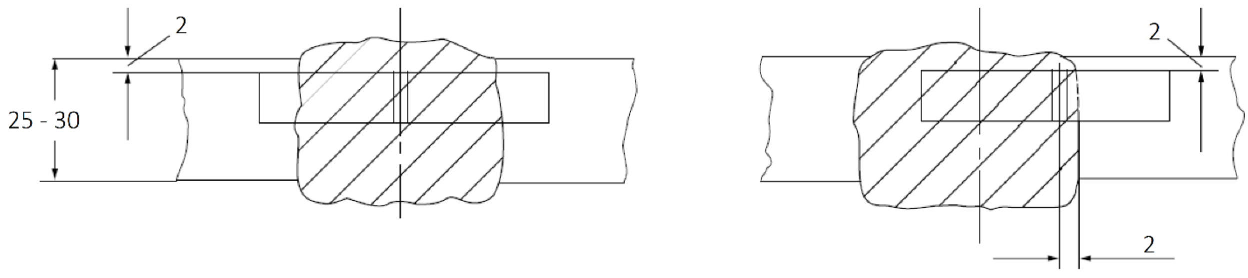


Fig. 5.15 Test piece for electrogas and electroslag welding



Notch in center of weld

Notch 2 mm from fusion line (weld metal side)

Fig. 5.16 Location of notched bar impact test specimens

3. Annual repeat tests

3.1 For the annual repeat testing of welding consumables and auxiliary materials covered by 1.1, a butt-welded test piece as shown in Fig. 5.15 with a medium plate thickness (20 - 25 mm unless otherwise specified) shall be welded in accordance with 2.2.

3.2 One round tensile test specimen, two side bend test specimens and three notched bar impact test specimens from the center of the weld metal in accordance with 2.3 and Fig. 5.16 shall be taken from the test piece prescribed in 3.1.

3.3 For the performance of the tests and the requirements to be met, see 2.4, B.2.4, 2.5 and B.3.4.

3.4 In special cases, the Society may require more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

F. Welding Consumables and Auxiliary Materials for High-Strength Structural Steels

1. General

1.1 The following provisions apply to welding consumables and auxiliary materials for welding of normalized or high-strength fine-grained structural steels with yield strengths levels from 420 up to 960 N/mm^2 and impact grades A, D, E and F, except that impact grade F is not applicable for 890 N/mm^2 and 960 N/mm^2 yield strength levels. For fine-grained structural steels with minimum yield strengths of up to 390 N/mm^2, the welding consumables and auxiliary materials for the corresponding hull structural steels (e.g. quality grade 3Y40 or 4Y40) may be used.

Note:

The chemical composition of the welding consumables and auxiliary material for high -strength fine grained structural steels necessary to obtaining weld metal with adequate mechanical properties often also results in good low temperature properties. In view of this fact and also bearing in mind the increased resistance to brittle fracture which is desirable when welding these steels, the welding consumables and auxiliary material referred to in 1.1 are generally approved only with a quality grade of 3 or above. Such approval normally also constitutes proof of suitability for low-temperature applications down to a minimum service temperature (design temperature) 5°C above the respective test temperature. See also G.

1.2 In a manner analogous to that applied to hull structural steels, welding consumables and auxiliary materials covered by 1.1 are approved according to quality grades 3 - 5 with the added symbol Y and an appended code number designating the minimum yield strength of the weld metal. The respective base materials will be classified in a manner analogous to that applied to hull structural steels see Section

12, Table.12.1) depending upon the particular strength and toughness properties in question. For other added symbols, see A.4.1; for inclusions and exclusions, see A.4.2.

1.3 Each higher quality grade includes the one (or those) below Grade A... and D... steels according to Rules for Materials (Pt.1, Vol.V) Sec.4 are to be welded using welding consumables of at least quality grade 3, grade E... steels using at least quality grade 4 and grade F... steels using at least quality grade 5, see the following table:

Consumable Grade	Steel Grades Covered
3Y...	D... and A...
4Y...	E..., D... and A...
5Y...	F..., E..., D... and A...

Welding consumable approved with grades.. Y42, ...Y46 and ...Y50 are also considered suitable for welding steels in the two strength levels below that for which they have been approved. Welding consumable approved with grades ...Y55, ...Y62 and ...Y69 are also considered suitable for welding steels in the one strength level below that for which they have been approved.

1.4 Welding consumables with grade Y89 are considered suitable for welding steels in the same strength level only. Welding consumables with grade Y96 are also considered suitable for welding steels in the one strength level below that for which they have been approved.

1.5 For grade Y89 and Y96, where the design requirements permit undermatching weld joint, then welding consumables within the scope of this rules can be considered subject to BKI discretion and Manufacturer's recommendations.

2. Testing of the weld metal

2.1 For testing the deposited weld metal, test pieces analogous to those called for in B.2.1, C.2.1 or D.2.1 shall be prepared, depending on the nature of the welding consumables and auxiliary materials (and according to the welding process). The base metal used shall be a fine-grained structural steel compatible with the properties of the weld metal- or the side walls of the weld shall be buffered with a weld metal of the same composition.

2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in B.2.2. The results of the analysis shall not exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

2.3 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the test specimens prescribed in B.2.3, C.2.3 or D.2.3 shall be taken from the weld metal test pieces in a similar manner.

2.4 The mechanical properties shall meet the requirements stated in Tables 5.16 and 5.17. The provisions of B.2.4, C.2.4 and D.2.4 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperature in the notched bar impact test and the carrying out of retests.

Table 5.16 Required properties of the weld metal, quality grades and test temperature

Quality Grade	Test temperature [°C]	Notch impact energy [J] 1) min.
3	- 20	2)
4	- 40	2)
5	- 60	2)

1) Charpy-V-notch specimens in accordance with ISO 148, mean value of three specimens; ( ) minimum individual values; for retests, see B.2.5.

2) See Table 5.17.

Table 5.17 Required properties of the weld metal

Symbols added to quality grade	Yield strength or 0,2 % proof stress [N/mm^2] min.	Tensile strength 1) [N/mm^2]	Elongation A [%] min.	Notch impact energy 2) [J] min.
Y42	420	530 - 680	20	47 (33)
Y46	460	570 - 720	20	47 (33)
Y50	500	610 - 770	18	50 (35)
Y55	550	670 - 830	18	55 (38)
Y62	620	720 - 890	18	62 (43)
Y89	890	940 - 1100	14	69 (48) 3)
Y96	960	980 - 1150	13	69 (48) 3)

1) The tensile strength of the weld metal may be up to 10% below the minimum tensile strength of the base material corresponding to the added symbol, provided that the results obtained with the transverse tensile specimens taken from the welded joints meet the minimum tensile strength requirements stated in Table 5.18. The elongation is to be stated in the test report.

Note:

For welding very large plate thicknesses where the "supporting effect" of the base material on either side of the weld no longer applies and the tensile strength of the weld metal also determines the tensile strength of the welded joint, it may be necessary, when applying footnote[1)], to choose welding consumables and auxiliary materials of the next higher strength category (next higher added symbol).

2) Mean value of three specimens; for minimum individual values ( ) and retests see B.2.5.

3) Quality grade 5 is not applicable for Y89 and Y96 grade consumable

3. Testing on welded joints

3.1 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the testing on the welded joints shall be performed on butt-weld test pieces in analogous manner to B.3.1, C.3.1 or D.3.1.

Note:

In testing welded joints made with wire-flux combinations for submerged-arc welding. it should be assumed that due to the limits on thermal input (heat input per unit length of weld) which are generally necessary, multi-run welding is the only suitable method 3.1 consequently refers only to the M type butt welded test piece for multi-run welding in accordance with D.3.1. Where approval is also solicited in exceptional cases for two-run welding (T, with one run on each side), "T"- type butt-weld test pieces shall be welded for this purpose in accordance with D.3.5 and tested in a manner similar to that prescribed in D.3.6 and D.3.7. For the same reasons, no reference is made below to the fillet-weld test pieces.

3.2 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the butt-weld test pieces called for in 3.1 shall be welded in a manner analogous to that prescribed in B.3.2, C.3.2 or D.3.2. The base metal used shall be a high-strength fine grained structural steel with an appropriate minimum yield strength and tensile strength and compatible with the added symbol for which application is made (see Table 5.17).

3.3 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the test specimens described in B.3.3, C.3.3 and D.3.3 shall be taken from the butt-weld test pieces.

3.4 The mechanical properties shall meet the requirements stated in Table 5.18. The provisions of B.3.4, C.3.4 and D.3.4 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperatures in the notched bar impact test and the requirements regarding the retest specimens.

4. Hydrogen test

4.1 Welding consumables and auxiliary materials for welding of high-strength fine-grained structural steels with yield strengths levels from 420 up to 960 N/mm^2 shall – taking due account of the provisions in C.4.1 - be subjected in every case to a hydrogen test in accordance with the mercury method to ISO 3690.

4.2 For quality grades or added symbols Y42 to Y50, the diffusible hydrogen content of the weld metal determined in accordance with the provisions of B.4.2 shall not exceed the figure of 10 cm^3/100 g weld metal (related to the quantity of metal deposited), specified in Table 5.7 as the maximum for the added symbol H10. For quality grades or added symbols Y55 to Y96, the maximum figure of 5 cm^3/100 g weld metal specified for the added symbol H5 shall not be exceeded.

5. Annual repeat tests

5.1 The annual repeat tests specified in A.3.1 shall entail the preparation and testing of weld metal test pieces as prescribed under 2. If the basis used for these tests is a reduced tensile strength of the weld metal as prescribed in footnote 1) to Table 5.17, or if the specified tensile strength is not attained, two transverse tensile specimens taken from the welded joint (in the down-hand position only) shall also be tested and these shall then meet the requirements stipulated in Table 5.17.

5.2 For grades Y69 to Y96 annual hydrogen test is required.

5.3 In special cases, BKI may require more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

Table 5.18 Required properties of welded joints

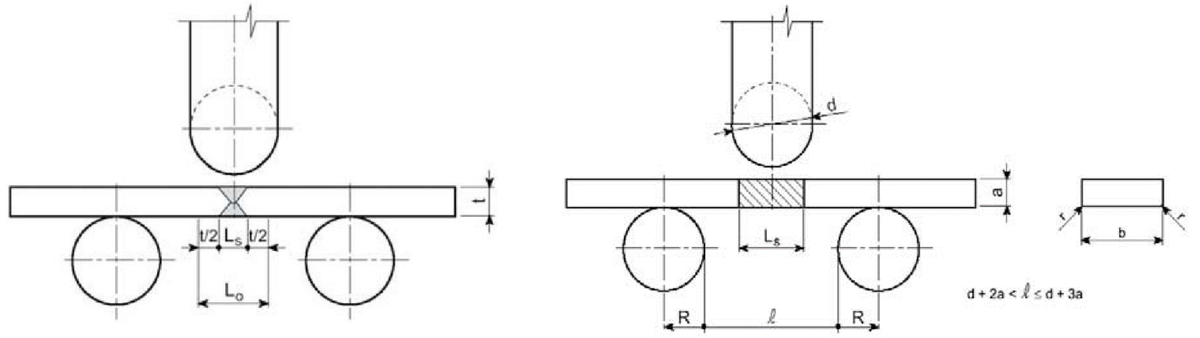
Quality grade	Added symbol	Tensile strength [N/mm^2]	Minimum notch impact energy, test temperature	Minimum bending angle [1]	Mandrel diameter (t = specimen thickness)
3 to 5 in accordance with Table 5.16	Y42	520	Depending on the quality grade and added symbol in accordance with Table 5.17	120° or providing that the bending elongation is attained [2]	4 t
	Y46	540			4 t
	Y50	590			4 t
	Y55	640			5 t
	Y62	700			5 t
	Y69	770			5 t
	Y89	940			6 t
	Y96	980			7 t

Table 5.18 Required properties of welded joints *(continued)*

Quality grade	Added symbol	Tensile strength [N/mm²]	Minimum notch impact energy, test temperature	Minimum bending angle [1]	Mandrel diameter (t = specimen thickness)

[1] Bending angle attained before the first incipient crack, minor pore exposures up to a maximum length of 3 mm allowed.

[2] If the specified bending angle of 120° is not attained, the requirements will still be regarded as having been met provided that the bending elongation attained with a gauge length of $L_0 = L_s + t$ (L_s = width of weld, t = a = thickness of specimen, see sketch below) before the first incipient crack complies with the elongation requirements given in Table 5.17.



G. Welding Consumables and Auxiliary Materials for Steels Tough at Sub-zero Temperatures

1. General

1.1 The following provisions apply to welding consumables and auxiliary materials for welding of steels tough at sub-zero temperatures in accordance with the Rules for Materials (Pt.1, Vol. V), governing the fabrication of vessels, pipelines, etc. for liquefied gases.

Note:

According to the Rules for Materials (Pt.1, Vol. V), the steels tough at sub-zero temperatures used in shipbuilding fall into three categories: low alloy carbon-manganese steels, nickel alloy steels and austenitic steels. The following paragraphs are therefore concerned with welding consumables and auxiliary materials for these three categories of materials. Other such products are to be treated in analogous manner, for aluminium alloys, see J.

1.2 Depending on their nature and properties (type of alloy), welding consumables and auxiliary materials for welding of steels tough at sub-zero temperatures are classified and approved in the same way as those for high-strength structural steels in accordance with F. or those for (austenitic) stainless steels or, where applicable, nickel alloy steels tough at sub-zero temperatures in accordance with I. No special indication of suitability for low-temperature service is given (except with the quality grade in accordance with F.); individual suitability for low-temperature service (test temperature for the notched bar impact test and proven notch impact energy) is indicated in the approval certificate. In general, the minimum service (design) temperature is 5°C above this test temperature.

2. Testing of the weld metal

2.1 Testing of the weld metal shall be carried out in accordance with the nature of the welding consumables and auxiliary materials, as described in F. and I. Unless otherwise stipulated in a particular case, the test temperatures for the notched bar impact test stated in these provisions shall be replaced by the test temperatures shown in Table 5.19.

2.2 The requirements applicable to the strength and elongation of the weld metal are determined by those applying to the base material; see Rules for Materials (Pt.1, Vol. V) Sec. 4, F., Sec. 5, D., Sec. 6, F.

and Sec. 7, E. If particular base materials are welded with dissimilar welding consumables and auxiliary materials with strength values below those of the base material (e.g. in welding of 9% nickel steel), the strength values used in the design calculations for the components shall apply. Unless otherwise stipulated, the minimum notch impact energy values at the test temperatures shown in Table 5.19 shall be 47 J (mean value) and 39 J (lowest individual value).

Table 5.19 Minimum design temperatures and test temperatures for the notched bar impact test

Welding consumables and auxiliary material for:	Reference to Rules and Standards relating to Materials	Minimum design temperature [°C]	Test temperature for the notched bar impact test [°C]
Fine grain structural steels for ammonia liquefied under pressure	in accordance with Rules for Materials (Pt.1, Vol.V) Sec. 4, F., Table 4.16	0	- 20
High strength (QT) fine grain structural steels with nominal yield strengths of 420 to 690 N/mm^2	in accordance with manufacturer's specification and Rules for Materials (Pt.1, Vol. V) Sec. 4, F., Table 4.17	0	- 20
Other fine grain structural steels with nominal yield strengths of up to 355 N/mm^2	e.g. EN 10028, Part 3	- 45 [1)]	5°C below minimum design temperature, but not above - 20°C
Nickel steels with: 0,5 % nickel steel 1,5 % nickel steel 3,5 % nickel steel 5 % nickel steel 9 % nickel steel	steel conforming to EN 10028 Part 4: 11MnNi5-3, 13MnNi6-3 15NiMn6 12Ni14 X12Ni5 X8Ni9, X7Ni9	 - 55 - 66 [2)] - 90 2) - 105 [2), 3)] - 165	 - 60 - 65 [2)] - 95 [2)] - 110 [2)] (- 196) [3)] - 196
Austenitic steel	e.g. to EN 10028-7 (AISI) X2CrNi19-11 / 1.4306 (304L) X2CrNiMo17-13-2 / 1.4404 (316L) X6CrNiTi18-10 / 1.4541 (321) X6CrNiNb18-10 / 1.4550 (347)	- 165	- 196

1) BKI may approve lower design temperatures (down to a maximum -55°C) provided that corresponding properties are demonstrated in the approval test.

2) A lower design temperature may be approved for QT steels with a 1,5%, 3,5% and 5% nickel content; in these instances BKI will specify the test temperature.

3) Steel with a 5% nickel content may be approved for a minimum design temperature of - 165°C subject to the provisions stipulated in the Rules for Materials (Pt.1, Vol.V) Sec. 4, F., Table 4.17, footnote[2)]; the test temperature is then - 196°C.

3. Testing on welded joints

The testing on the welded joints shall be performed in accordance with the nature of the welding consumables and auxiliary materials as described in F. and I. In the case of welding consumables and auxiliary materials for nickel alloy steels, the welded joints shall be made with the base material for which approval has been solicited. In the case of such products for (low-alloy) carbon-manganese steels and austenitic steels, a base material of similar composition may be used. In all other respects, 2.1 and 2.2 apply in analogous manner.

4. Hydrogen test

If a hydrogen test is stipulated for the welding consumables and auxiliary materials in question (e.g. according to F.4), it shall be performed in this case too. The requirements stipulated for each individual case apply.

5. Annual repeat tests

The annual repeat tests specified in A.3.1 shall entail the preparation and testing of weld metal test pieces as prescribed under 2. BKI may require more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

H. Welding Consumables and Auxiliary Materials for High-Temperature Steels

1. General

1.1 The following provisions apply to welding consumables and auxiliary materials for welding of high-temperature steels in accordance with the Rules for Materials (Pt.1, Vol. V) governing the fabrication of steam boilers, pressure vessels, pipelines, etc. with high service temperatures.

Note:

Under the Rules for Materials (Pt.1, Vol. V) this essentially applies to the carbon-manganese steels P235GH (H I), P265GH (H II), P295GH (17Mn4), P355GH (19Mn6), the molybdenum alloy steel 16Mo3 (15Mo3) and the chromium - molybdenum alloy steels 13CrMo4-5 (13CrMo4-4) and 10CrMo9-10 (10CrMoI-10) and 12CrMo9-10 in accordance with EN 10028 Part 2. The following paragraphs are therefore concerned with welding consumables and auxiliary materials for these steels. Other such products are included if they can be classed among the materials also covered by the approval as shown in Table 5.20. Other welding consumables and auxiliary materials for other high-temperature steels are to be treated in analogous manner.

1.2 Welding consumables and auxiliary materials for high-temperature steels are classified into the quality grades shown in Table 5.20 according to their chemical composition (type of alloy) and mechanical (strength) characteristics and approved according to these grades. The testing and approval of a steel in the left-hand columns of Table 5.20 encompasses the steel(s) in the right-hand columns. The different high-temperature strength properties are to be borne in mind. The table applies in analogous manner to the corresponding grades of forgings and steel castings.

1.3 Welding consumables and auxiliary materials for components which are to undergo postweld heat treatment shall be tested and approved separately for the untreated condition and for each heat-treated condition. In general, the relevant conditions are:

U = untreated (as-welded condition) and

S = annealed to relieve stresses.

In special cases, normalizing (N) or quenching and tempering (V) may be necessary. The annealing temperatures and times shall be those applicable to the subsequent heat treatment of the components according to the standards, material data sheets, etc. Unless more precise data are given in these documents, the annealing temperatures and times specified in Section 9, Table 9.2 may be used.

2. Testing of the weld metal

2.1 The testing of the weld metal shall be performed according to the nature of the welding consumable or auxiliary material (and, where applicable, according to the welding process) using test pieces and specimens in analogous manner to the provisions of B.2, C.2 or D.2. In addition, for determining the 0.2% proof stress at the maximum application temperature and at a second lower temperature according to 2.3 two further round tensile specimens are to be taken from each test piece and tested. For this purpose, the test pieces shall be made correspondingly larger.

Table 5.20 Welding consumables and auxiliary materials for high-temperature steels

Quality grades	Testing and approval relating to steel [1] :		Steel also covered by the approval [2] :	
	Designation	Material No.:	Designation [1]	Material No.:
2235GH	P235GH	1.0345	-	-
265GH	P265GH	1.0425	P235GH	1.0345
295GH	P295GH	1.0481	P235GH P265GH	1.0345 1.0425
355GH	P355GH	1.0473	P235GH P265GH P295GH	1.0345 1.0425 1.0481
16Mo3	16Mo3	1.5415	P235GH P265GH P295GH P355GH	1.0345 1.0425 1.0481 1.0473
13CrMo4-5	13CrMo4-5	1.7335	16Mo3	1.5415
10CrMo9-10	10CrMo9-10	1.7380	16Mo3 13CrMo4-5	1.5415 1.7335
12CrMo9-10	11CrMo9-10	1.7383	16Mo3 13CrMo4-5 10CrMo9-10	1.5415 1.7335 1.7380

[1] Steel grades in accordance with the Rules for Materials (Pt.1, Vol.V) or conforming to EN 10028.
[2] Steel grades in accordance with the Rules for Materials (Pt.1, Vol.V) or conforming to EN 10028 as well as other grades of forgings and steel castings.

2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in B.2.2. The results of the analysis shall not exceed the limit values specified in the standards (e.g. ISO 3580, ISO 21952 or ISO 17634) or by the manufacturer, the narrower tolerances being applicable in each case.

2.3 As a minimum requirement, the test specimens prescribed in B.2.3, C.2.3 or D.2.3 shall be taken from the weld metal test pieces and tested at room temperature. In addition, to determine the yield strength or the 0,2% proof stress at the highest application temperature and at a second test temperature 100°C lower in accordance with Table 5.22, two further round tensile test specimens shall be taken from the test pieces and tested.

BKI may require further specimens to be taken and tests to be performed, e.g. determination of the 1,0% proof stress, creep tests, notched bar impact tests on specimens subjected to ageing treatment or embrittlement tests.

2.4 The mechanical properties at room temperature shall meet the requirements stated in Table 5.21, while the 0,2% proof stresses at elevated temperature shall conform to Table 5.22. If further tests are demanded by BKI, the requirements will be stipulated separately on a case-by-case basis. The provisions of A.7.6, B.2.4, C.2.4 and D.2.4 apply in analogous manner to the performance of the tests and any retest which may be required.

3. Testing on welded joints

3.1 Depending on the nature of the welding consumables and auxiliary materials (and on the welding process concerned), the testing on the welded joints shall be performed on butt-weld test pieces in analogous manner to the provisions of B.3, C.3, D.3 or E.2.

3.2 The butt-weld test pieces shall be prepared in analogous manner to the procedures described in B.3.2, C.3.2, D.3.2 or E.2.2, taking Table 5.21 into account. Wherever possible, the base material should be a high-temperature steel corresponding to the quality grade in question.

3.3 Depending on the welding process, the test specimens described in B.3.3, C.3.3, D.3.3 or E.2.3 shall be taken from the butt-welded test pieces, unless otherwise specified.

3.4 The mechanical characteristics of the welded joint shall meet the requirements for the weld metal stated in Table 5.21, except in the case of the yield strength. The provisions of A.7.6, B.3.4, C.3.4, D.3.4 and E.2.4 apply in analogous manner to the performance of the tests and retest which may be required.

Table 5.21 Required properties of the weld metal at room temperature (+20°C)

Quality grade	Yield strength R_{eL} [1] or 0,2%-proof stress $R_{p0,2}$ [N/mm²] min.	Tensile strength R_m [N/mm²] min.	Elongation A [%] min.	Notch impact energy [2] [J] min.
235GH	285	480	22	47 (33)
265GH				
295GH	360	520	22	
355GH				
16Mo3	355	510	22	
13CrMo4-5	355	510	20	
10CrMo9-10	400	520	18	
12CrMo9-10				

[1] The lower yield strength (R_{eL}) shall apply. Where the yield strength is not clearly defined, the 0,2% proof stress ($R_{p0,2}$) shall be used.
[2] Mean value of three specimens; for minimum individual values ( ) and retest, see B.2.5.

Table 5.22 Yield strength resp. 0,2% proof stress at elevated temperatures

Quality grade	Minimum yield strength resp. 0,2% proof stress [1] at a temperature of °C									
	50	100	150	200	250	300	350	400	450	500
	[N/mm²]									
235GH	206	190	180	170	150	130	120	110	-	-
265GH	234	215	205	195	175	155	140	130	-	-
295GH	272	250	235	225	205	185	170	155	-	-
355GH	318	290	270	255	235	215	200	180	-	-
16Mo3	-	-	-	215	200	170	160	150	145	140
13CrMo4-5	-	-	-	230	220	205	190	180	170	165
10CrMo9-10	-	-	-	215	200	170	160	150	145	140
11CrMo9-10	-	-	-	-	255	235	225	215	205	195

[1] The lower yield strength (R_{eL}) shall apply. Where the yield strength is not clearly defined, the 0,2% proof stress ($R_{p0,2}$) shall be used.

4. Hydrogen test

If a hydrogen test is required, it shall be performed in accordance with B.4. The diffusible hydrogen content shall not exceed 10 ml per 100 g of deposited weld metal.

5. Testing for hot cracks

If testing for hot cracks is required, this shall be performed in accordance with B.5 or the relevant standards (e.g. ISO 17641-2).

6. Annual repeat tests

6.1 The annual repeat tests specified in A.3.1 shall entail the preparation and testing of weld metal test pieces as prescribed under 2. BKI may require more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

6.2 The annual repeat tests shall be performed according to the prescribed scope for both the untreated condition and the various (approved) heat treated conditions (see 1.3).

I. Austenitic and Austenitic-Ferritic Welding Consumables and Auxiliary Materials for Stainless Steels, Non-Magnetic Steels and Nickel Alloy Steels Tough at Sub-Zero Temperatures

1. General

1.1 The following provisions apply to welding consumables and auxiliary materials for welding of stainless (austenitic) steels and steel castings, plates clad with these materials and joints of these materials with unalloyed and low-alloy (hull) structural steels. They also apply to welding consumables and auxiliary materials for welding of non-magnetic steels, nickel alloy steels tough at sub-zero temperatures and other, similar steels. Austenitic welding consumables and auxiliary materials for clad welding and for joining difficult weldable (ferritic) materials are to be treated in analogous manner.

Notes:

In (tanker) shipbuilding, the current practice is to use, in the main, the (austenitic or austenitic-ferritic) molybdenum alloy stainless steels listed in the three left-hand columns of Table 5.21. For equipment components, use is also made of, among others, steels of types 5CrNi18-10 (mat. no. 1.4301, AISI 304) and X6CrNiTi18-10 (mat. no. 1.4541, AISI 321). The following paragraphs therefore relate to welding consumables and auxiliary materials for these base materials including their joints with hull structural steels. Furthermore, the welding consumables and auxiliary material- for which BKI had already granted approval have also been included. Welding consumables and auxiliary materials for other base materials should, where applicable, be allocated to the appropriate categories and treated in analogous manner.

Inert gases with 1 to 3% of oxygen added or those with a maximum of 2,5% CO_2 added can be used as shielding gases for welding austenitic welding consumables in the range of application specified in 1.1. Those inert gases with a high level of nitrogen. Gas mixtures of the type M21 (see Table 5.10) with a maximum of 18% of CO_2 added may only be used with slag-forming flux-cored wire electrodes. Approvals for (flux-cored) wire-gas combinations are also granted accordingly

1.2 Welding consumables and auxiliary materials for welded joints uniting (austenitic or austenitic ferritic) stainless steels to one another are classified into the quality grades shown in Table 5.23 according to the chemical composition (material no.) and mechanical (strength) characteristics of the base materials to be welded. The testing and approval of a steel in the left-hand column of the table encompasses the steel (s) in the right-hand column, subject to separate consideration of the corrosion conditions in each case. The table applies in analogous manner to the corresponding grades of forgings and steel castings.

Table 5.23 Austenitic welding consumables and auxiliary materials for welding of stainless steels

Quality grade	Testing and approval relating to steel		Steel also covered by the approval	
	Designation	Mat. No. / AISI	Designation	Mat. No. / AISI
4301	X5CrNi18-10	1.4301 / 304	-	-
4306	X2CrNi19-11	1.4306 / 304 L	X5CrNi18-10 C2CrNi18-9 GX6CrNi18-9	1.4301 / 304 1.4307 / 3047L 1.4308 / -
4307	X2CrNi18-9	1.4307 / 304 L	X5CrNi18-10	1.4301 / 304
4404	X2CrNiMo17-13-2	1.4404 / 316 L	X5CrNi18-10 X2CrNi19-11 GX6CrNi18-9 X5CrNiMo17-12-2 GX6CrNiMo18-9	1.4301 / 304 1.4306 / 304 L 1.4308 / - 1.4401 / 316 1.4408 / -
4429	X2CrNiMoN17-13-3	1.4429 / 316 LN	X2CrNiN18-10 X5CrNiMo17-12-2 X2CrNiMo17-13-2 X2CrNiMoN17-12-2 GX6CrNiMo18-9 X2CrNiMo18-14-3 X5CrNiMo17-13-3 X6CrNiMoTi17-12-2 X10CrNiMoTi18-12 X6CrNiMoNb17-12-2 X10CrNiMoNb18-12	1.4311 / 303 LN 1.4401 / 316 1.4404 / 316 L 1.4406 / 316 LN 1.4408 / - 1.4435 / 316 L 1.4436 / 316 1.4571 / 316 Ti 1.4573 / - 1.4580 / 316 Cb 1.4583 / 318
4435	X2CrNiMo18-14-3	1.4435 / 316 L	X5CrNi18-10 X2CrNi19-11 GX6CrNi18-9 X5CrNiMo17-12-2 X2CrNiMo17-13-2 GX6CrNiMo18-9	1.4301 / 304 1.4306 / 304 L 1.4308 / - 1.4401 / 316 1.4404 / 316 L 1.4408 / -

Table 5.23 Austenitic welding consumables and auxiliary materials for welding of stainless steels *(continue)*

Quality grade	Testing and approval relating to steel		Steel also covered by the approval	
	Designation	Mat. No. / AISI	Designation	Mat. No. / AISI
4438	X2CrNiMo18-16-4	1.4438 / 317 L	X5CrNiMo17-12-2 X2CrNiMo17-13-2 X2CrNiMo18-14-3 X5CrNiMo17-13-3	1.4401 / 316 1.4404 / 316 L 1.4435 / 316 L 1.4436 / 316
4439	X3CrNiMoN17-13-5	1.4439 / (317 LN)	X2CrNiMoN17-12-2 X2CrNiMoN17-13-2 X2CrNiMo18-16-4 GX2CrNiMoN17-13-4 GX6CrNiMo-17-13 X5CrNiMo17-13	1.4406 / 316 LN 1.4429 / 316 LN 1.4438 / 317 L 1.4446 / - 1.4448 / - 1.4449 / 317
4462	X2CrNiMoN22-5	1.4462 / -	X8CrNi Mo27-5 X6CrNiMo24-8-2 X4CrNiMoNb25-7	1.4460 / 329 1.4463 / - 1.4582 / 329
I4550	X6CrNiNb18-10	1.4550 / 347	X5CrNi18-10 X2CrNi19-11 GX6CrNi18-9 X6CrNiTi18-10 GX7CrNiNb18-9	1.4301 / 304 1.4306 / 304 L 1.4308 / - 1.4541 / 321 1.4552 / -
4571	X6CriMoTi17-12-2	1.4571 / 316 Ti	X5CrNi18-10 X2CrNi19-11 GX6CrNi18-9 X5CrNiMo17-12-2 X2CrNiMo17-13-2 GX6CrNiMo18-9 X2CrNiMo18-14-3 X5CrNiMo17-13-3 X6CrNiTi18-10 X6CrNiNb18-10 GX7CrNiNb18-9 X10CrNiMoTi18-12 X6CrNiMoNb17-12-2 GX7CrNiMoNb18-2 X10CrNiMoNb18-12	1.4301 / 304 1.4306 / 304 L 1.4308 / - 1.4401 / 316 1.4404 / 316 L 1.4408 / - 1.4435 / 316 L 1.4436 / 316 1.4541 / 321 1.4550 / 347 1.4552 / - 1.4573 / - 1.4580 / 316 Cb 1.4581 / - 1.4583 / 318

1.3 Welding consumables and auxiliary materials for welding of non-magnetic stainless steels are approved according to a quality grade corresponding to the chemical composition (material no.) of the weld metal. Table 5.24 contains a number of examples. The testing and approval of a steel in the left-hand column encompasses the steel(s) in the right-hand column, subject to separate consideration of the corrosion conditions in each case. The table applies in analogous manner to the corresponding grades of forgings and steel castings.

1.4 Welding consumables and auxiliary materials for joining (austenitic or austenitic-ferritic) stainless steels to unalloyed or low-alloy steels, for intermediate runs in welding of clad plates and for clad welds are approved according to a quality grade corresponding to the chemical composition of the weld metal. Table 5.25 gives a number of examples. Approval is granted with due regard to the mechanical and other properties in relation to the base materials concerned and/or for a particular type of application for which suitability has been proved.

Table 5.24 Austenitic welding consumables and auxiliary material for welding of non-magnetic stainless steel

Quality grade	Testing and approval relating to steel		Steels also covered by the approval	
	Designation	Mat. No.	Designation	Mat No.
3954	X2CrNiMnMoNNb21-16-5-3	1.3964	X4CrNiMnMoN19-13-8 X2CrNiMoN22-15 X2CrNiMoN18-14-3 X2CrNiMo18-15	1.3948 1.3951 1.3952 1.3953
3984	X2CrNiMnMoNNb23-17-6-3	1.3974	X2CrNiMnMoNNb21-15-7-3 X2CrNiMoN22-15 X2CrNiMoN18-14-3 X2CrNiMnMoNNb21-16-5-3	1.3914 1.3951 1.3952 1.3964

Table 5.25 Austenitic welding consumables and auxiliary materials for joining stainless steels to unalloyed or low-alloy steels, for intermediate runs and for clad welds (examples)

Quality grade	Welding consumable (weld metal)		Usage (Instructions) [2]
	Designation [1]	Mat. No. / AWS	
4332	E 23 12 nC X2CrNi24-12	(1.4332) / E 309 L 1.4332 / E 309 L	Intermediate runs for welded joints between clad plate of similar composition. Welded joints between heat resistant CrNi steels, joints between stainless and unalloyed or low-alloy steels. Clad welds.
4370	E 18 8 Mn 6 X15CrNiMn18-8	(1.4370) / (E 307) 1.4370 / -	Joints between stainless and unalloyed or low-alloy steels.
4431	E 20 10 3 X12CrNiMo19-10	1.4431 / - 1.4431 / -	as for 4370
4459	E 23 12 2 X8CrNiMo23-3	1.4459 / E 309 Mo (1.4459) / (E 309 Mo)	as for 4332

[1] First line (E...): designation for covered electrodes, second line: designation for (fluxed-cored) wire-gas and wire-flux combinations.
[2] The manufacturer's information given for the individual product are decisive abbr. information mentioned in the approval

1.5 Austenitic welding consumables and auxiliary materials for welding of nickel steels tough at subzero temperatures are classified into quality grades as shown in Table 5.26 according to the chemical composition (material no.) and mechanical (strength and toughness) characteristics of the base materials to be welded. The testing and approval of a steel in the left- hand column encompasses the steel(s) in the right-hand column. The table applies in analogous manner to the corresponding grades of forgings and steel castings.

Table 5.26 Austenitic welding consumables and auxiliary materials for welding of nickel steels tough at sub-zero temperatures (examples)

Quality grade	Testing and approval relating to steel [1)]		Steel also covered by the approval [1)]	
	Designation	Mat. No.	Designation	Mat. No.
5637	12Ni14 (3,5 % Ni)	1.5637	-	-
5680	X12Ni5 (5 % Ni)	1.5680	12Ni14 (3,5 % Ni)	1.5637
5662	X8Ni9 (9 % Ni)	1.5662	12Ni14 (3,5 % Ni) G9Ni14 (3,5 % Ni) X12Ni5 (5 % Ni)	1.5637 1.5638 1.5680
5663	X7Ni9 (9 % Ni)	1.5663	12Ni14 (3,5 % Ni) G9Ni14 (3,5 % Ni) X12Ni5 (5 % Ni) X8Ni9 (9 % Ni)	1.5637 1.5638 1.5680 1.5662

1) Steels conforming to EN 10028-4 and EN 10213-3

2. Testing of the weld metal

2.1 For testing the deposited weld metal, test pieces analogous to those called for in B.2.1 (only one test piece welded in the down-hand position), C.2.1 or D.2.1 shall be prepared, depending on the nature of the welding consumables and auxiliary materials (and according to the welding process). The base material used shall be a stainless steel of the same composition, or the side walls of the weld shall be buffered with a weld metal of such composition.

2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in B.2.2. As an alternative, the chemical composition may be determined in a manner analogous to ISO 15792-1 by analysis of a build-up weld. The results of the analysis shall not exceed the limits specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

For the welding consumables and auxiliary materials specified in Tables 5.25 and 5.26, the pitting resistance equivalent (% Cr + 3,3 % Mo) shall be at least 1% higher than that of the base material on which the test was carried out resp. on which approval was based. The analysis of the weld metal and an average chemical composition determined from the data given in the standards shall be the determining factors in such a case.

2.3 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the test specimens shall be taken from the weld metal test pieces in a manner analogous to the provisions of B.2.3, C.2.3 or D.2.3.

2.4 The mechanical properties shall meet the requirements stated in Table 5.27. The provisions of B.2.4, C.2.4 and D.2.4 apply in analogous manner to the performance of the tests and the carrying out of retests. For the welding consumables and auxiliary materials referred to in 1.4, the requirements depend on the particular application and are determined on a case-by-case basis. The notch impact energy values demonstrated during the test and also the test temperatures are indicated in the approval certificate. Welding consumables and auxiliary materials for joining stainless to normal-strength or higher-strength hull structural steels shall, as a minimum requirement, meet the requirements relating to those for the latter. For welding consumables and auxiliary materials referred to in 1.5, G.2.2 and Table 5.19 should also be noted.

3. Testing on welded joints

3.1 Depending on their nature (and on the welding process concerned), the testing on welded joints made with the welding consumables and auxiliary materials referred to in 1.2, 1.3 and 1.5 shall be performed on butt-weld test pieces analogous to those prescribed in B.3.1, C.3.1 or D.3.1. For the welding consumables and auxiliary materials covered by 1.4, testing of welded joints is required only if the products are used wholly or chiefly for making welded joints or where, in welded joints, they constitute a substantial proportion of the weld section (as in the case of the intermediate runs of welds joining clad plates). However, BKI may call for specimen welds to prove the satisfactory performance of these products in the various positions for which approval is solicited (see also A.6.). For welding consumables and auxiliary materials covered by 1.3 which are used exclusively for clad welding, the scope of the tests to be applied shall be determined on a case-by-case basis.

3.2 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the butt-weld test pieces called for in 3.1 shall be welded in a manner analogous to that prescribed in B.3.2, C.3.2 or D.3.2. The base material used shall be a steel of the same or similar composition in accordance with Tables 5.23, 5.24 and 5.26 and shall possess at least the mechanical properties indicated in Table 5.27. An analogous procedure shall be adopted in the case of the welding consumables and auxiliary materials covered by 1.4 and Table 5.27.

Table 5.27 Required properties of the weld metal

Quality grade	0,2% proof stress [N/mm^2] min.	Tensile Strength [N/mm^2]	Elongation [%] min.	Notch impact energy [J] 1) min.	Test temperature [°C]
4306	195	500 – 700	30	47 (33)	+ 20 2)
4404	205	510 – 710	30		
4429	295	580 - 800	30		
4435	205	510 - 710	30		
4438	205	510 - 710	30		
4439	295	580 - 800	30		
4462	480	680 - 900	25	35 (24)	- 30
4550	205	510 - 740	30	47 (33)	+ 20 2)
4571	225	500 - 740	30		
3954	430	700 – 950	30	70 (49)	+ 20
3984	510	850 - 1050			
5637	355	490 - 640	22	47 (33)	- 95 3)
5680	390	530 - 840	20		- 196 3)

Table 5.27 Required properties of the weld metal *(continued)*

Quality grade	0,2% proof stress [N/mm²] min.	Tensile Strength [N/mm²]	Elongation [%] min.	Notch impact energy [J] [1] min.	Test temperature [°C]
5662	490 [5]	640 [5] - 840	18		- 110 (- 196) [3), 4)]
5663	585	680 - 820	18		- 196 [3]

1) Mean value of three specimens; for individual values ( ) and retest, see I.2.4.

2) In the case of low-temperature applications, special requirements apply: see G. (Table 5.19 and G.2.2).

3) See G. (Table 5.19 and G.2.2).

4) If quality grade 5680 (welding of 5% nickel steel) is to be applied at a minimum design temperature of - 165°C. The test temperature shall be - 196°C.

5) If the "as delivered" condition (of the base material) is HT 640, this welding consumable shall also be approved for the as delivered condition HT 680 of the base materials. In such a case the same minimum requirements as stated for quality grade 5663 shall apply.

3.3 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the test specimens prescribed in B.3.3, C.3.3 or D.3.3 shall be taken from the butt-welded test pieces.

3.4 The mechanical properties shall meet the requirements stated in Table 5.27. BKI may agree to the application in analogous manner of footnote [1] in Table 5.17 also for the austenitic welding consumables and auxiliary materials covered by this section. The provisions of A.7.6, B.3.4, C.3.4 and D.3.4 apply in analogous manner to the performance of the tests and the carrying out of retests.

4. Testing of resistance to intergranular corrosion

4.1 Testing of resistance to intergranular corrosion (IC) shall be performed in accordance with ISO 3651-2 on test specimens with intersecting butt welds using the copper sulphate - sulphuric acid method (Strauss test). No cracks may be detected and the metallographically measured depth of penetration of the attack at the grain boundaries shall not exceed 0,05 mm.

4.2 In the case of special corrosion conditions or particular materials, BKI may stipulate other corrosion tests as an additional or alternative measure, e.g. testing of resistance to pitting under corrosive attack by chlorides, e.g. by seawater.

5. Testing for hot cracks

5.1 Testing for hot cracks is to be performed in analogous manner to the provisions of B.5. or ISO 17641-2 on the (shape 2) test piece prescribed for austenitic welding consumables and auxiliary materials.

5.2 Other methods of testing for hot cracks may be agreed with BKI.

6. Annual repeat tests

6.1 The annual repeat tests specified in A.3.1 shall entail the preparation and testing of weld metal test pieces as prescribed under 2. (determination of the mechanical properties and chemical composition of the weld metal). If the tensile strengths prescribed in Table 5.27 are not attained and footnote [1] in Table 5.17 applies analogously, the repeat test, too, shall include the testing of flat tensile specimens taken from the welded joint.

6.2 In special cases, BKI may require more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

J. Welding Consumables and Auxiliary Materials for Aluminium Alloys

1. General

1.1 The following provisions apply to welding consumables and auxiliary materials for the welding of aluminium alloys for structural components and equipment parts used in shipbuilding and mechanical engineering. Welding consumables and auxiliary materials for the welding of aluminium alloys for low-temperature applications are dealt with separately, the requirements being specified on a case-by-case basis in accordance with the application conditions. see G.

Note:

In the present state of shipbuilding technology only the MIG and TIG inert gas welding methods using argon or helium or their mixtures and plasma arc welding are of practical significance. Because of their suitability for seawater applications, the wrought alloys indicated in Rules for Materials (Pt.1, Vol. V) Sec. 10, A.4. Cast alloys are hardly ever used for load-bearing structural components in shipbuilding. The following paragraphs therefore relate chiefly to wire-gas combinations for the aforementioned wrought alloys. Other welding consumables and auxiliary materials or those for other base materials shall be treated in analogous manner. The requirements are determined by those applicable to the base materials being welded together and are specified on a case-by-case basis.

1.2 The welding consumables preferably to be used for the aluminium alloys concerned are divided into two categories as follows:

W = wire electrode and wire gas combinations for MIG 131 according to ISO 4063, TIG 141 and plasma arc welding (15)

R = rod - gas combinations for TIG 141 or plasma arc welding (15)

Welding consumables and auxiliary materials for the welding of aluminium alloys are classified into the quality grades shown in Table 5.28 on the basis of the base materials used for the approval tests.

Table 5.28 Welding consumables for aluminium alloys

Quality grade	Base material for the test	
	Alloy Designation	
	Numerical	Chem. symbol
RA/WA	5754	AlMg3
RB/WB	5086	AlMg4
RC1/WC1	5083	AlMg4,5Mn0,7
RC2/WC2[1)]	5383	AlMg4,5Mn0,9
	5456	AlMg5
RC3/WC3[2)]	5059	AlMg5,5Mn0,8ZnZr
RD/WD[3)]	6005A	AlSiMg(A)
	6061	AlMg1SiCu
	6082	AlSi1MgMn

1) Approval of grade RC2/WC2 confers approval of 5383, 5456 and 5083 base material grade.
2) Approval of grade RC3/WC3 confers approval of 5059, 5383, 5456 and 5083 base material grade.
3) Approval of grade RD/WD confers approval of 6005A, 6061 and 6082 base material grade.

1.3 Approval of welding consumables is tied up with a specific shielding gas as prescribed in Table 5.28 or with a "special gas" which is defined separately according to its composition and purity. The composition of the shielding gas used in the test is to be recorded. The approval of a wire or rod with any particular gas can be applied or transferred to any combination of the same wire or rod and any gas in the same numbered group as defined in Table 5.28, provided that the gas composition is within the range recommended by the manufacturer, subject to the agreement of BKI

2. Testing of the weld metal

2.1 Unless otherwise specified (e.g. testing of the strength properties of the pure weld metal for the welding together of large wall thicknesses), the testing of the weld metal shall consist of an analysis of the deposited weld metal.

2.2 The chemical composition of the weld metal shall be determined and certified in a manner analogous to that prescribed in B.2.2. For the testing of the chemical composition of the weld metal, a test piece according to Fig. 5.17 shall be prepared. The size depends on the type of the welding consumable (and on the welding process) and shall give a sufficient amount of pure weld metal for chemical analysis. The base metal used shall be compatible with the weld metal in respect of chemical composition. The results of the analysis shall not exceed the limits specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

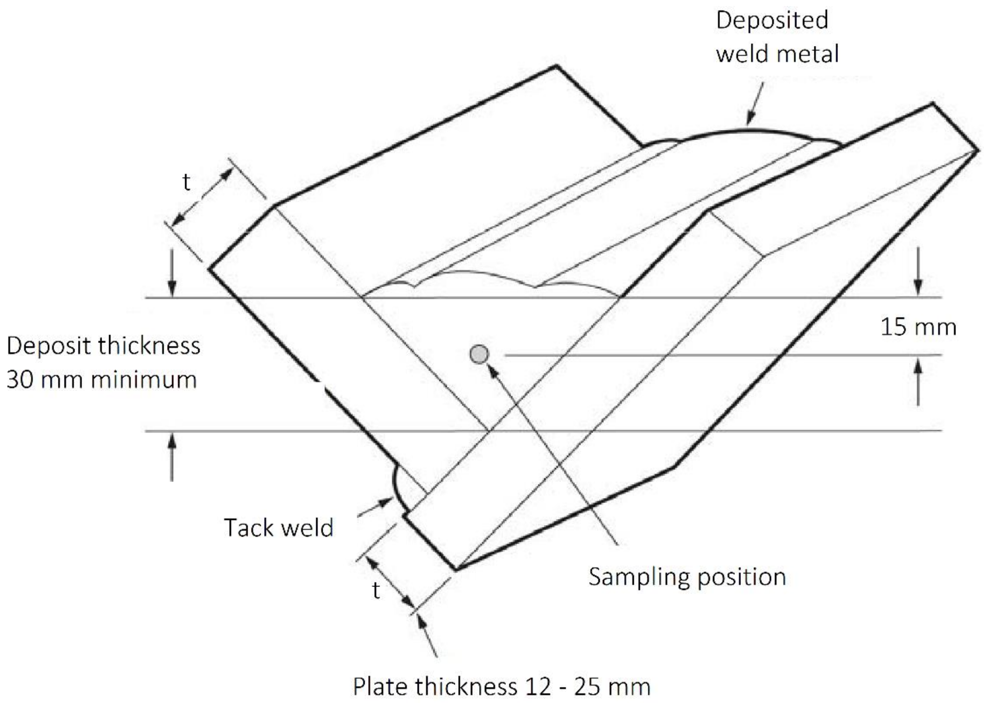


Fig. 5.17 Weld metal test assembly

Table 5.29 Shielding gases for the welding of aluminium alloys

Group	Composition of shielding gas (Vol. %) 1)	
	Argon	Helium
I-1	100	-
I-2	-	100
I-3 (1)	Remainder	> 0 to 33 2)

Table 5.29 Shielding gases for the welding of aluminium alloys

Group	Composition of shielding gas (Vol. %) [1]	
	Argon	Helium
I-3 (2)	Remainder	> 33 to 66 [2]
I-3 (3)	Remainder	> 66 to 95 [2]
S	"Special gas", Composition specified, see 1.3	

[1] The purity and other properties of the shielding gases shall comply with ISO 14175.

[2] Where argon (up to a max. 95 %) is replaced by helium and the helium content is marked by means of an added symbol, a gas with the following composition shall be used for the test.:

- for (1) = > 0 to 33 % He:
  an argon-helium mixture containing approx. 15 % helium
- for (2) = > 33 to 66 % He:
  an argon-helium mixture containing approx. 50 % helium
- for (3) = > 66 to 95 % He:
  an argon-helium mixture containing approx. 75 % helium, Group I-2 is included in this case.

3. Testing on welded joints

3.1 The testing on welded joints shall be performed in a manner analogous to that prescribed in B.3 resp. C.3, as applicable, on butt-weld test pieces conforming to Fig. 5.18. The base materials indicated in Table 5.28 shall be used. The plate thicknesses shall be 10-12 mm for MIG and plasma arc welding and 4-6 mm for TIG welding.

3.2 Depending on the welding positions for which approval is solicited (see A.4.9), the butt-weld test pieces shown in Fig. 5.18 shall be welded in the positions indicated in Table 5.5. Additionally one test piece according to Fig. 5.19 with a thickness of 20 to 25 mm is to be welded in the downhand position only.

The wire diameters shall conform to Table 5.11 and the welding parameters to the manufacturer's or supplier's recommendations. The composition of the shielding gas used for the test shall be stated in the report.

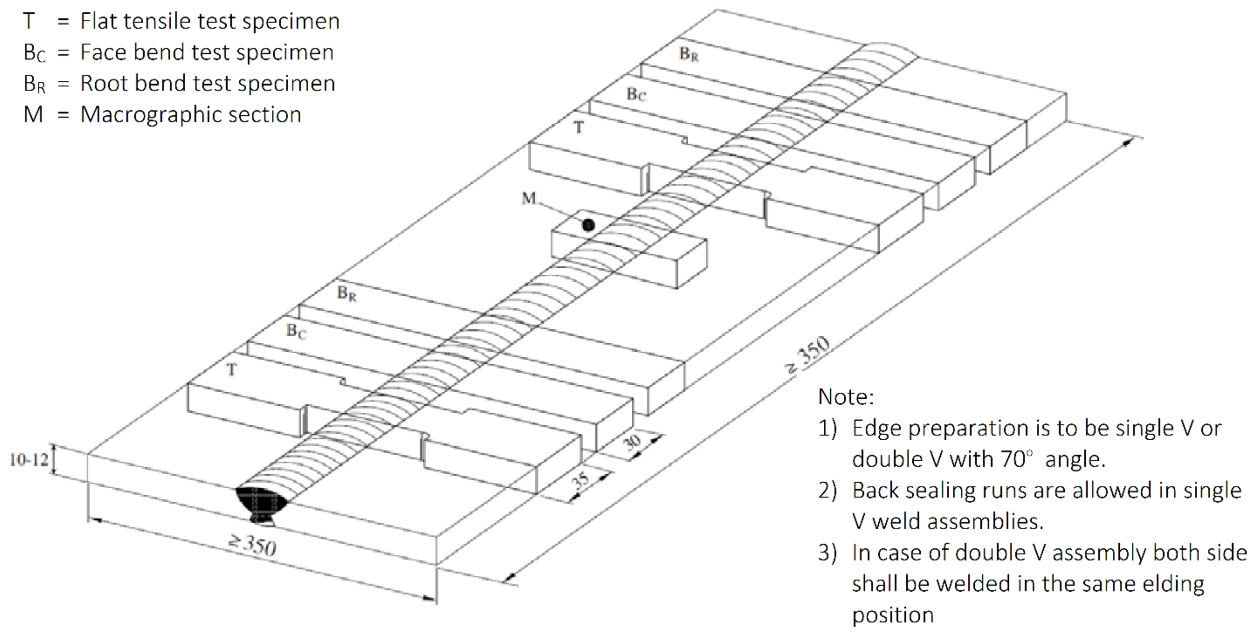


Fig. 5.18 Butt-weld test piece

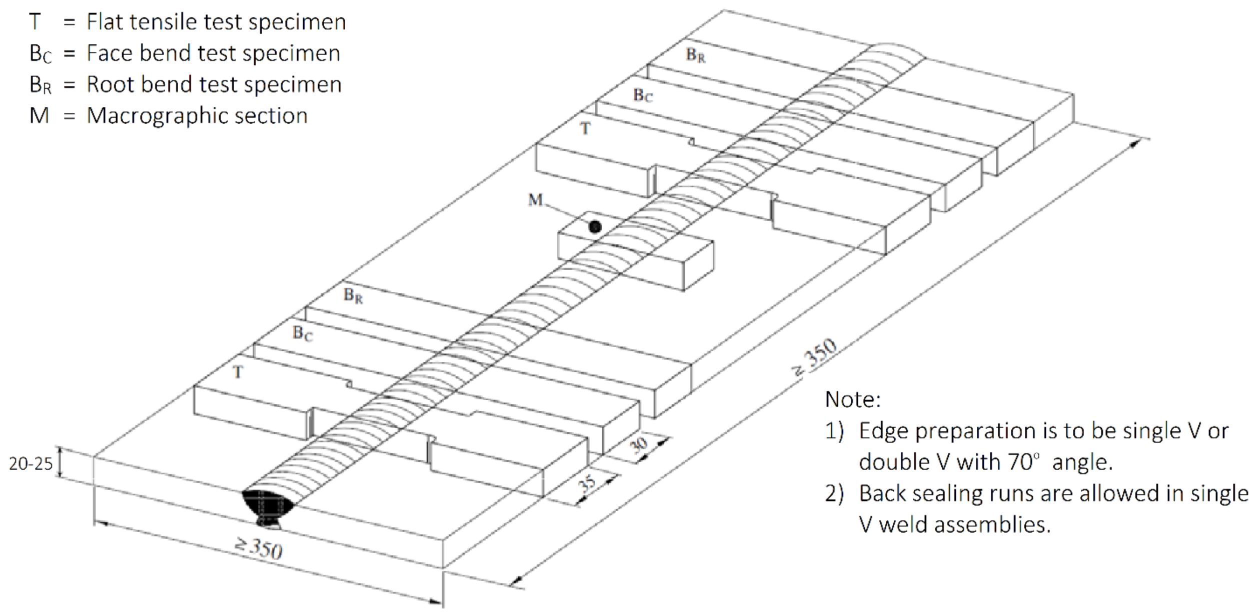


Fig. 5.19 Additional butt-weld test piece in downhand position

On completion of welding, assemblies must be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens must not be subjected to any heat treatment. Grade D assemblies should be allowed to naturally ageing for a minimum period of 72 hours from the completion of welding before testing is carried out.

Post-weld heat treatment of the test piece (e.g. in the case of age-hardenable alloys) is only allowed if such heat treatment may and is to be carried out in the future production of welded components (see the preliminary remarks to Section 5). Where necessary, the heat treatment shall be agreed prior to the test and is to be recorded in the test report.

3.3 Following the recommended radiographic examination, the following test specimens shall be taken from each butt-weld test piece in accordance with Figs. 5.18 and 5.19: two flat tensile test specimens conforming to ISO 4136, four transverse bend test specimens (two FBB and two RBB) conforming to ISO 5173 and a macrographic specimen. Both flat tensile specimens shall be tested with the weld reinforcement in place. Of the transverse bend tests (with the weld reinforcement machined off), two are to be tested with the cover pass in tension and two with the back pass in tension.

3.4 The mechanical characteristics shall meet the requirements stated in Table 5.30. The provisions of A.7.6, B.3.4 and C.3.4 apply in analogous manner to the performance of the tests and the carrying out of retests. The position of the fractures is to be stated in the test report. With the transverse bend test specimens the bending elongation is to be determined. The macrographic specimen shall be examined for defects (such as lack of fusion, cavities, inclusions, pores and cracks).

Table 5.30 Requirements applicable to welded joints

<table>
<tr><th>Quality grade</th><th>Tensile strength 1) [N/mm²] min.</th><th>Diameter of mandrel (t = specimen thickness)</th><th>Minimum bending angle 2)</th><th>Bending elongation 3) [%]</th></tr>
<tr><td>RA/WA</td><td>190</td><td>3 t</td><td rowspan="4">180°</td><td>20</td></tr>
<tr><td>RB/WB</td><td>240</td><td rowspan="3">6 t</td><td>17</td></tr>
<tr><td>RC1/WC1</td><td>275</td><td>17</td></tr>
<tr><td>RC2/WC2</td><td>290</td><td>17</td></tr>
<tr><td>RC3/WC3</td><td>330</td><td rowspan="2"></td><td rowspan="2"></td><td>24</td></tr>
<tr><td>RD/WD</td><td>170</td><td>8</td></tr>
</table>

1) Using the base materials shown in Table 5.28.

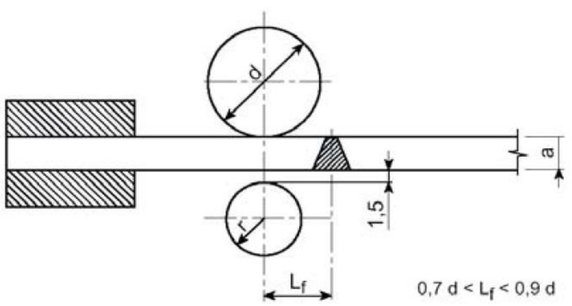
2) Bending angle achieved before first incipient crack, minor pore exposures permitted up to a max. length of 3 mm.

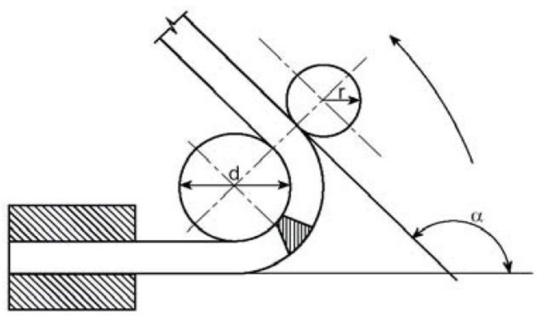
3) Where the bending angle is not achieved, the requirements shall still be regarded as having been met if the elongation achieved with a gauge length $L_0 = L_s + t$ before the first incipient crack meets the requirements

– (L_s = width of seam, t = thickness of specimen, see sketch below)

Note:

Because of the different flow behaviour of the base material and the weld metal, incipient cracking of the specimens may occur prematurely - especially with too rapid deformation - when the "free" bending test according to ISO 5173 is carried out. It is recommended that a test rig of the type shown in the following sketch be used in which the bending test specimen, clamped at one end, is "rolled" around the mandrel





3.5 Fillet-weld test pieces analogous to those called for in B.3.5 or C.3.5, as applicable, shall be provided for those welding consumables and auxiliary materials (wire-gas combinations) which are to be approved or used exclusively for the execution of fillet welds. In special cases, BKI may call for fillet-weld test pieces in addition to the butt-weld test pieces prescribed in 3.1.

4. Annual repeat tests

4.1 The annual repeat tests called for in A.3.1 shall entail the preparation and testing of the deposited weld metal test assembly as prescribed under 2.2 (Fig. 5.17) and of butt-weld test piece in accordance with 3. welded in the down -hand position with wire of 1,2 mm diameter. Half as many specimens may be used in the repeat tests as in the initial test (Fig. 5.18).

4.2 In special cases, BKI may require more extensive repeat tests (e.g. analysis of the weld metal as an additional measure) (see A.3.2, A.7.4 and A.7.5)

K. Welding Consumables and Auxiliary Materials for Copper and Copper Alloys

1. General

1.1 The following provisions apply to welding consumables and auxiliary materials for the welding of copper and copper alloys conforming to the Rules for Materials (Pt.1, Vol. V) and used for structural components in shipbuilding (e.g. rudders) and especially for pipelines conveying seawater.

Note:

According to the Rules for Materials (Pt.1, Vol. V) besides copper and high-strength brass, the copper-nickel alloys CuNi10Fe1Mn and CuNi30Mn1Fe as well as certain cast copper alloys (used in the manufacturer of propellers) are mainly used for welding purposes. In accordance with current approval practice, the following paragraphs therefore relate to welding consumables and auxiliary materials for these base materials; other such products for the welding of other cast alloys are to be treated in analogous manner.

1.2 Welding consumables and auxiliary materials for welding of copper and copper alloys are classified into the quality grades shown in Table 5.31 on the basis of their chemical composition (type of alloy) and mechanical (strength) properties. Testing and approval in respect of a base material in the lefthand column of Table 5.31 also encompasses the base material(s) shown in the right-hand column.

Table 5.31 Welding consumables and auxiliary materials for copper and copper alloys

Quality grade	Testing approval relating to		Materials also covered by the approval	
	Designation	Mat. No.	Designation	Mat. No.
CuNi30Fe	CuNi30Mn1Fe	2.0882	CuNi5Fe CuNi10Fe1Mn CuNi20Fe	 2.0872 2.0878
CuNi30Mn	CuNi30Mn1Fe	2.0882	CuNi5Fe CuNi10Fe1Mn CuNi20Fe	 2.0872 2.0878
SCU1 1)	CU1 5)	-	-	-
SCU2 2)	CU2 5)	-	CU1 1)	-

Table 5.31 Welding consumables and auxiliary materials for copper and copper alloys *(continued)*

Quality grade	Testing approval relating to		Materials also covered by the approval	
	Designation	Mat. No.	Designation	Mat. No.
SCU3 [3)]	CU3 [5)]	-	CU1 [1)] CU2 [1)]	- -
SCU4 [4)]	CU4 [5)]	-	CU1 [1)] CU2 [1)] CU3 [1)]	- - -

1) e. g. Al-bronze or Mn-bronze.
2) e. g. Al-bronze or Ni-Mn-bronze.
3) e. g. Al-bronze, Ni-Al-bronze or Mn-Al-bronze.
4) e. g. Mn-Al-bronze.
5) Cast copper alloys (for propeller manufacture) in accordance with the Rules for Materials (Pt.1, Vol. V) or other comparable alloys with the appropriate strength properties.

2. Testing of the weld metal

2.1 Unless otherwise stipulated, the testing of the weld metal shall consist of a chemical analysis of the deposited weld metal and a tensile test analogous to that described in B.2 (only one test piece to be welded in the down-hand position).

2.2 The chemical composition shall be determined and certified in a manner analogous to that prescribed in B.2.2. The results of the analysis shall not exceed the limits specified in the standards (e.g. ISO 24373) or by the manufacturer, the narrower tolerances being applicable in each case.

3. Testing on welded joints

3.1 The testing on welded joints shall be performed in a manner analogous to that prescribed in J.3. for welding consumables and auxiliary materials for aluminium alloys.

3.2 The mechanical properties shall conform to the required properties of the base materials shown in Table 5.32. Different values for these properties are only permissible with BKI's consent and are to be taken into account where applicable when dimensioning the components.

4. Annual repeat tests

The annual repeat tests called for in A.3.1 shall entail the preparation and testing of a butt-weld test piece in accordance with 3.1 welded in the down-hand position as in the case of aluminium alloys (see J.4.1).

Table 5.32 Required properties of welded joints

Quality grade	0.2 %-proof stress [N/mm^2] Min.	Tensile strength [N/mm^2]	Elongation [%] Min.
CuNi30Fe CuNi30Mn	120 120	360 – 490 360 – 490	30 30

Table 5.32 Required properties of welded joints *(continued)*

Quality grade	0.2 %-proof stress [N/mm^2] Min.	Tensile strength [N/mm^2]	Elongation [%] Min.
SCU1	175	min. 370	20
SCU2	195	min. 410	18
SCU3	245	min. 500	16
SCU4	275	min. 550	18

L. Welding Consumables and Auxiliary Materials for Nickel and Nickel Alloys

1. General

1.1 The following provisions apply to welding consumables and auxiliary materials for welding of nickel and nickel alloys.

Note:

According to current approval practice, the welding consumables and auxiliary materials shown in the left-hand column of Table 5.33 are used. The following paragraphs therefore relate to welding consumables and auxiliary materials for these materials, but also cover such products for joining of different materials by welding (e.g. austenitic steels to ferritic/perlitic steels) and especially for nickel steels tough at sub-zero temperatures.

1.2 Welding consumables and auxiliary materials for welding of nickel and nickel alloys, for joining of different materials by welding and for welding of nickel steels tough at sub-zero temperatures are classified according to their chemical composition (type of alloy) and mechanical properties (mechanical and tensile strength) into the quality grades shown in Table 5.33. The testing and approval of a base material in the left-hand columns of Table 5.33 encompasses the material(s) in the right-hand columns. Suitability for welding of the nickel steels tough at sub-zero temperatures in low-temperature applications is indicated separately in the approval certificate; see G.

Table 5.33 Welding consumables and auxiliary materials for nickel and nickel alloys

Quality grade	Testing and approval relating to		Materials also covered by the approval	
	Designation	Mat. No.	Designation	Mat. No.
NiTi3 (2.4156)	Ni 99,6	2.4060	Ni 99,2	2.4066
			Ni 99,6	2.4056
			LCNi99,6	2.4061
			LCNi99	2.4068
			and joints between different non-ferrous metal alloys and with steels	
NiTi4 (2.4155)	Ni 99,6	2.4060	as for NiTi3	
NiCr19Nb (2.4648)	NiCr15Fe	2.4816	NiCr15Fe	2.4816
			LC-NiCr15Fe	2.4817
			NiCr20Ti	2.4951
			NiCr20TiAl	2.4952
			NiCr23Fe	2.4851
			and welded joints between different nickel alloys (except for NiCu) and with steels; welded joints in nickel steels tough at sub-zero temperatures	
NiCr20Nb (2 4806)	NiCr15Fe	2.4816	as for NiCr19Nb	
NiCr16FeMn (2.4620)	NiCr15Fe	2.4816	as for NiCr19Nb	
NiCr20Mo9Nb (2.4621)	NiCr22Mo9Nb	2.4856	NiCr21Mo	2.4858
			NiCr22Mo6Cu	2.4618
			NiCr22Mo7Cu	2.4619
			NiCr21Mo6Cu	2.4641
			nickel steels tough at sub-zero temperatures	
NiCr21Mo9Nb (2.4831)	NiCr22Mo9Nb	2.4856	as for NiCr20Mo9Nb	
NiCu30Mn (2.4366)	NiCu30Fe	2.4360	Joints with dissimilar materials, namely with unalloyed structural steels to EN 10025 and boiler steels to EN 10028	
NiCu30MnTi (2.4377)	NiCu30Fe	2.4360		

2. Testing of the weld metal

2.1 For testing the deposited weld metal, the test pieces described in the standards (e.g. ISO 18274 and ISO 15792) shall be prepared according to the provisions of B.2., C.2., and D.2. The provisions of the standards with regard to the base materials to be used, including, where applicable, the buffering of the side walls of the weld, and to the welding parameters shall be complied with.

2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to the provisions of B.2.2, taking into account the provisions of the standards. The results of the analysis shall not exceed the limits specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

2.3 Depending on the nature of the welding consumables and auxiliary materials (and according to the welding process), the test specimens shall be taken from the weld metal test pieces in accordance with the standards and the provisions of B.2.3, C.2.3 and D.2.3.

2.4 The mechanical properties shall meet the requirements stated in Table 5.34. For welding of nickel steels tough at sub-zero temperatures, the notch impact energy requirements stated in G.2.1 and G.2.2 apply. The provisions of A.7.6, B.2.4, C.2.4 and D.2.4 apply in analogous manner to the performance of the tests and any retests that maybe necessary.

Table 5.34 Required properties of the weld metal [1)]

Quality grade	Proof stresses		Tensile strength R_m [N/mm²] min.	Elongation A [%] min.
	$R_{p\,0,2}$ [N/mm²] min.	$R_{p1,0}$ [N/mm²] min.		
NiTi3 NiTi4	200	220	410	25
NiCr19Nb NiCr20Nb	360	380	600	
NiCr16FeMn	360	380	600	
NiCr20Mo9Nb NiCr21Mo9Nb	420	440	700	
NiCu30Mn NiCu30MnTi	200	220	460	

1) The notch impact energy stated in 2.4 and, where applicable, G.2.1 and G.2.2.

2.5 BKI may require other tests to be performed or stipulate other values for the required properties if they are more appropriate to the character of the welding consumables and auxiliary materials or are necessitated by the intended use of the material.

3. Testing on welded joints

3.1 Depending on the nature of the welding consumables and auxiliary materials (and on the welding process concerned), the tests are to be performed on butt-weld test pieces in a manner analogous to B.3., C.3., or D.3.

3.2 The butt-weld test pieces shall be welded in accordance with B.3.2, C.3.2 or D.3.2, taking into account the provisions of the above-mentioned standards (see 2.1). Wherever possible, the base materials shall be the materials to be welded in the future application; in any case, however, materials of adequate strength shall be used.

3.3 Unless otherwise stipulated, the test specimens prescribed in B.3.3, C.3.3 and D.3.3 for the various types of welding consumables and auxiliary materials (and, where applicable, the various welding processes) shall be taken from the butt-weld test pieces.

3.4 The mechanical properties shall meet the requirements stated in 2.4 and Table 5.34, with the exception of the proof stresses. BKI may stipulate other values for the required properties; see 2.4.

4. Annual repeat tests

The annual repeat test specified in A.3.1 shall entail the preparation and testing of a weld metal test piece in accordance with 2. BKI may require more extensive repeat tests (see A.3.2, A.7.4 and A.7.5).

Section 6 Overweldable Shop Primers

A. General

1. Overweldable shop primers applied to plates, sections, etc. before welding shall not significantly impair the quality of welded joints.

Note:

Research and practical experience hitherto indicate that the characteristics of welded joints suffer practically no deleterious effects apart from an increased tendency towards porosity in fillet welds. Tests, approvals and supervisory measures are therefore exclusively concerned with this increased tendency towards porosity.

2. Only those overweldable shop primers shall be used for which BKI has issued a confirmation of acceptability based on a porosity test relating to overwelding.

3. The requirements relating to shop primers in respect of corrosion protection are covered in the Rules for Hull (Pt.1, Vol. II) Sec. 38.

4. Even where a confirmation of acceptability has been issued, overweldable shop primers shall only be approved for fully mechanized double fillet welding after a special welding procedure test in the user’s works.

B. Testing and Approval of Shop Primers

1. Initial confirmation of acceptance

1.1 Application for a confirmation of acceptability shall be made to BKI Head Office together with the following information and supporting documents:

- Manufacturer (and licensor, where applicable)
- Brand name (and licensor's brand name, where applicable) together with the original brand name in the case of commercial designations used for marketing
- Code number / short name/ symbol identifying the formulation or product
- Characteristic pigment base
- Characteristic binding agent base
- Data sheet with instructions for use (preparation of surface, methods of application, dry coat thickness, etc.)
- Documentation relating to previous tests, approvals,.etc.
- Place and date of proposed tests.

1.2 BKI reserves the right to carry out an inspection of the manufacturer=s work. To this end, BKI Surveyor shall be granted access to all production and test departments and laboratories. An explanation of the production conditions is to be given to the Surveyor and particularly satisfactory quality assurance measures demonstrated.

1.3 The porosity test shall be performed by neutral, properly equipped testing authorities recognized by BKI for that purpose or by a suitable test laboratory under the supervision of a BKI Surveyor.

1.4 The test is to be performed in accordance with ISO 17652 or other recognized standards.

1.5 The identity of the coating material submitted for testing shall be established and recorded in the test report. This may be done by, for instance, stating the batch number and date of manufacture. In case of doubt, BKI may require a test (e.g. of the chemical composition) to verify the identity of the sample.

1.6 The mean total pore area shall not exceed 150 mm^2.

1.7 BKI Head Office issues a confirmation of acceptability based on the tests performed and the records relating to these which shall be submitted and also based on the inspection of the manufacturer's work where applicable and adopts the shop primer in the list of approved welding consumables.

1.8 The confirmation of acceptability relates to the particular product tested (brand name, formulation, identification number etc.) from a specific manufacturer (production site). It does not relate to any other products or to products from another production process. For information on transferring approval documents, see 2.

1.9 With the issue by BKI of a confirmation of acceptability, the manufacturer (or, where applicable, the marketing company) assumes responsibility for ensuring that the composition and characteristics of the shop primer remain constant (see Section 1, F.1.). Any modifications shall automatically be drawn to BKI attention and shall normally necessitate a new test in accordance with 1.4.

2. Transferring approval documents

2.1 In the case of products which have a different brand name but an identical formulation/ identification no. or another manufacturer's products (a different production site) with the same brand name, formulation/identification no. etc., BKI may agree to transfer the approval documents for products for which a confirmation of acceptability has already been issued without necessitating a retest of the product as specified in 1.3 and 1.4.

2.2 The information and documentation specified in 1.1 and also a statement of conformity from both manufacturers, together with documentary proof of the identity of the product for which the first confirmation of acceptability was issued and that to which the approval document is to be transferred, shall be submitted to BKI with the simple application for the transfer of approval documents.

2.3 Where an approval document is to be transferred to a product from another manufacturer, BKI may also carry out an inspection of the manufacturer's work at this other production site in accordance with 1.2. BKI may also require production tests to be performed in accordance with C.

3. Validity, Extensions to Validity

3.1 Approvals (initial and transferred) are valid for 5 (five) years. On application by the manufacturer they may be extended by a further 5 (five) years at a time. In the application, the manufacturer shall confirm in writing that no changes have been made to the product since the initial approval was granted.

3.2 Proof that regular identity validation checks have been made shall be furnished by the manufacturer. The requirement for product validation checks may be satisfied by the submission of the manufacturer=s quality inspection records and confirmation of outside supervision from a testing authority recognised by BKI for that purpose.

3.3 BKI may demand a repeat test as specified in 1.3 to 1.5 in doubtful cases or where changes have been made to the product or the manufacturing conditions themselves have been altered.

C. Supervising the Use of Shop Primers, Production Tests

1. By suitable checks carried out in the course of normal production (e.g. measurements of coat thickness, production tests), workshops using shop primers shall ensure that the conditions of use on which the confirmation of acceptability was based are adhered to and that, in fillet welding, no excessive pore formation occurs which adversely affects the application.

Note:

The pores in fillet welds due to overweldable shop primers occur mainly as strings of pores made up of round or elongated individual pores. They originate at the gap between the web plate and the plating or flange, to which they are usually joined, and seldom extend to the surface. They can therefore practically only be detected by non- destructive or destructive inspection methods.

2. Production tests are to be performed under BKI supervision on a random basis during normal fabrication, as a supplementary test when a transfer of approval is sought, when a shop primer is changed or when the conditions of use are altered. BKI may demand production tests in doubtful cases. The conditions in which the production test pieces are welded shall be the same as those prevailing in normal fabrication. Fabrication off-cuts may be used as production specimens.

3. T-joints as shown in Fig. 6.1 shall be produced as part of the production test. To facilitate the breaking open of the two welds (if possible, on the bisector of the angle made by the web plate and the plating or flange), the test piece shall be grooved in the manner shown in Fig. 6.1 and shall be divided into test sections each 100 mm long. Alternatively, fillet weld (cruciform) test pieces may be welded in accordance with Section 12, F.4.3.1.3 (Fig. 12.8) and tested in accordance with F.4.3.3.2.

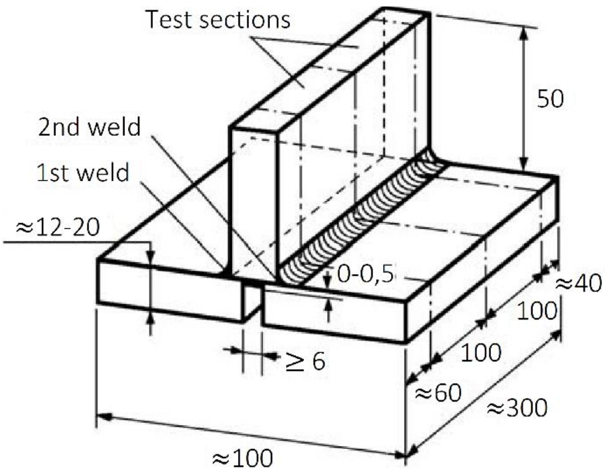


Fig. 6.1 Double fillet weld production test piece

4. The production test piece shall be broken open for assessment. The fracture surfaces of the weld revealing the largest number of pores shall be assessed. The number of pores over a 100 mm weld length shall be established and the individual pore areas shall be measured (e.g. as ellipses with the length and breadth of the pore providing the main axes). Pores whose largest main axis is less than 0,5 mm are ignored.

5. The number of pores and individual pore areas are used to calculate the total pore area and this is then related to the area of the weld fracture. The percentage pore area arrived at in this way shall be stated in the test report. The test report shall also state the shop primer material, the coat thickness and the welding parameters.

Note:

The maximum permissible relative pore areas are specified as 4 % for dynamic loading and 7 % for static loading. (Positive) Experience to date shows that these figures are "on the safe side". In shipbuilding, somewhat higher figures may be acceptable.

Section 7 General Design Principles

A. General

1. Scope

These Rules contain universal principles applicable to the designing and dimensioning of welded joints, and the information contained in the manufacturing documents.

2. Supplementary Rules

The designing and dimensioning of welded joints in the various range of application is additionally governed by the component-specific requirements stated in the various sections of Section 12 to 16 and in the respective Rules for Construction.

B. Information Contained in Manufacturing Documents

1. Joint/weld shapes, symbols

1.1 The depiction of welded joint and also the shapes of joints and welds shall conform to the standards (e.g. EN ISO 17659, ISO 2553 or ISO 9692). They shall be identified in the manufacturing documents (drawings, etc.) in an unambiguous manner, e.g. by means of the standard symbols.

1.2 Non-standard weld shapes or symbols shall be illustrated and, where applicable, explained in detail in the manufacturing documents (drawings, welding schedules or specifications). They shall be approved by BKI (e.g. in conjunction with the inspection of drawings or a welding procedure test).

1.3 A weld shape appropriate to, and adequately dimensioned or well designed for the nature (static or dynamic) and magnitude of the forces to be transmitted shall be chosen. Where necessary, documentary proof of the design calculations shall be submitted (see the supplementary rules mentioned in A.2).

2. Information on fabrication

2.1 The manufacturing documents to be submitted for approval shall contain information on fabrication insofar as is relevant to the quality of the welded joints and necessary for inspection by BKI. Besides the materials and weld shapes, this comprises the following information:

– Method of weld preparation (mechanical, thermal, etc.)
– Welding process, welding positions
– Welding consumables and auxiliary materials
– Preheating and, where applicable, heat input during welding
– Weld build-up and number of passes

- Welding sequence (in special cases)
- Grooving of root (method)
- Post-weld (heat) treatments, if any
- Number and location of any production specimens to be welded at the same time (where stipulated).

With regard to the information on the requirements applicable to the welded joints and their inspection,

2.2 If the preparation and execution of the welds (in conjunction with approved welding procedures, welding consumables and auxiliary materials) conform to normal welding and shipbuilding practice as well as to these Rules and the recognized standards, BKI may waive the requirement that they be specially illustrated or indicated in the manufacturing documents.

3. Requirements for welded joints, inspections

3.1 The manufacturing documents (e.g. drawings, welding or inspection schedules) to be submitted for approval shall also indicate the quality requirements for the welded joints. Depending on the range of application, this may be done by means of the weld factor (see Sections 13 and 14), or by means of the weld quality grade (see Section 12, I., Table. 12.9) or the evaluation category according to ISO 5817 or ISO 10042 (see Annex F and G). The tests (testing methods and scope of testing) to be used to verify the stipulated weld quality shall also be indicated.

3.2 The requirements to be stated also include the leak-tightness to gases and liquids or the corrosion resistance to particular media.

3.3 With regard to the welding procedure and production tests, see Section 4 and the application specific Sections 12 to 16; with regard to non-destructive testing, see Section 10 and the application-specific Sections 12 to 16.

C. Materials, Weldability

1. Weldability, processing

Only materials of proven weldability may be used for welded structures. Any conditions linked to the approval of the materials or to the welding procedure tests which impose restrictions on processing and the materials manufacturer's recommendations shall be allowed for when designing the welded joint.

2. Material-related characteristics

Material-related characteristics, such as the (inferior) strength of rolled products in the thickness direction (see D.7.2), the softening of hardened aluminium alloys when welded, or the different degrees of thermal expansion of the various materials, shall be allowed for when designing and dimensioning the components and welded joints.

3. Clad plates

Clad plates where the efficiency of the bond between the supporting and cladding material has been proved by materials testing (see Rules for Materials (Pt.1, Vol. V) Sec. 4) may generally be treated as solid plates (up to medium plate thicknesses with mostly fillet welds).

4. Pairs of materials, corrosion

Where pairs of different materials are exposed to seawater or other electrolytes, e.g. welded joints between unalloyed (hull) structural steels and stainless steels, attention shall be paid to the increased tendency towards corrosion due to the differences in electrochemical potential. Where possible, these welded joints should be located at points where there is less danger of corrosion, or special corrosion protection should be provided (e.g. coating or cathodic protection).

D. Design Details

1. Accessibility, workmanship and fitness for inspection

1.1 Welded joints shall be planned at the design stage to ensure that they are readily accessible during fabrication and can be executed in the optimum welding position and welding sequence.

1.2 Welded joints and welding sequences shall be designed to minimize residual weld stresses and avoid excessive deformation. Welded joints should therefore not be over-dimensioned.

1.3 Welded joints shall be designed to ensure that the proposed weld type and quality (e.g. complete root fusion in the case of single- and double-bevel butt welds) can be satisfactorily achieved under the given fabricating conditions. Failing this, provision shall be made for welds which are easy to execute and their (possibly inferior) load-bearing capacity shall be allowed for when dimensioning the welds.

1.4 Severely stressed welded joints, which are therefore normally subject to compulsory inspection, shall be designed to facilitate application of the most appropriate inspection technique (radiography, ultrasonic or surface crack inspection, possibly in combination) so that tests offering reliable results can be carried out.

2. Location and configuration of welded joints

2.1 In areas of high stress concentrations resulting from the design - and especially in cases of dynamic loading -, welded joints should be avoided as far as possible or designed in such a way as to provide a generally smooth stress profile without a significant additional notch effect originating from the welding operation. See Rules for Hull (Pt.1, Vol.II), Sec. 20 "Fatigue Strength".

2.2 Intersecting butt welds in load-bearing walls of steam boilers and pressure vessels shall be avoided. The longitudinal seams of pipes shall be offset relative to one another at the pipe joints by at least 50 mm. Intersecting butt welds in hull structures are allowed; if possible, however, the first (e.g. longitudinal) welded joint shall be completed and cleanly finished at the ends before the second (e.g. transverse) joint is made.

3. Local clustering of welds, minimum spacing

3.1 The local clustering of welds and insufficient distances between welded joints are to be avoided (see also Section.12, G.4). Welds shall not be over-dimensioned. The thickness of fillet welds shall not exceed 0,7 times the thickness of the thinner of the two parts to be joined.

3.2 Adjacent butt welds should be separated from each other by a distance of at least 50 mm + 4 x plate thickness. Fillet welds should be separated from each other and from butt welds by a distance of at least 30 mm + 3 x plate thickness. The width of interchangeable sections (strips) of plate should, however, be at least 300 mm or 10 x plate thickness, whichever is the greater. See also Section12, G.4.1.

4. Cut-outs, welding apertures

4.1 Adequately sized cut-outs (welding apertures) shall be provided when, for instance, stiffeners are applied to plating before the butt joints in the plating are welded, see also Section 12, G.5. The welding apertures shall be rounded with a minimum radius of 25 mm or 2 x plate thickness, whichever is the greater.

4.2 In special cases, e.g. when welding components subject to severe dynamic stresses, instead of providing welding apertures in the area of the butt welds it may be advisable to make a double-bevel weld preparation on the component to be attached to the plating, to weld up to this from both sides and to machine out the resulting root defect in the butt weld from the opposite side (of the plating).

5. Local reinforcements, plate doubling

5.1 Where platings (including girder plates and tube or vessel walls) are subjected locally to increased stresses, thicker plates should be used wherever possible in preference to plate doublings. Bearing bushes, hubs, etc. shall invariably take the form of thicker plates, forgings or the like welded into the plating.

5.2 Where doubling plates cannot be avoided, their thickness should not exceed twice the plating thickness and their width should not exceed 30 times their own thickness. With regard to welding of doubling plates and especially the ends of such plates, see Section 12, G.6. With regard to the design and welding of doubling plates as cut-out reinforcements in pressure vessels, see the Rules for Construction.

6. Stress flow, transitions

6.1 All welded joints on supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to expansion.

6.2 To this end, components with different dimensions shall be adjusted to one another by means of gradual transitions (e.g. by beveling the edges of the thicker component). Steel castings and forgings shall therefore be provided with integrally cast or forged welding flanges. See Section 12, G.3. and the Rules for Construction.

7. Double-T (cruciform) joints, stress in the thickness direction

7.1 Where, in the case of double-T (cruciform) joints, rolled products are stressed in the thickness direction due to the residual weld stresses or the applied loads, suitable measures shall be taken in the design of the structures to prevent lamellar tearing (stratified fractures). Such measures include the use of suitable weld shapes with a minimum weld volume and a welding sequence designed to reduce the shrinkage stresses in the thickness direction.

7.2 Where there are very severe stresses in the thickness direction (e.g. due to bulky single- or double-bevel butt welds), materials with enhanced characteristics in the direction at right angles to the surface of the product are to be used (see Rules for Materials (Pt.1, Vol. V) Sec. 4).

8. Welding of cold-formed sections

Welding of cold-formed sections of (hull) structural steels is permissible provided that the conditions stated in Section 12, G.8. are complied with. In special cases, post-weld heat treatment may be necessary or documentary proof of adequate toughness after welding may be demanded.

9. Other design measures

9.1 Welds should not be located in channels of sections owing to the danger of the presence of segregation and the residual stresses in these areas arising from the rolling process.

9.2 Welded joints (fillet weld joints) in areas where the risk of corrosion cannot be excluded shall be continuously executed around components, cut-outs, etc. to provide a seal.

9.3 If heat treatment is carried out on components with sealed-off hollow spaces necessitated by the design, such as occur in the case of cut-out reinforcements (doubling), mounted loose flanges or suspender rings, a means of venting, e.g. a drilled hole, shall be provided.

E. Dimensioning of Welded Joints

1. Dimensioning, design calculations

1.1 Dimensioning shall be carried out in accordance with the Rules for Hull (Pt.1, Vol. II) with reference to the shape and quality of the weld in question and the type (static or dynamic) and level of stress. The dimensions of the weld (if required) shall be apparent from the manufacturing documents to be submitted for approval. In the case of fillet welds, an indication shall also be given as to whether the dimensional data refer to the throat thickness of the weld "a" or to the leg length "z".

1.2 Where required by BKI (e.g. in the Rules for Hull (Pt.1, Vol. II) or as part of the examination of the drawing), mathematical proof (a general stress analysis and/or proof of fatigue strength) shall be furnished that the weld is adequately dimensioned.

2. Minimum thicknesses of fillet welds

Fillet weld throat thicknesses shall conform to the Rules or the results of design calculations. Throat thicknesses not established according to the Rules or design calculations shall be executed, as a minimum requirement, with a throat thickness of

$$a = 0{,}5 \text{ x plate thickness,}$$

the smaller plate thickness being the ruling dimension. Unless otherwise agreed (e.g. for the fully mechanized welding of smaller plate thicknesses in appropriate clamping jigs), the minimum fillet weld throat thickness shall be

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \text{ [mm], but not less than 3 mm}$$

t_1 = smaller (e.g. the web) plate thickness in [mm]

t_2 = larger (e.g. the flange) plate thickness in [mm]

A smaller minimum fillet weld throat thickness (e.g. 2,5.mm) may be agreed to if its faultless execution is demonstrated by means of a welding procedure test.

3. Machining allowance

Adequate machining allowances (thicker welds) shall be provided for the subsequent machining of welds to ensure that the prescribed minimum weld thicknesses are achieved on completion of the work. This particularly applies to welds with only partial penetration, as occasionally occur for instance in machinery components, in which case provision shall be made for machining correspondingly deeper joints from the outset. In the case of the notch-free grinding of the welds, which is employed in the case of particular weld quality requirements, correspondingly thicker welds shall be deposited.

Section 8 Execution of Welds

A. General

1. Scope, supplementary provisions

1.1 This Section contains universal rules applicable to the performance of welding work, extending from the weld preparation to the completion of the welded joints including any finishing operations. For heat treatment see Section 9; for testing of the welded joints see Sections 10 and 11.

1.2 The performance of the welding work is additionally governed by the application-specific requirements stated in the various section of Sections 12 to 16. The relevant provisions of the respective Rules for Construction shall also be complied with.

2. Welding shop requirements

2.1 All welding shops wishing to carry out welding work shall comply with the welding shop requirements stipulated in Sections 2 (Approval), 3 (Welder's Qualification Tests) and 4 (Welding Procedure Tests), and where necessary, Section 10 (Non-destructive Testing of Welds).

2.2 Welding shops shall maintain up-to-date records of this compliance and shall submit them to the Surveyor at his request. If necessary (e.g. in the case of a prolonged interruption to the work, see Section 2, A.4.2 and Section 3, F.), BKI may re-inspect the workshop.

3. Materials, marking

3.1 Welding may only be performed on materials whose identity and weldability under the given fabricating conditions can be unequivocally established by reference to markings, certificates, etc.

3.2 In case of doubt, the identity and weldability of the materials shall be verified before welding commences.

4. Welding consumables and auxiliary materials

4.1 Only welding consumables and auxiliary materials tested in accordance with Section 5, approved by BKI and of a quality grade appropriate to the base material to be welded shall be used. The various quality grades corresponding to the different hull structural steels shall be as shown in Table 12.1 in Section 12.

4.2 Welding consumables and auxiliary materials for particular materials and those intended for special welding processes which have been approved on the basis of a (preliminary) welding procedure test may be used only for the range of application specified in the relevant approval certificate. Any special conditions or rules associated with such applications shall be complied with.

4.3 Welding consumables and auxiliary materials may only be used with the electrode diameters covered by the tests and for the approved welding positions. The manufacturer's instructions and recommendations for use (e.g. the type of current and polarity used) shall be complied with.

4.4 If necessary, welding consumables and auxiliary materials are to be baked, prior to use, in accordance with the manufacturer's instructions (keeping to the specified maximum baking time) and are to be kept dry at the place of work (in heated containers or similar).

5. Overweldable shop primers

5.1 Overweldable shop primers which are applied to plates, sections, etc. prior to welding and are not removed shall be tested and approved in accordance with Section 6.

5.2 Welding shops shall ensure by suitable checks (especially on the thickness of the coating) and production tests carried out at random during the course of normal fabrication that the quality of the welded joints is not impaired to an unacceptable degree.

6. Manufacturing documents, company standards

6.1 Welds shall be executed in accordance with approved drawings, welding schedules or company standards recognized by BKI. Exceptions to this rule are subject to BKI consent in each individual case.

6.2 Compliance with the manufacturing documents is the responsibility of the welding shop.

B. Weld Preparation, Assembly

1. Weld preparation

1.1 Weld preparation may be carried out by thermal cutting or machining. Seam edges (groove faces) prepared by thermal cutting shall be finished by machining (e.g. grinding) if a detrimental effect on the welded joint as a result of the cutting operation cannot be ruled out. Welding edges of steel castings and forgings shall always be ground as a minimum requirement; roll scale or casting skin is to be removed.

1.2 Groove faces shall be free from impurities and defects liable to impair the quality of the welded joint, e.g. laps, coarse grooves made by the cutting torch and slag. Prior to welding, the welding edges shall be inspected for defects, e.g. cracks, inclusions, blowholes or pores, using non-destructive testing methods if necessary.

2. Weld shapes, root openings (air gaps)

2.1 When preparing and assembling components, care shall be taken to ensure compliance with the weld shapes and root openings (air gaps) specified in the manufacturing documents. With single- and double-bevel butt welds in particular, care shall be taken to make an adequate root opening to achieve sufficient root penetration.

2.2 The root opening shall not exceed twice the specified gap. If the size of the gap permitted by this rule is exceeded locally over a limited area, the gap may be reduced by build-up welding of the side walls, subject to the consent of the Surveyor. With fillet welds, the "a" dimension shall be increased accordingly, or a single- or double-bevel weld shall be made if the air gap is large. Inserts and wires may not be used as fillers.

3. Alignment of components

3.1 Components which are to be united by butt welding are to be aligned as accurately as possible. Sections welded to plating shall be left unwelded at the ends for this purpose. Special attention shall be paid to the alignment of (abutting) girders which are interrupted by transverse members. If necessary, such alignment shall be facilitated by drilling check holes in the transverse member which are subsequently closed by welding.

3.2 The permissible edge alignment error depends on the nature, importance and loading of the component concerned and is dealt with in the various section of Sections 12 to 16. Where special loading conditions or other requirements relevant to the application necessitate a limitation of the edge alignment error, the allowable error shall be stated in the manufacturing documents.

4. Tack welds and preparations for welding

4.1 Tack welds should be used as sparingly as possible and should be made by trained personnel. Where their quality does not meet the requirements applicable to the welded joint, they are to be carefully removed before the permanent weld is made.

4.2 Clamping plates, temporary ties and aligning pins shall be made from the same material as the base material or from a material of similar composition and should not be used more than necessary. Any damage caused during their removal shall be competently repaired.

4.3 With mechanized welding processes or when arc striking and end crater defects in butt welds have to be avoided, run-in and run-off plates shall be provided in continuation of the line of the weld.

4.4 Components shall be clean and dry in the area of the welds. Any scale, rust, cutting slag, grease, paint (except for approved overweldable shop primers), moisture or dirt shall be carefully removed before welding.

C. Weather Protection, Preheating

1. The areas to be welded shall be adequately protected against climatic influences such as wind, damp and cold and shall be preheated where necessary.

2. The need for and degree of preheating is determined by various factors, such as chemical composition, plate thickness, two- or three-dimensional heat dissipation, ambient and workpiece temperatures, or heat input during welding (energy applied per unit length of weld). Details are given in Section 9 and various section of Sections 12 to 16.

3. Preheating shall be applied uniformly throughout the thickness of the plate or component over a width of 4 × plate thickness, but not less than 100 mm. Preheating may be as necessary for tack and auxiliary welds as for fabricating welds.

D. Welding Positions, Welding Sequence

1. Welding should be performed in the optimum welding position; positional welding is to be limited to the indispensable minimum. The welders employed on positional welding shall be qualified for the welding positions concerned. With regard to welding in the vertical-down position, see Section 12, H.6.

2. The welding sequence shall be chosen to allow shrinkage to take place as freely as possible. Butt joints in areas of plating shall invariably be fully welded prior to attaching girders and stiffeners. BKI may require an assembly procedure or welding sequence schedule to be drawn up in special cases.

E. Performance of Welding

1. The welding shop shall ensure that the specified welding parameters are adhered to and that the welding work is expertly performed.

2. Components shall not be subjected to any appreciable movements or vibration during welding. Parts to be assembled while suspended from cranes or floating shall be clamped prior to tack-welding of the joints in such a way that no relative movement of the parts is possible. Components which have not been fully welded and which are to be handled or turned shall have welded joints of adequate strength.

3. Cracked tack welds may not be welded over, but are to be machined out. In multi-pass welding, the slag of the previous run shall be completely removed before the next pass is laid down. Pores, visible slag inclusions and other welding defects and cracks may not be welded over, but are to be machined out and repaired.

4. Welds shall have sufficient penetration and shall display a clean, regular surface with "gentle" transitions to the base material. Excessive weld reinforcements and undercuts or notches affecting the edges of plates and cutouts are to be avoided.

5. Butt-welded joints shall display full fusion over the entire cross-section, unless otherwise specified in a particular case. For this purpose, the root shall normally be grooved and capped. Following a successful welding procedure test confirmed by BKI, single-side welds, e.g. using ceramic backings, may be regarded as equivalent to butt welds executed from both sides. Other joints welded on one side only, e.g. using permanent backings, are subject to the BKI approval when scrutinizing the relevant drawings.

6. Single- and double-bevel butt welds are to be made according to the design specification either with grooved roots as full penetration welded joints or with a permitted incomplete penetration at the root or defined, unwelded root face subject to the appropriate reduction factors (see Section 12, G.10.2). The type of weld is to be specified in the drawings in each case and shall have received BKI approval when scrutinizing the drawings.

7. With fillet welds, particular attention shall be paid to good root penetration. The penetration shall extend to at least the immediate vicinity of the theoretical root point. The ideal fillet weld section is that of an equal-sided flat-faced weld with smooth transitions to the base material. At the ends of web plates, at cutouts and at welding apertures, the fillet welds shall be formed round the web to form a seal.

8. Major cases of faulty workmanship or defects in the material may only be repaired with the Surveyor's agreement. Minor surface defects shall be removed by shallow grinding. Defects which penetrate more deeply into the material (e.g. cracks, or damage caused by the removal of auxiliary erection equipment) shall be cleanly machined out and where necessary repair-welded with an adequate heat input.

9. Repair (so-called production welds) on steel castings and forgings shall only be made with the consent of the Surveyor. If their volume is considerable, sketches and descriptions of the repair work shall be submitted to BKI Head Office for approval, together with details of the analysis of the base material, the welding process and the welding consumables and auxiliary materials. BKI may require stress relief heat treatment or, in special cases, further heat treatment of the components after welding.

10. When working and welding higher-strength hull structural steels, high-strength (quenched and tempered) fine-grained structural steels, austenitic stainless steels and aluminium alloys, attention should be paid to the relevant information and instructions in the various section of Sections 12 to 16. For this work, BKI may require an appropriate welding specification to be submitted.

F. Straightening, Tolerances

1. Straightening operations (whether thermal or mechanical) shall not impair the quality of the materials and welded joints. BKI may require verification of the suitability of the straightening method (e.g. by means of a welding procedure test). This especially applies to high-strength (quenched and tempered) fine grain structural steels.

2. Unless specific tolerances are stated in the various section of Sections 12 to 16 or in the manufacturing documents, the dimensional tolerances for welded structures shall be as specified in the standards, e.g. ISO 13920 and for welded joints conforming to ISO 5817 or ISO 10042, (see Annex F and G). The degree of fineness and the evaluation category shall be stipulated in the manufacturing documents. BKI may specify other (tighter) tolerances where this is necessary for reasons of strength and/or operational safety.

G. Post-Weld Treatment of Welds

1. If it is intended to carry out post-weld treatment of the welds, e.g. to improve the surface finish in the case of dynamic loading, such treatment shall not impair the characteristics (mechanical properties) of the welded joints. BKI may demand documentary proof thereof.

2. For post-weld heat treatment, see Section 9; for the post-treatment of surfaces for non-destructive testing, see Section 10, F.1.

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Section 9 Heat Treatment

A. Scope

1. These Rules apply to preheating for, and heat input during welding and to post-weld heat treatment of welded components where required. For preheating of hull structural steels, see also Section 12, H.4 and H.5.

2. Requirements relating to the heat treatment of hot or cold formed welded components (e.g. spherical or dished ends, T-pieces and elbows) are stipulated in the Rules for Materials (Pt.1, Vol. V).

B. Equipment and Appliances for Heat Treatment

1. Equipment and appliances for preheating

Preheating may be carried out either in heat treatment equipment or by means of mobile heating appliances, e.g. gas burners or electrical induction or resistance heating appliances as applicable (resistance mats). A condition of their use is that the prescribed preheating and interpass temperatures shall be capable of being kept constant and monitored throughout the welding operation.

The temperature may be monitored by means of suitable appliances or aids, e.g. contact thermometers, temperature sensors or temperature-sensitive crayons.

2. Fixed heat-treatment equipment (heat-treatment furnaces)

2.1 The fixed heat-treatment facilities (heat-treatment furnaces) shall be of suitable size for the particular components and structures in question and be fitted with an appropriate temperature control facility. The furnaces shall ensure that the particular heat treatment temperatures stipulated can be guaranteed and that the temperature is evenly and accurately controlled (DIN 17052, quality grade C).

2.2 An adequate number of temperature recorders shall be provided, subject to a minimum of 2 to each furnace. The temperature variation over the period shall be established and recorded. The temperature control device and the temperature and time recording instruments used shall be checked at regular intervals (at least once a year) and documentary proof of the inspection results submitted to BKI on request.

3. Other heat-treatment equipment

The primary requirements are given in 1., but depend upon the particular requirements relating to the component or structure. The type and method of the heat treatment in question is subject to the BKI's consent.

If no heat treatment furnaces of sufficient size are available for the heat treatment of components, heat treatment may be carried out in mobile facilities (transportable furnaces) or in equipment which has been specially designed for the purpose, subject to BKI's consent. Such equipment shall comply with the requirements stated in 2.1 and 2.2 with regard to function, temperature control and temperature recording and shall be presented to BKI for inspection before being used. Care shall be taken to ensure that there is adequate insulation of the components or welds needing heat treatment. Unacceptable temperature gradients in the component shall be avoided.

C. Principles Relating to Heat Treatment

1. Heat treatment, temperature measurements and recording shall be performed by competent personnel.

2. The type, temperature and duration of the heat treatment process, in addition to the rates of heating and cooling are determined by material, the thickness of the material, the production process and the nature of the component or structure. See also the provisions of ISO 17671 Parts 1 to 4 and in the regulations given in Sections 12 to 16. The information and recommendations provided by the manufacturer of the materials and welding consumables shall be observed.

3. Details of the pre- and post-weld heat treatment of a component or structure shall be included in the production documents submitted for inspection by BKI. Where the manufacturer's welding procedure specifications (WPS) are used, these shall contain the necessary information relating to preheating, heat input during welding and post-weld heat treatment.

4. The whole of the component is normally subject to post-weld heat treatment. The heat treatment of part or sections of welds or the heat treatment of partial areas, especially pressurized components, require the BKI's consent in each individual case. A specification relating to this shall be submitted to BKI for examination.

5. Where welded joints are to be produced between different materials, in the case of complex welded components (e.g. LNG/LPG process pressure vessels and gas tanks), components which have high levels of cold forming (more than 3%) or extensive structural and repair welds to castings, the need for, type and extent of any heat treatment shall be agreed with BKI.

6. Parts shall be properly prepared for heat treatment in due order. Flange facings and sealings shall be adequately protected against scaling. Precautions shall be taken to protect against component distortion; components and structures shall be positioned accordingly. Unacceptable temperature gradients during the heat treatment process and during heating and cooling shall be avoided.

D. Weather Protection, Preheating, Heat Input during Welding

1. Weather protection, welding at low temperatures

1.1 The area in which welding work is performed is to be sheltered from wind, damp and cold, particularly if out of doors. Where gas-shielded arc welding is carried out, special attention is to be paid to ensuring adequate protection against draughts. When working in the open under unfavourable weather conditions it is advisable to dry welding edges by heating.

1.2 At ambient temperatures below +5°C, additional measures shall be taken, such as shielding of components, extensive preliminary heating and preheating, especially when welding with a relatively low heat input (energy input per unit length of weld), e.g. when laying down thin fillet welds or in the case of rapid heat dissipation, e.g. when welding thick-walled components. Wherever possible, no welding should be performed at ambient temperatures below -10°C.

2. Preheating for the welding of ferritic steels

2.1 The need for preheating of ferritic steels and the preheating temperature depend on a number of factors. Chief among these are:

- the chemical composition of the base material (carbon equivalent) and the weld metal,
- the thickness of the workpiece and the type of weld joint (two or three dimensional heat flow),
- the welding process and the welding parameters (energy input per unit length of weld),
- the shrinkage and transformation stresses,
- the temperature dependence of the mechanical properties of the weld metal and the heat-affected zone,
- the diffusible hydrogen content of the weld metal.

2.2 The operating temperature to be maintained (minimum preheating temperature and maximum interpass temperature) for (hull) structural steels may be determined in accordance with ISO 17671-2. Guide values for the preheating temperature are contained in Fig. 9.1 and 9.2 shown below for two different energy inputs per unit length of weld [1] and hydrogen contents HD [2] of the weld metal, together with the various carbon equivalents CET [3] .

Note:

Table 9.1 below gives guide values for the carbon equivalents CET [3)] of some of the standard grades of steel. Basis were the information the steel manufacturers. In case of doubt CET has to calculate by the actual analysis.

---

1 Energy input per unit length of weld:

$$E = \frac{U[\text{volts}] \cdot I[\text{amps}] \cdot \text{Welding time}[\text{min}] \cdot 6}{\text{Length of weld}[\text{mm}] \cdot 100} \cdot \left[\frac{\text{kJ}}{\text{mm}}\right]$$

2 HD 5 = max. 5 ml diffusible hydrogen per 100 g of weld metal
HD 15 = max. 15 ml diffusible hydrogen per 100 g of weld metal

3 Carbon equivalent:

$$C_{ET} = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40} \qquad [\%\ \text{in weight}]$$

The above formula for calculating the carbon equivalent CET in accordance with ISO 17671 can be applied to steels which have yield strengths ranging from 300 to 1000 MPa and to the following chemical composition: 0.05 - 0,32 % C, max. 0,8 % Si, 0,5 - 1,9 % Mn, max. 0,75 % Mo, max. 1,5 % Cr, max. 0,7 % Cu, max. 2,5 % Ni, max. 0,12 % Ti, max. 0,18 % V, max. 0,005 % B, max. 0,06 % Nb.

Table 9.1 Guide values for the carbon equivalent CET

Steel grades	CET [% in weight]	
	Average value [1)]	Maximum value [1)]
KI-A	0,27	0,28
KI-E	0,26	0,27
KI-D36	0,33	0,34
KI-E36TM	0,27	0,28
KI-D40	0,27	0,28
KI-E40TM	0,24	0,25
S275NL	0,25	0,27
S460NL	0,34	0,36
S460ML (TM)	0,27	0,28
S690QL	0,26	0,38
S890QL	0,38	0,41
2C22	0,26	0,29
34CrMo4	0,49	0,55
GS20Mn5	0,34	0,41

1) For product thicknesses up to 50 mm.

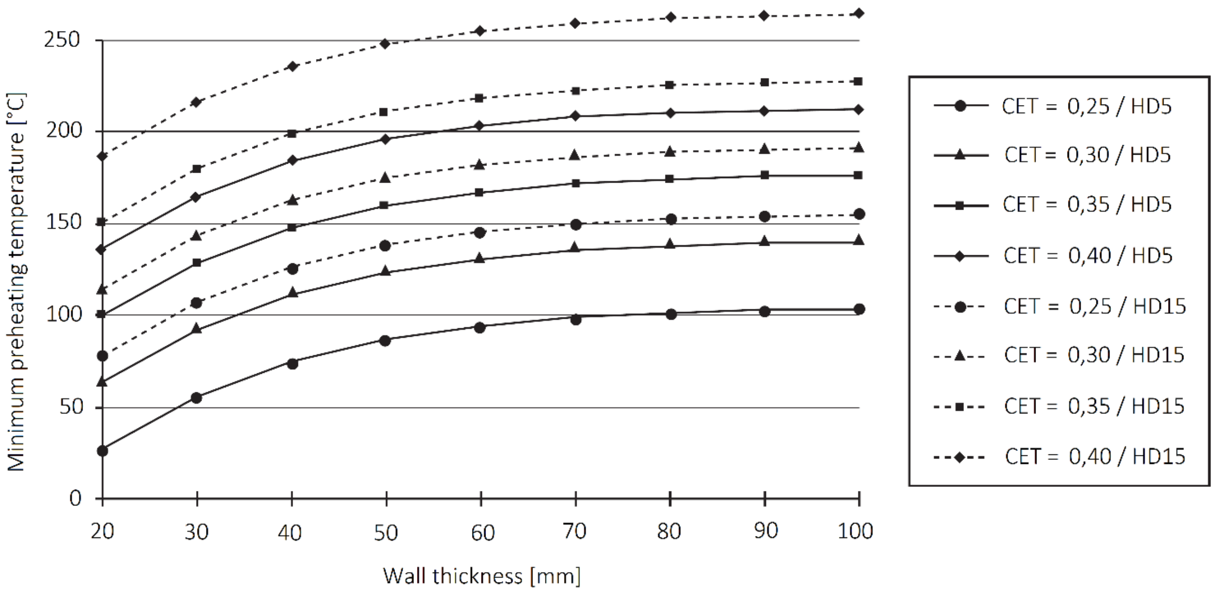

Fig. 9.1 Minimum preheating temperatures (operating temperatures) applicable to welding processes with a relatively low heat input (energy input per unit length[1] E ≈ 0,5 kJ/mm) as a function of the carbon equivalent CET[3] of the base material and the hydrogen content of the weld metal

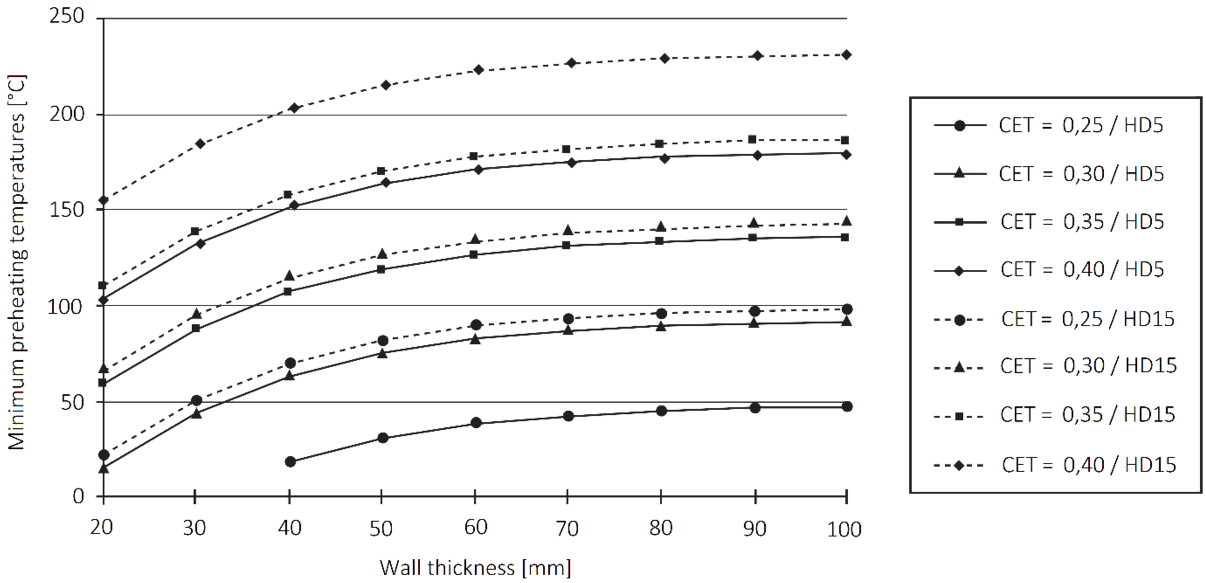

Fig. 9.2 Minimum preheating temperatures (operating temperatures) applicable to welding processes with a relatively high heat input (energy input per unit length[1] E ≈ 3,5 kJ/mm) as a function of the carbon equivalent CET[3] of the base material and the hydrogen content of the weld metal

2.3 Table 9.2 contains guide values for preheating high temperature Mo or CrMo alloy steels (used for steam boiler) in accordance with the Rules for Materials (Pt.1, Vol. V), see ISO 17671-2.

2.4 Table 9.3 contains guide values for preheating nickel steels tough at sub-zero temperatures in accordance with Rules for Materials (Pt.1, Vol. V). For details of this and also particulars relating to the se of austenitic or nickel-based welding consumables, see ISO 17671-2.

2.5 Depending on the complexity of the component, the welding process applied, the level of the residual stresses in the component and the (low) ambient temperature, the preheating temperatures shall be increased or the boundary wall thicknesses reduced as appropriate. For the effect of the various factors on the preheating temperature level, see Table 9.4.

2.6 If the temperature of the workpiece is lower than the minimum operating temperature calculated on the basis of the above data, preheating is called for. Various methods are available:

- Continuous heating prior to and during welding
- Alternate heating and welding
- Heating only prior to the start of welding, if the heat input during welding is sufficient to maintain the minimum operating temperatures.

The heating method may be chosen at will, provided that it does not harm the material by localized overheating or cause a nuisance by making the welding area contaminated.

Table 9.2 Guide values for preheating high-temperature steels (used for steam boiler)

Category in accordance with ISO 15608	Steel grade	Thickness [mm]	Minimum preheating temperature [°C] given an H_2 content of the weld metal of		
			≤ 5 ml/100 g	> 5 - ≤ 10 ml/100 g	> 15 ml/100 g
1.1	16Mo3	≤ 15 > 15 - ≤ 30 > 30	20 20 75	20 75 100	100 100 not permitted
5.1	13CrMo4-5	≤ 15 > 15	20 100	100 150	150 not permitted
5.2	10CrMo9-10 11CrMo9-10	≤ 15 > 15	75 100	150 200	200 not permitted

Table 9.3 Guide values for preheating nickel steels tough at sub-zero temperatures

Category in accordance with ISO 15608	Steel grade	Thickness [mm]	Minimum preheating temperature [°C] given an H_2 content of the weld metal of	
			≤ 5 ml/100 g	> 5 - ≤ 10 ml/100 g
9.2	12Ni14 (3,5 % Ni)	> 10	100	150
9.3	12Ni19 (5 % Ni)	> 10	100	not permitted
	X8Ni9 (9 % Ni)	> 10	100	not permitted
	X7Ni9 (9 % Ni)	> 10	100	not permitted

Table 9.4 Effect of the various factors on the level of preheating

Shift in the preheating temperature to lower values	Factors influencing preheating	Shift in the preheating temperature to higher values
low alloying element content	chemical composition of the base material (hardenability), e.g. expressed by the carbon equivalent	higher alloying element content
thin	thickness of the workpiece or component (heat dissipation, rigidity, residual stress condition)	thick
butt joints (2 planes), thick (multiple run) welds	type of joint, weld shape and dimensions, heat input, heat dissipation	T-joints (3 planes) thin (single-run) welds
high	ambient or workpiece temperature (heat dissipation)	low
high	heat input (energy input per unit length of weld) during welding	low
low	hydrogen content of the weld metal (type and rebaking of the welding consumables and auxiliary materials)	high

2.7 Preheating is always necessary for tack and auxiliary welds whenever preheating is needed for the rest of the welding. Possible exceptions to this rule are tack and auxiliary welds where it can be guaranteed that subsequent welds are remelted the heat affected zone, for instance tacks for submerged arc welds.

2.8 Irrespective of the information given above, preheating is always necessary when making major auxiliary erection welds e.g. when welding on handling lugs and when welding very large wall thicknesses and also thick-walled castings and forgings.

2.9 Preheating shall be applied uniformly throughout the thickness of the plate or component over a distance of four times the plate thickness, minimum of 100 mm, on both sides of the weld. Localized overheating is to be avoided. Preheating with gas burners should be performed with a gentle, though not sooty, flame in order to prevent dirt being deposited in the area of the weld. For details on the recording of the preheating temperature, see EN IS0 13916.

2.10 To prevent cold cracks in higher-strength and high-strength (quenched and tempered) steels, thick-walled components or components of complex design, it is advisable to use measures which give the hydrogen introduced into the weld metal during welding sufficient time to escape. The following methods are well established:

– Maintenance of a specific minimum preheating and interpass temperature throughout the welding operation
– Delayed cooling after welding
– Holding at approximately 250°C prior to cooling (hydrogen-reducing heat treatment) or
– Heat treatment immediately after welding (without cooling in between).

2.11 Where hull structural steels or fine-grained structural steels have undergone thermo-mechanical processing (TM steels), the need for and degree of preheating shall be decided on separately on the basis of the carbon equivalent and the results of the approval or welding procedure tests as applicable. Drying of the areas to be welded by heating may be sufficient.

3. Monitoring interpass temperatures

The guide values contained in Table 9.5 for the interpass temperatures relating to the various steels shall not be significantly exceeded.

Table 9.5 Guide values for the maximum interpass temperature during welding

Category in accordance with ISO 15608	Steel grades	Maximum interpass temperature [°C]
1.1	Normal-strength hull structural steels and comparable structural steels	250
1.2	Higher-strength structural steels and comparable structural steels	250
1.1	High-temperature, low Mo alloy steels	250
2	Normalised or thermo-mechanically processed fine-grained steels with yield strengths of > 360 N/mm^2	250
3	Quenched and tempered or precipitation-hardened (excluding stainless) steels with yield strengths of > 360 N/mm^2	250
5	Steels with a max. Cr content of 10% and a max. Mo content of 1,2%	350
9	Nickel alloy steels with a max. Ni content of 10 %	250

4. Welding with controlled heat input per unit length of weld

In addition to controlling the preheating and interpass temperature, the heat input per unit length of weld shall be controlled during welding, especially in the case of weldable, high-strength (quenched and tempered) fine-grained structural steels. The heat input per unit length of weld shall not fall below or exceed the values indicated by the steel manufacturer or those used in the welding procedure tests and specified in the welding procedure specifications (WPS) by any significant amount.

5. Preheating and heat input during the welding of other steels or metallic materials

5.1 Preheating is not normally required for austenitic materials. Preheating may be necessary for austenitic-ferritic materials. A maximum permitted interpass temperature which is normally between 150°C and 180°C shall be complied with in order to prevent hot cracks.

5.2 Ferritic and stainless martensitic steels shall be adequately preheated and welded using controlled heat input per unit length of weld. Guide values for the preheating and interpass temperatures are prescribed in ISO 17671-3.

5.3 Preheating is not normally required for welding aluminium alloys, but should not exceed 50°C. A maximum permitted interpass temperature of 100°C to 120°C shall be complied with in order to prevent undesirable phase dispersion. ISO 17671-4 contains guide values for the preheating temperature to be applied and the interpass temperature.

E. Post-Weld Heat Treatment

1. Welded components shall be subjected to post-weld heat treatment where this is prescribed in Sections 12 to 16. Post-weld heat treatment is generally used for ferritic steels, in which case stress relief heat treatment or tempering is normally sufficient. Where consideration also has to be paid to other codes of practice in the manufacture of certain components or structures, the provisions relating to post-weld heat treatment contained in these codes of practice shall also be complied with.

Note:

The need for and type of post-weld heat treatment is determined by various factors, the most important of which are given below:

- *material characteristics and dimensions (wall thicknesses)*
- *minimum anticipated operating temperature (design temperature)*
- *type of operating and background environment (e.g. risk of corrosion)*
- *build-up of welds to inhibit elongation and shrinkage*
- *risk of distortion during subsequent machining*

2. If stress relief heat treatment after welding is insufficient and more extensive heat treatment is required (e.g. normalising or quenching and tempering), the method of heat treatment shall be specially established in accordance with the material specification and the conditions of use and subject to agreement by BKI. This shall also apply in analogous manner to materials and material combinations other than those dealt with here and also to other methods of stress-relief.

3. The stress relief heat treatment shall be carried out by means of slow, even heating of the components to the prescribed temperature ranges (Table 9.6 contains guide values), holding in these ranges for two minutes per mm of wall thickness (but not less than 30 minutes), slow cooling to 400°C in the furnace or heat treatment appliance, and then complete cooling in still air. For thick-walled components, the holding time need not be more than 150 minutes.

4. If there is a risk of the components being distorted during cooling, the heat treatment may, within certain limits, be carried out at a lower temperature with an increased holding time. The required temperatures and holding times shall be agreed with BKI.

5. Joints between ferritic and austenitic steels (weld metal) shall not, as a general rule, be subjected to heat treatment due to the risk of carbon diffusion, except where the welds are made using nickel-base filler materials.

Table 9.6 Heat treatment temperatures for stress-relief heat treatment of welded joints using similar filler metals

Category in accordance with ISO 15608	Steel grades	Examples of appropriate steels in accordance with BKI's Rules or the standards [1)]	Heat treatment temperature [°C]
1.1	Normal-strength hull structural steels and comparable structural steels, grade of steel forgings and castings	KI Grade A - E	550 - 600
1.2	Higher-strength hull structural steels and comparable structural steels, grades of steel forgings and castings	KI Grade A 36 - E 36	530 - 580
1.1	High-temperature, low Mo alloy steels	16Mo3	550 - 620
2	Normalized or thermo-mechanically processed fine-grained steels with yield strengths > 360 N/mm^2	KI Grade A 40 - E 40 S 460 TM	530 - 600
3	Quenched and tempered fine-grained structural steels with yield strengths > 360 N/mm^2	S 690 QL	530 - 580
5 5.1 5.2	Steels with a max. Cr content of 10 %, max Mo content of 1,2%	13CrMo4-5 10CrMo9-10, 11CrMo9-10,	630 - 680 670 - 720
9 9.1 9.2 9.3 9.3 9.3	Nickel steels with a maximum Ni content of 10%	13MnNi6-3 (0,5 % Ni) 12Ni14 (3,5 % Ni) X12Ni5 (5 % Ni) X8Ni9 (9 % Ni) X7Ni9 (9 % Ni)	530 - 560 530 - 560 530 - 560 [2)] [2)]

1) Steel grades not listed here are to be classed together with comparable grades.
2) Heat treatment should be avoided.

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Section 10 Non-destructive Testing of Welds

A. General

1. Scope

1.1 This Section apply to the performance of conventional and advanced non-destructive tests of welded joints according to the methods and scopes prescribed in the individual in Sections 12 to 16 for the various fields of application. See also Section 1, A.1. and A.2.

1.2 They also apply to the performance of all non-destructive weld tests which are stipulated in other Rules. Regulations or technical instructions and for which no specific details are given therein.

1.3 The quality levels given in this Section refer to production quality and not to fitness for-purpose of the welds examined (see G.2.1).

(IACS UR W33 1.2)

1.4 The NDT is normally to be performed by the shipbuilder, manufactures or its subcontractors in accordance with these requirements. BKI Surveyor may require witnessing of the testing.

(IACS UR W33 1.3 & IACS UR W34 1.2)

1.5 It is the shipbuilder's or manufacturer's responsibility to assure that testing specifications and procedures are adhered to during the construction and the reports are made available to BKI on the findings made by the non-destructive test.

(IACS UR W33 1.4 & IACS UR W34 1.3)

2. Standards and other codes of practice

2.1 The standards, etc. mentioned in the following paragraphs are an integral part of these Rules and shall also be complied with when performing the non-destructive weld tests. Where the standards contradict these Rules, the latter shall take precedence.

2.2 The performance of tests according to other, comparable codes of practice requires the prior consent of BKI. For this purpose, the relevant codes of practice shall be submitted to BKI together with the other inspection documents (see D.1.1) for examination and approval.

(IACS UR W33 6.1.1)

3. Requirements applicable to the inspection department

3.1 The works' inspection department shall be as independent and free from the influence of the fabrication department as it is necessary to ensure that the inspection and the evaluation of the inspection results are carried out objectively. This applies in analogous manner to outside inspection bodies.

4. Application

4.1 Base Metals

This Section applies to conventional NDT for fusion welds made in normal and higher strength hull structural steels in accordance with Rules for Materials (Pt.1, Vol.V) Sec.4.B and 4.L, high strength steels for welded structures in accordance with Rules for Materials (Pt.1, Vol.V) Sec.4.D and connections welds with hull steel forgings in accordance with Rules for Materials (Pt.1, Vol.V) Sec.6 and hull steel castings in accordance with Rules for Materials (Pt.1, Vol.V) Sec.7. Base metal other than the above may be applied by BKI.

(IACS UR W33 2.1.1)

For advanced NDT see O.2.1.

4.2 Welding processes

This Section applies to welding processes specified in Table 10.1. This Section may also be applied to other welding processes at the discretion of BKI.

Table 10.1 Applicable welding process

Welding process		ISO 4063:2009
Manual welding	Shield Metal Arc Welding (SMAW)	111
Semi-automatic welding	(1) Metal Inert Gas welding (MIG) (2) Metal Active Gas welding (MAG) (3) Flux Cored Arc Welding (FCAW)	131 135, 138 136
TIG welding	Gas Tungsten Arc Welding (GTAW)	141
Automatic welding	(1) Submerged Arc Welding (SAW) (2) Electro-gas Welding (EGW) (3) Electro-slag Welding (ESW)	12 73 72

(IACS UR W33 2.2.1)

4.3 Weld joints

This Section applies to butt welds with full penetration, tee, corner and cruciform joints with or without full penetration, and fillet welds.

(IACS UR W33 2.3.1)

B. Test Methods, Appliances and Test Media

1. Test methods

1.1 The choice of the test method to be used in each case is determined among other things by the component or weld shape, the material and the defects to be demonstrated (type and position). See the individual application-specific in Sections 12 to 16.

1.2 Unless otherwise stated in the individual application-specific sections of Sections 12 to 16, the following basic requirements apply:

– Up to a wall or weld thickness of approx. 40 mm, radiographic inspection is the preferred method; for larger thicknesses, ultrasonic inspection is to be used as the primary test method

– For wall or weld thicknesses of approx. 8 mm and above, either radiographic or ultrasonic inspections may be performed, in consultation with BKI

– For radiographic inspection, X-ray sources shall be used wherever possible. Gamma ray sources may only be used with BKI's consent on the basis of an examination and recognition of the test method; see K.1

– For magnetic materials, testing for surface cracks shall wherever possible be carried out by magnetic particle inspection; the use of liquid penetrant inspections for magnetic materials requires BKI's consent in each individual case.

1.3 The test method shall be capable of reliably detecting the external and /or internal defects which may be present. Applicable methods for testing of the different types of weld joints are given in Table 10.2. Where necessary, this shall be achieved by using two or more test methods in combination. The particular test method (s) to be used shall be stated in the inspection schedule (see D.1.1).

Table 10.2 Test method for detecting external and or internal defects of the different types of weld joints[4]

Weld joint	Base material thickness	Test method	
		External defects	Internal defects
Butt welds with full penetration	t < 8mm[1]	Visual Testing (VT), Penetrant Testing (PT), Magnetic Testing Particle (MT)	Radiographic Testing (RT)
	t ≥ 8 mm		Ultrasonic Testing (UT), Radiographic Testing (RT)
Tee joints, corner joints, and cruciform joints with full penetration	t < 8mm[1]		Radiographic Testing (RT[3])
	t ≥ 8 mm		Ultrasonic Testing (UT), Radiographic Testing (RT[3])
Tee joints, corner joints, and cruciform joints without full penetration and fillet welds	All		Ultrasonic Testing (UT[2]), Radiographic Testing (RT[3])

Note:

1 In cases of thickness below 8 mm BKI may consider application of an appropriate advanced UT method.

2 UT may be used to check the extent of penetration in tee, corner and cruciform joints. This requirement is to be agreed with BKI.

3 RT may be applied however there will be limitations

4 Test method for detecting external and internal defects using advanced non-destructive test (ANDT) see Table 10.10

(IACS UR W33 2.3.1 & 2.5)

1.4 All welds over their full length are to be subject to VT by personnel designated by the Shipbuilder, who may be exempted from the qualification requirements defined in C.

(IACS UR W33 5.4)

1.5 As far as practicable, PT or MT shall be used when investigating the outer surface of welds, checking the intermediate weld passes and back-gouged joints prior to subsequent passes deposition. MT shall be performed in ferromagnetic materials welds unless otherwise agreed with BKI. Surface inspection of important tee or corner joints, using an approved MT or PT method, shall be conducted to the satisfaction of the surveyor.

(IACS UR W33 5.5)

1.6 Welded connections of large cast or forged components (e.g. stern frame, stern boss, rudder parts, shaft brackets) are to be tested over their full length using MT (MT is the preferred method) or PT, (PT is to be applied for non-ferrous metals) and at agreed locations using RT or UT.

(IACS UR W33 5.6)

1.7 As given in Table 10.2, UT or RT or a combination of UT and RT may be used for testing of butt welds with full penetration of 8 mm or greater. Methods to be used shall be agreed with BKI. The method used shall be suited for the detection of particular types and orientations of discontinuities. RT and UT are used for detection of internal discontinuities, and in essence they supplement and complement each other. RT is generally most effective in detecting volumetric discontinuities (e.g. porosity and slag) whilst UT is more effective for detecting planar discontinuities (e.g. laminations, lack of fusion and cracks). Although one method may not be directly relatable to the other, either one would indicate conditions of inadequate control of the welding process.

(IACS UR W33 5.7)

1.8 In general start/stop points in welds made using automatic (mechanized) welding processes are to be examined using RT or UT, except for internal members where the extent of testing is to be agreed with the attending Surveyor.

(IACS UR W33 5.8)

1.9 Welds in thick steels (>50mm) used in container carrier, deck and hatch coaming areas are to be inspected in accordance with the additional requirements in Rules for Container Ships (Pt.1, Vol.XVIII) Sec.27.

(IACS UR W33 5.10)

2. Test appliances and media

2.1 The test appliances and media used shall conform to the state of the art and the relevant standards and shall be in perfect, serviceable condition. BKI may require an inspection of the test appliances and/or media used.

2.2 When making use of test equipment, test appliances, etc. owned by other, outside testing bodies, the works shall ensure that the conditions stated in 2.1 are satisfied.

C. Qualification of Personnel involved in NDT

1. Qualifications of personnel

1.1 The Shipbuilder, manufacturer or its subcontractors is responsible for the qualification and preferably 3rd party certification of its supervisors and operators to a recognised certification scheme based on ISO 9712:2012.

1.2 Personnel qualification to an employer-based qualification scheme as e.g. SNT-TC-1A, 2016 or ANSI/ASNT CP-189, 2016 may be accepted if the Shipbuilder, manufacturer or its subcontractors written practice is reviewed and found acceptable by BKI. The Shipbuilder, manufacturer or its subcontractors written practice shall as a minimum, except for the impartiality requirements of a certification body and/or authorised body, comply with ISO 9712:2012.

1.3 The supervisors' and operators' certificates and competence shall comprise all industrial sectors and techniques being applied by the Shipbuilder or its subcontractors. Level 3 personnel shall be certified by an accredited certification body.

(IACS UR W33 3.1 & W34 3.1)

2 Supervisors

2.1 The Shipbuilder, manufacturer or its subcontractors shall have a supervisor or supervisors, responsible for the appropriate execution of NDT operations and for the professional standard of the operators and their equipment, including the professional administration of the working procedures.

2.2 The Shipbuilder, manufacturer or its subcontractors shall employ, on a full-time basis, at least one supervisor. The supervisor(s) shall, as a minimum, be certified to Level 2 in the method(s) concerned as per the requirements of item 1, with minimum experiences for 5 years in the stated method (for Level 3, experience is not necessary).

2.3 The supervisor shall be directly involved in review and acceptance of NDT Procedures, NDT reports, calibration of NDT equipment and tools.

2.4 The supervisor shall on behalf of the Shipbuilder, manufacturer or its subcontractors re-evaluate the qualification of the operators annually.

(IACS UR W33 3.2 & UR W34 3.2)

3. Operators

3.1 The operator carrying out the NDT and interpreting indications, shall as a minimum, be qualified and certified to Level 2 in the NDT method(s) concerned, having at least 2 years of proven practical testing experience who are recognized by BKI and as described in item 1.

However, operators only undertaking the gathering of data using any NDT method and not performing data interpretation or data analysis may be qualified and certified as appropriate, at Level 1.

3.2 The operator shall have adequate knowledge of materials, welding, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

(IACS UR W33 3.3 & UR W34 3.3)

D. Inspection Schedule, Inspection Reports

1. Inspection schedule

1.1 Unless already stated in the other manufacturing documents (drawings, parts lists, etc.) to be submitted for approval, an inspection schedule for the non-destructive weld tests shall be drawn up by the welding shop according to the construction design, construction type and welding processes used which shall contain the following information:

- Components and welded joints to be tested
- Scope and method of testing, areas to be tested, location of testing positions (see the application-specific sections of Sections 12 to 16)
- Requirements applicable to the welded joints (for evaluation criteria, see the application-specific sections of Sections 12 to 16)
- Testing standards and/or specifications, if it is intended to use standards or specifications different from those mentioned in these rules.

For new construction survey reference is to be made to the NDT requirements of Rules for Classification and Surveys (Pt.1, Vol.I) Annex A.2.

(IACS UR W33 5.1 & 5.2)

For criticality of structure reference is to be made to Rules for Hull (Pt.1, Vol.II) Table 2.2 and Rules for Bulk Carrier and Oil Tanker (Pt 1, Vol. XVII).

(IACS UR W33 1.5)

1.2 The location of testing positions shall be subject to agreement between the welding shop and BKI Surveyor, whereupon the inspection schedule shall be submitted to BKI Head Office for approval. BKI reserves the right to make changes to this inspection schedule even after approval has been given and especially to change the location of the individual testing positions or to extend the scope of testing (see H.) if the production process and/or test results suggest this to be necessary.

1.3 In selecting test positions, emphasis shall be given to the following inspection locations:

- Welds in high stressed areas
- Fatigue sensitive areas
- Other important structural elements
- Welds which are inaccessible or very difficult to inspect in service
- Field erected welds
- Suspected problem areas

Block construction welds performed in the yards, or at subcontracted yards/facilities, are to be considered in selecting test positions. For other marine and offshore structures, the extent is to be agreed by BKI.

(IACS UR W33 5.2)

1.4 The minimum inspected weld length for each test position shall be specified in the approved inspection schedule and shall follow the requirements in relevant Sections.

(IACS UR W33 6.6.2)

1.5 The plan shall only be released to the personnel in charge of the NDT and its supervision.

(IACS UR W33 5.2)

1.6 The identification system shall identify the exact locations of the lengths of weld examined.

(IACS UR W33 5.3)

2. Inspection reports

2.1 Reports shall be prepared on all (initial and repeat) tests, and these shall be submitted to the Surveyor together with the other documentation (e.g. radiographs). The inspection reports shall contain all the necessary details according to K. to O. relating to the particular test method used, the position at which the test was performed and the results obtained. In addition, as a minimum, the following information shall be given :

- Date of testing
- Hull number, location and length of weld inspected
- Names, qualification level and signature of personnel that have performed the testing
- Identification of the component examined
- Identification of the welds examined
- Material, type of joint, thickness of parent material, welding process
- Acceptance criteria
- Testing standards used
- Testing equipment and arrangement used
- Any test limitations, viewing conditions and temperature
- Results of testing with reference to acceptance criteria, location and size of reportable indications
- Statement of acceptance / non-acceptance, evaluation date, name and signature of evaluator
- Number of repairs if specific area repaired more than twice

(IACS UR W33 8.2)

Note:

Where the test results are to be recognized in place of the prescribed welder's repeat tests in accordance with Section.3, E.3, the inspection reports shall also state the names or identification numbers of the welders.

2.2 Repeat tests (following repairs) and their results shall be specially identified in the inspection reports; see I.2.2. The results and documents relating to the initial test shall be submitted to BKI Surveyor along with the results and documents relating to the repeat tests and also specifically if the repair was arranged for in-house.

2.3 Inspection reports shall be signed by the inspector and the test supervisor. Reports and documentation shall be kept for 5 (five) years.

E. Timing of Inspection, Waiting Times

1. Non-destructive testing of welds shall as a general rule not be carried out until all the welding operations on the component concerned have been completed. NDT shall be conducted after welds have cooled to ambient temperature.

In special cases, e.g. in the case of thick-walled components at risk of cracking, it may be advisable to carry out non-destructive tests, e.g. for surface cracks examinations, as an interim measure (in the course of the welding work).

2. Before using the test methods described in K. to O, a visual inspection of the welded joints shall be performed. Surface defects which restrict the ability of the tests to produce meaningful results or which may lead to misinterpretation of the results shall be remedied before any further tests are performed. See also J.3.

3. Components which are subjected to post- weld heat treatment (e.g. stress relief heat treatment) shall as a general rule be inspected after heat treatment. Inspection of the welds for welding defects before heat treatment as well is recommended. BKI may take previous inspections into account when establishing the final scope of inspection. Details shall be agreed with BKI on a case-by-case basis.

4. For high strength steels for welded structure with specified minimum yield stress in the range of 420 N/mm^2 to 690 N/mm^2, where the possibility of delayed cracking (e.g. due to the presence of hydrogen in the weld metal) cannot be ruled out, the tests shall not be carried out earlier than 48 hours after completion of the welding work.

For steel with specified minimum yield greater than 690 N/mm^2 NDT shall not be carried out before 72 hours after completion of welding. Regardless of yield strength consideration is to be given to requiring a delayed inspection where evidence of delayed cracking has been observed in production welds. At the discretion of the surveyor, a longer interval and/or additional random inspection at a later period may be required, (for example in case of high thickness welds).

At the discretion of the surveyor, the 72 hour interval may be reduced to 48 hours for RT or UT inspection, provided there is no indication of delayed cracking, and a complete visual and random MP or PT inspection to the satisfaction of the surveyor is conducted 72 hours after welds have been completed and cooled to ambient temperature.

Where post weld heat treatment (PWHT) is carried out the requirement for testing after a delay period may be relaxed, at the discretion of the surveyor.

(IACS UR W33 2.4.2)

5. Repetition of non-destructive tests shall be allowed for or may be demanded if the components or welded joints have been subjected to abnormal stresses (e.g. while in transit or during trial loading or pressure testing) before being stressed in normal service. The type and scope of these tests shall be agreed with BKI on a case-by-case basis.

F. Requirements, Preparation and Performance of Tests

1 Requirements of tests

1.1 The shipyard is to ensure that personnel carrying out NDT or interpreting the results of NDT are qualified to the appropriate level as detailed in C.

1.2 Procedures

1) All NDT are to be carried out to a procedure that is representative of the item under inspection.
2) Procedures are to identify the component to be examined, the NDT method, equipment to be used and the full extent of the examinations including any test restrictions.
3) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
4) Procedures are to include the method and requirements for equipment calibrations and

   functional checks, together with specific technique sheets/scan plans, for the component under test.

5) Procedures are to be approved by personnel qualified to Level III in the appropriate technique in accordance with a recognised standard.

6) Procedures are to be reviewed by the BKI's Surveyor.

(IACS UR W34 7.1.2)

2. Preparation of areas to be tested

2.1 The areas to be tested (surfaces of welds and of adjacent parts of the workpiece) shall be sufficiently clean and smooth for the respective test method. Irregularities in the welded joint (see E.2.), remains of auxiliary welds, welding spatter, fragments of slag, etc. and any protective coatings or preservatives shall be removed before the tests if they are liable to prevent them from being performed properly.

Note:

The overweldable shop primers normally used in shipbuilding have been found not to affect the tests and therefore can generally be left in place. With "reprimed" welds, however, the coating should not be significantly thicker than the normal coating thickness.

2.2 Preparation and cleaning of welds for subsequent NDT are to be in accordance with the accepted NDT procedures, and are to be to the satisfaction of the surveyor. Surface conditions that prevent proper interpretation may be cause for rejection of the weld area of interest.

(IACS UR W33 4.1 & 6.5.3)

2.3 In special cases, e.g. ultrasonic testing for transverse defects (see L.4.3), grinding of the seam and the surface of the workpiece may be necessary.

3. Performance of tests

3.1 Non-destructive testing of welds shall be carried out in the manner described in K. to O. The place and date for the tests shall be notified to BKI Surveyor in good time. The Surveyor shall be given the opportunity to participate in or supervise the tests if he so wishes.

3.2 Sufficient details shall be given in a written procedure for each NDT technique submitted to BKI for acceptance.

(IACS UR W33 6.1.2)

3.3 The testing volume shall be the zone which include the weld and parent material for at least 10 mm each side of the weld, or the width of the heat affected zone (HAZ), whichever is greater. In all cases inspection shall cover the whole testing volume.

(IACS UR W33 6.1.3)

3.4 Provision is to be made for the Surveyor to verify the inspection, reports and records (e.g. radiographs) on request.

(IACS UR W33 6.1.4)

3.5 The individual positions (sections) to be tested shall be durably marked on the component or the welded joint in such a way that the test findings (e.g. weld defects requiring repair) can be unequivocally localized at any time up to the completion of all tests and, where applicable, repairs. If the dimensions are appropriately indicated (or a similar measure is used) in the drawings, inspection schedules and inspection reports, marking of the component may be dispensed with.

G. Evaluation of Test Results

1. Identification of test findings

1.1 In the case of radiographic testing and, where applicable, the methods of surface testing, the reference numbers and/or symbols conforming to ISO 6520 or, as applicable, in Table 10.3 (extract from the standard) may be used to identify (describe) test findings (e.g. welding defects). With regard to the description of defects in ultrasonic testing, see L.5.

2. Evaluation criteria

2.1 Unless otherwise specified for the respective components or welded joints in the application-specific sections of Sections 12 to 16, the quality levels according to ISO 5817 (Annex F) may be used as evaluation criteria for steel and those according to ISO 10042 (Annex G) for aluminium alloys. All quality levels (B, C and D) in the above-mentioned standards refer to production quality and not to the fitness for purpose (ability of product, process or service to serve a defined purpose under specific conditions).

The acceptance levels for each test method are given in K. to O.

(IACS UR W33 7.2 & 7.4)

2.2 In the inspection schedules, testing instructions, etc. to be drawn up by the welding shop (see D.1.), the quality levels to be determined according to the type and level of stress or, where necessary, other individual evaluation characteristics shall be assigned to the individual components and welded joints. With regard to the evaluation of results of ultrasonic testing in conjunction with the stipulations in the above-mentioned standards (quality levels), see L.5.

2.3 BKI may consent to the use of different evaluation criteria or criteria conforming to other standards, etc. if they are approximately comparable to those mentioned in 2.1 and are suited to the particular test method used. Details shall be agreed with BKI on a case-by-case basis.

3. Evaluation, rating

3.1 The inspection results shall be evaluated by the testing department or body and/or the welding supervisory staff. The ultimate evaluation and the decision whether to leave defects in materials and welds as they are or to repair them is reserved for BKI Surveyor.

3.2 The results may be rated according to Table 10.4 (in the case of radiographic inspection) or, in the case of ultrasonic testing or if a broader statistical evaluation is not required, by "leave as is" or "satisfied" or, as the case may be, "to be repaired" or "not satisfied".

Table 10.3 Symbols denoting defects (taken from ISO 6520)

Reference No. / Symbol conforming to the IIW X-ray manual		Description [1)]
100	E	Cracks
101	Ea	Longitudinal crack
102	Eb	Transverse crack
104	Ec	Crater crack
2011	Aa	Gas Pore
2015	Ab	Elongated cavity
2016	Ab	Worm hole

Table 10.3 Symbols denoting defects (taken from ISO 6520) *(continued)*

Reference No. / Symbol conforming to the IIW X-ray manual		Description [1)]
2024	K	Crater pipe (End crater cavity)
301	Ba	Slag inclusion
304	H	Metallic inclusion
4011	–	Lack of side-wall fusion
4012	–	Lack of inter-run fusion
4013	C	Lack of root fusion
402	D	Lack of penetration (Incomplete penetration)
5011	F	Undercut, continuous
5012	F	Undercut, intermittent
5013	–	Shrinkage groove, groove in the root (see 515)
502	–	Excessive weld reinforcement (butt weld)
503	–	Excessive convexity (fillet weld)
504	–	Excessive root reinforcement
507	–	Misalignment of edges
510	–	Burn-through
511	–	Incompletely filled groove
515	–	Root concavity (see 5013)
517	–	Poor restart
[1)] For explanations and illustrations, see ISO 6520.		

Table 10.4 Evaluation ratings (for a more comprehensive statistical interpretation)

Findings	Rating	Remarks
Weld free from detectable defects	1 = good	–
Minor defects such as isolated pores and small slag inclusion which do not reduce the strength or tightness of the welded joint	2 = serviceable	–
Avoidable defects such as small rows or clusters of pores, small slag lines short root defects and minor lack of fusion	3 = leave as is	Repair not recommended for components subject to normal stresses. Short root defects and minor lack of fusion may be left only at non- critical points
Defects which shall be avoided, e.g. coarse slag inclusion, accumulations of pores, generally all root defects and lack of fusion, and small isolated cracks	4 = to be repaired	Repair of defect required. Exceptions only for components without particular requirements on strength and tightness, but not at cracks.
Extensive major defects and cracks	5 = to be replaced	Replacement of the section of weld or of the entire welded joint required.

H. Extension of the Scope of Inspection

1. If it is not certain that a defect to be repaired ends within the tested section of the weld, the adjacent sections of the weld shall also be inspected. In case of automatic welded joints, additional NDT shall be extended to all areas of the same weld length.

(IACS UR W33 9.2)

2. If major defects are found during inspections at random, the scope of inspection shall be extended. Unless otherwise agreed, for each section of weld to be repaired two more of the same length shall be inspected.

(IACS UR W33 6.5.2 & 9.3)

The number of test position is to be increased if the proportion of non-conforming indications is abnormally high or repeated nonacceptable discontinuities are found.

3. In the case of ultrasonic testing, BKI reserves the right to carry out control tests at random on the basis of the inspection reports compiled by the firm's inspector or to require control tests to be performed by a second, independent testing authority. If major differences from the results of the initial tests performed in the firm are found, the scope of the control tests may be extended.

I. Repairs, Re-inspection

1. Repairs

1.1 Defects requiring repair on the basis of the evaluation shall be carefully grooved over a sufficient length (especially in the case of intersecting welds) and/or re-welded. Where a number of defects needing repair are located close together in a single section of weld, the entire section shall be machined out and re-welded.

1.2 Undercuts in need of repair, poor transitions to the surrounding material or other surface defects shall, where possible, be remedied by grinding out with smooth transitions to the surrounding material or, if they are too deep for this, they shall, with the Surveyor's consent, be ground out and repair-welded.

1.3 Where the Surveyor becomes aware that an NDT location has been repaired without a record of the original defect, the shipyard is to carry out additional examinations on adjacent areas to the repaired area to the satisfaction of the attending Surveyor. Reference is to be made to Rules for Classification and Surveys (Pt.1, Vol.I) Annex A.2.

(IACS UR W33 5.9)

2. Re-inspection

2.1 Repaired welds shall be re-inspected. Where welds have been completely remade, retesting at least equal in scope to the initial inspection shall be performed at random in accordance with the Surveyor's instructions.

2.2 Re-inspections shall be specially indicated in the inspection reports and on the radiographs, e.g. by means of an "R" (= repair) next to the title of the film (see D.2.2).

J. Visual Inspection

1. The surfaces and back sides of the welds shall undergo a complete visual inspection, with the aid of optical (magnifying) appliances where necessary, to check their external characteristics. The following characteristics shall be checked:

- Completeness
- Dimensional accuracy
- Compliance with the specified weld shape
- Absence from inadmissible external defects.

2. The dimensional accuracy shall be checked with suitable measuring instruments on a random sampling basis. When measuring fillet weld throat thicknesses, measuring gauges which measure with sufficient accuracy in throats which are not an exact right angle shall be used where necessary.

3. When checking for the correct shape of weld and external defects, attention shall be paid to the following:

- Weld reinforcement or top bead depression
- Weld edge angles (transitions to surrounding material)
- Misalignment of edges
- Undercuts
- Visible pores and slag inclusions
- Fused weld spatter
- Arc strikes on the surface of the base material
- Concave root surface and incomplete root fusion
- Cracks
- Unequal side lengths (in the case of fillet welds).

With regard to the limits of acceptability, see G.2. and the application-specific in Sections 12 to 16. Repairing of visible cracks is mandatory.

K. Radiographic Inspection

1. Radiation sources, appliances

1.1 Radiographic testing shall be carried out in accordance to ISO 17636-1:2013 or an accepted recognized standard and any specific requirement of BKI. Wherever possible, X-ray units shall be used as radiation sources for radiographic inspections. The radiation energy (tube voltage) should lie within the energy limits specified in ISO 17636. Allowing for the differences in thickness of the component, the radiation energy (tube voltage) should be kept as low as possible within the permissible working range so as to obtain a high-contrast image.

(IACS UR W33 6.5.1)

1.2 Where justified in exceptional cases (e.g. by lack of accessibility), gamma ray sources – preferably Ir 192 or Se 75 – may be used as radiation sources, subject to BKI's consent in each instance; see 4.4.

2. Films, intensifying screens

2.1 Class C5 films conforming to ISO 11699-1 or G III conforming to ISO 5579 may normally be used in shipbuilding for X-raying steel. Class C3 or C4 and GI or GII films, as applicable, are to be used for the radiographic inspection of aluminium alloys and when using gamma rays to inspect steel. The use of class C3 or C4 and GI or GII films, as applicable, is obligatory in steam boiler, pressure vessel and pipeline manufacture (pipe class I and II).

Note:

Annex H provides a summary of the classification of the most popular X-ray films currently on the market. This summary does not claim to be exhaustive and manufacturers of other X-ray films are invited to make the classification of their products by independent inspection institutes public and make the appropriate documents available to BKI so that they can supplement the list.

2.2 Front and rear 0,02 mm lead screens shall normally be used when radiographing steel. During radiography, the film and the screens shall be kept in intimate contact in suitable cassettes, packs, etc. Radiographs may be made of aluminium alloys up to about 65 mm thick without the use of intensifying screens.

2.3 The use of salt intensifying screens and fluorometal screens is not allowed.

3. Radiographic parameters

3.1 As a general rule, the radiographic parameters prescribed in ISO 17636 for test category A (general inspection procedure) shall be applied in shipbuilding and those for test category B (higher-sensitivity inspection procedure) shall be applied in steam boiler, pressure vessel and pipeline manufacture (pipe class I and II). In special cases BKI may stipulate application of test category B in shipbuilding as well. The minimum inspected weld length for each test position is to be specified in the approved NDT plan (see D.1) and shall follow the requirements in Section 12, I.6.3. For radiographic inspection using X-rays and a film length of 480 mm, the distance between the film and the focal point shall normally be 700 mm, and in any case not less than the length of the film.

3.2 If several films are used to inspect a seam (e.g. for circumferential radiographs), they shall overlap at the ends in such a way that the full pattern of the weld can be traced without interruption.

3.3 When inspecting pipes with an outside diameter ≤ 90 mm, elliptical radiographs may be made. Depending on the diameter and wall thickness of the pipe, two or more elliptical radiographs are to be made so that the full length of the weld (the entire circumference of the pipe) is shown in the area of the radiographs capable of evaluation.

3.4 For larger-diameter pipes, either double-wall radiographs or, if the pipe diameter permits, central or single-wall radiographs shall be made. Care shall be taken to ensure that the film is capable of evaluation at both its ends. The area capable of evaluation shall only be the section of the weld in which the rays delimiting the beam do not cover more than 1,1 times the weld thickness that is radiographed with vertical irradiation. The number of radiographs shall be determined accordingly.

3.5 In order to determine the image quality EN 462-3 standard, at least one image quality indicator to EN 462-1, (wire indicator) shall, for each radiograph, be laid on the side of the weld away from the film and facing the radiation source and shall be radiographed together with the weld. Should this be impossible, the image quality indicator may, with BKI's consent and after the preparation of comparative radiographs designed to determine the changed index of image quality, be fixed to the workpiece on the side close to the film (i.e. between the film and the weld). The film image shall be marked with a corresponding identification ("N") to indicate that this arrangement was used, and appropriate mention shall be made in the inspection report.

3.6 Each film image shall be clearly and unmistakably identified by lead figures or letters simultaneously irradiated and depicted on the film. This identification shall be the same as that given in the inspection schedule and shall enable any defects found to be readily located. The marking is to be located outside the weld area to be evaluated (the weld width plus at least 10 mm on each side).

4. Film processing, density, image quality

4.1 The films shall be processed in properly equipped darkrooms insuch a way as to avoid any blemishes which interfere with their evaluation (e.g. fogging, scratches, dark crescent-shaped marks due to kinks in the film, etc.). The instructions and recommendations issued by the film and chemical manufacturers are to be followed. Premature interruption of the developing process and reduction with chemicals of over-exposed films is not allowed.

4.2 The radiographic images shall have a density D of at least 2,0 over the entire area for evaluation. The upper limit value depends on the brightness of the film viewers available for the evaluation, but should not exceed 2,5 to max. 3,0. Wide differences in density within a single radiograph are to be avoided.

4.3 The image quality shall be determined with an image quality indicator of the type prescribed in 3.5 and in accordance with EN 462-1. For category A inspection (see 3.1), image quality B is desirable for steel, with image quality A as the minimum requirement. In the case of aluminium alloys and test category B, image quality B shall be attained. The criterion in each case is the smallest wire of the image quality indicator which is still visible in the area to be evaluated, the density being uniform.

4.4 The works or the inspection department/body shall demonstrate on request by means of specimen radiographs that the required radiographic parameters and image quality can be attained.

5. Viewing conditions, evaluation, inspection report

5.1 Viewers with a luminous density to ISO 5580 sufficient for the required film density shall be used for the examination and evaluation of radiographs. Stops shall be fitted to enable the field of view to be adapted to the film size for, or capable of, evaluation. The brightness shall be adjustable.

5.2 The viewing and evaluation of radiographs shall take place in a dimly lit though not completely darkened room. Evaluation should only be performed after a sufficient period has been allowed for adaptation. Bright, dazzling areas within the field of view are to be screened. The use of magnifying glasses for the detection of fine details may be beneficial.

The acceptance levels and required quality levels for radiographic testing are provided in Table 10.5.

Table 10.5 Acceptance levels for radiographic testing

Quality levels in accordance with ISO 5817 or ISO 10042	Acceptance levels in accordance with ISO 10675-1 or ISO 10675-2
B	1
C	2
D	3

(IACS UR W33 7.8)

5.3 In addition to the items listed under D.2.1 the following information is to be given in the inspection report, together with explanatory sketches where necessary:

- Radiation source and size of tube focus or emitter
- Tube voltage or activity at time of inspection

- Radiographic arrangement to ISO 17636, position of wire indicator
- Type of film, nature and thickness of intensifying screens
- Number of radiographs (exposures)
- Test category, image quality index and image quality class
- Symbols denoting defects and assessment in accordance with G.
- Exposure technique, time of exposure and source-to-film distance as per below:
  - A) Distance from radiation source to weld
  - B) Distance from source side of the weld to radiographic film
- Angle of radiation beam through the weld (from normal)
- Sensitivity, type and position of IQI (source side or film side)
- Density
- Geometric un-sharpness
- Specific acceptance class criteria for RT

(IACS UR W33 8.5)

The inspection report shall also indicate whether the information relates to an initial radiograph or to a follow-up inspection after repair work has been carried out (see D.2.1 and I.2.2).

5.4 The initial evaluation shall be carried out by the welding supervisory staff and/or the works inspection department. Then the films (initial and follow-up radiographs, see D.2.1 and I.2.) shall be submitted to BKI Surveyor for evaluation together with the inspection reports (see G.3.1).

L. Ultrasonic Inspection

1. Test appliances and accessories

1.1 Ultrasonic testing shall be carried out according to procedure based on ISO 17640:2018 (testing procedure), ISO 23279:2017 (characterization) and ISO 11666:2018 (acceptance levels) or accepted standards and the specific requirements of BKI. The test appliances, probes and other accessories (calibration and reference blocks for adjusting the sensitivity, reference scales, etc.) shall conform to the state of the art and the relevant standards (e.g. ISO 2400, ISO 7963, ISO 17640).

(IACS UR W33 6.6)

1.2 All possible echo heights within the range of instrument sensitivity used shall be capable of being determined with the aid of an amplification control calibrated in dB and a suitable scale marking on the display. The interval between the switching stages shall not exceed 2 dB. Instruments not equipped with a calibrated amplification control may not be used.

1.3 Stepless controls shall enable the ranges of adjustment available on the instrument to follow on from one another, as far as possible without any intervening gap. Within each individual range the time sweep shall be continuously adjustable.

1.4 With regard to the geometrical characteristics of the sound field, especially the incidence and squint angles, the testing frequency and the resolution, the probes shall lie within the tolerances specified in the standards mentioned above. The incidence and squint angles shall not in either case deviate by more than 2° from the nominal value or from the centre line of the probe. The angle of incidence and the probe indeks (of angle beam probes) shall be verified.

2. Calibration, sensitivity setting

2.1 The distance signal (time sweep) may be calibrated in projection distances "PA", shortened projection distances "VPA" or sonic distances "s" as desired or, if necessary, depth positions "b". Unless otherwise agreed, calibration in shortened projection distances "VPA" is preferred for weld inspections, or in sonic distances "s" for parts of complex shape.

2.2 For calibration in accordance with 2.1 a calibration block to ISO 2400 or ISO 7963 shall be used when testing (hull) structural steels. Appropriate calibration or reference blocks shall be used for materials having other sound velocities (e.g. high-alloy steels and non-ferrous metals). Bore holes used for calibration shall not be larger than 2 mm and shall lie parallel to the testing surface. Where possible, calibration should not be performed at edges.

2.3 Depending on the intended method of echo height definition, the sensitivity setting shall be performed using calibration reflectors of known shape, position and size (e.g. large flat reflectors, side-drilled holes) in accordance with the provisions of EN 583-2. Unless otherwise agreed, the DGS method of inspection shall be used. With the DGS method, the sensitivity setting is to be carried out in accordance with the instrument manufacturer's instructions using calibration blocks to ISO 2400 and ISO 7963. Flat-bottom holes and grooves should not be used as calibration reflectors.

2.4 If necessary (e.g. for defects close to the surface), the sensitivity setting is to be corrected in accordance with EN 583-2. When testing unalloyed and low-alloy (hull) structural steels and where the sonic distances are not too far (see EN 583-2), the sound attenuation may normally be disregarded. A transfer correction to determine the coupling differences between the surface of the reference block and that of the test piece shall, however, be performed in every case. The value of the transfer correction shall be stated in the inspection report.

2.5 For more efficient detection of defects it is recommended that testing be performed with a test sensitivity (search sensitivity) increased by approximately 6 dB over the chosen registration level (see 5.1). However, the registration level setting is generally to be used when evaluating defect indications. All echo indications to be registered shall attain at least 20% of the display height even at the maximum sonic distance (see EN 583-2). In the case of electrogas welded seams, the inspection shall normally be performed with a sensitivity increased by 12 dB, and this fact shall be expressly stated in the inspection report with a reference to the welding process (e.g. EG + 12 dB).

3. Surface preparation, coupling

3.1 On both sides of the welded seam (see 4.1) the testing surfaces shall be smooth and free from impurities liable to interfere with coupling. Rust, scale and weld spatter are to be removed so that the probes lie snugly against the surfaces, which should if necessary be ground. Firmly adhering paint need not be removed provided that it does not interfere with the inspection and quantitative allowance can be made for the resulting loss of sensitivity when evaluating the echo heights.

3.2 Where angle beam probes have to be applied to the surface of the weld for the inspection of transverse defects (see 4.3), this shall also be prepared as a testing surface in the manner described above. Notches, grooves and the like lying across the beam axis which produce false indications and may impair the test are to be removed.

3.3 Coupling to the testing surfaces prepared in accordance with 3.1 should be as uniform as possible and should not vary by more than ± 4 dB. If greater variations are found, the condition of the surface shall be improved. Where greater variations cannot be avoided, this fact shall be stated in the inspection report. Running water, cellulose glue, oils, grease or glycerin may be used as coupling media.

4. Scanning directions, angle of incidence

4.1 Unless otherwise agreed or stipulated, testing for longitudinal defects shall be performed from one surface and from both sides of the weld, as shown in Fig. 10.1. The testing area shall embrace the weld metal itself and an area on both sides of the seam equal to about 1/3 of the wall thickness, subject to a minimum of 10 mm and a maximum of 20 mm. The testing surface shall encompass a width at least equal to the full skip distance plus twice the length of the probe.

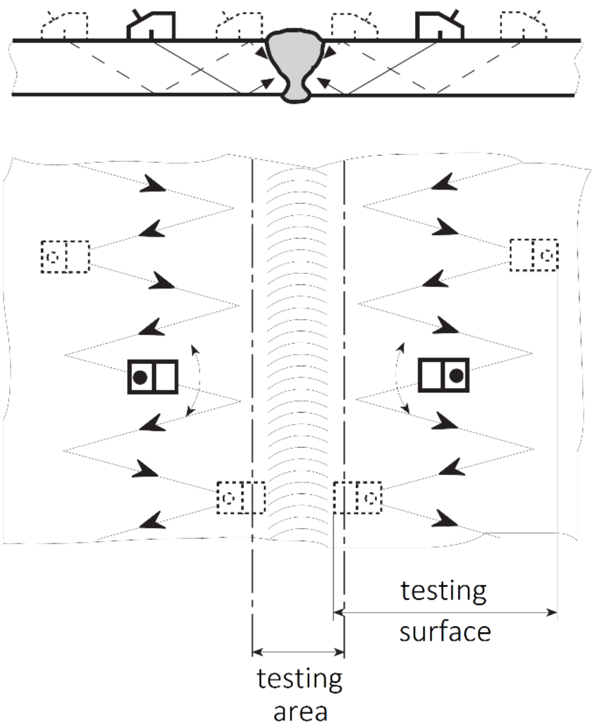

Fig. 10.1 Testing for longitudinal defects

4.2 Depending on the weld geometry and the possible orientation of defects, it may be expedient to perform the test from both surfaces or (e.g. in the case of bevels) from only one side of the seam. With corner and T-joints, the testing shall normally be performed both from the side of the web and from that of the continuous (flange) plate using a standard probe, as shown in Fig. 10.2. Such probe arrangements differing from 10.1 shall be specially noted in the inspection report. The same applies in analogous manner to curved surfaces.

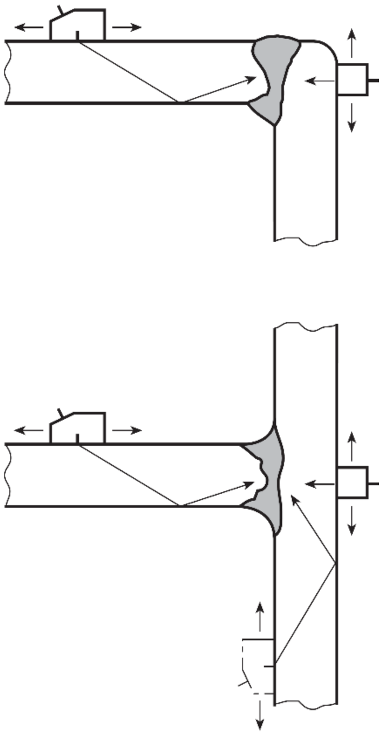

Fig. 10.2 Testing for longitudinal defects in corner and T-joints

4.3 Testing for transverse defects shall be performed from both sides of the weld in two directions along the seam as shown in Fig. 10.3 or - where the test requirements are more stringent - on the face of the weld which has been machined flush with the surface. BKI may require that testing for transverse defects be performed with two probes connected in parallel. Where welds are made with a large weld pool (as in electroslag welding), testing for oblique defects shall also be performed at an angle of approximately 45° (see ISO 17640).

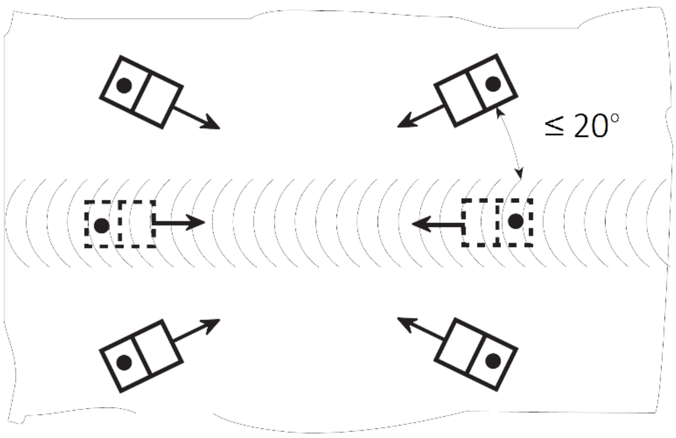

Fig. 10.3 Testing for transverse defects

4.4 With plate thicknesses (weld thicknesses) of less than 30 mm, testing may be performed with an angle of incidence of 70°. With thicknesses of 30 mm and over, two angles of incidence (70° and 45° or 60°) shall be used. Where the surface is curved, the necessary angle of incidence shall be determined in accordance with EN 583-2. With very large wall thicknesses (above about 100 mm), the inspection shall be performed using a tandem technique (with fixed, mechanical coupling of two similar probes) for different depth zones.

5. Registration level, evaluation of echo indications

5.1 For tests carried out by the DGS method, the registration level (reference reflector size) for longitudinal and transverse defects is given by the diameters of the disc-shaped reflectors specified in Table 10.6 in relation to the wall thickness (weld thickness).

Table 10.6 Registration levels

Wall thickness (weld thickness)	Diameter of disc-shaped reflector	
	4 MHz	2 MHz
from 10 up to 15 mm	1,0 mm	1,5 mm
over 15 up to 20 mm	1,5 mm	2,0 mm
over 20 up to 40 mm	2,0 mm	3,0 mm
over 40 up to 60 mm	3,0 mm	4,0 mm

Where the thickness is greater than 60 mm, the registration level will be determined on a case-by-case basis. For tandem testing, the registration level shall be determined by a 6 mm diameter disc-shaped reflector. For other methods of echo height definition (e.g. the reference block method), the registration level shall be determined in accordance with EN 583-2.

5.2 The registration of non-form-related echo indications which are observed when inspecting welded joints and whose echo heights attain or exceed the registration level (reference reflector size) specified in 5.1 is required only when expressly stipulated by BKI or where subsequent repeat tests have to be performed. Otherwise only those echo indications shall be registered which exceed the repair limit value specified in 5.4.

5.3 One characteristic which is to be stated for the classification of echo indications is by how many dB the maximum echo height of the reflections found differs from the registration level defined in 5.1. In the case of the DGS method, the size of the (substitute) disc-shaped reflector may also be stated. Further characteristics to be stated are the registration lengths and half-value depths in accordance with ISO 17640. The location of reflections shall be defined by coordinates indicating the "longitudinal and transverse distances from a reference point" and the "depth position".

5.4 Unless otherwise stated in the application-specific sections of Sections 12 to 16, echo indications produced by longitudinal defects which exceed the repair limit values shown in Table 10.7 (excess of registration lengths and/or echo heights above the registration level shown in Table 10.6) shall be regarded as weld defects which shall be repaired.

5.5 Continuous echo indications which point to systematic weld defects (such as root defects due to incomplete penetration or rows of pores) call for repairs even if the repair limit values are not attained. Echo indications which point to the presence of cracks necessitate repairs in every case.

5.6 Echo indications produced by transverse defects shall in every case count as weld defects requiring repair unless they can be unequivocally associated with the indications produced by longitudinal defects and remain below the repair limit values stipulated in Table 10.7.

5.7 Where the evaluation of echo indications gives rise to doubt regarding the need for repair, recourse may be had to radiographic inspection to help in the assessment (see B.1.3). However, echo indications obtained with welded seams 30 mm or more in thickness which exceed the repair limit values invariably necessitate repair even if radiographic inspection fails to reveal any defects or fails to reveal them clearly.

6. Inspection reports

6.1 Complete inspection reports as prescribed in ISO 17640 and containing the information listed below shall be prepared for all ultrasonic inspections in accordance with the inspection schedule; see D.1. The inspection reports shall enable the inspections to be repeated identically. They shall be signed by the person performing the inspection and the supervisor.

6.2 Inspection reports shall contain the following general information:

- Clear identification of the component, the material, the welded joint inspected together with its dimensions and location (sketch to be provided for complex weld shapes and testing arrangements) and the welding process
- Indication of any other rules (e.g. specifications, standards or special agreements) applied to the inspection
- Place and time of the inspection, testing body and identification of the person performing the test.

6.3 In addition to the items listed under D.2.1, inspection reports shall contain at least the following specific details relating to the inspection:

- Make and type of test equipment
- Make, type, nominal frequency and angle of incidence of probes
- Distance calibration (testing range)
- Sensitivity setting (calibration reflector used, instrument sensitivity, registration level)
- Correction values (for defects close to surface, transfer correction)
- Test sensitivity
- Surface preparation, coupling media
- Testing surfaces, testing directions, angles of incidence.

(IACS UR W33 8.6)

6.4 The test results (where these are to be stated in the inspection report; see 5.2) shall, wherever possible, be tabulated or shown on sketches with the following details:

- Coordinates of defects with indication of reference point
- Maximum excess echo height (+ ... dB) compared with the given registration level (reference reflector size) or, where applicable, the diameter of the corresponding (substitute) disc-shaped reflector
- Defect characteristics (registration length, half-value depth).

Where echo indications below the repair limit values shown in Table 10.7 are also registered, each defect thus identified is to be allocated an assessment (e.g. leave as is or repair, a = acceptable or na = not acceptable).

M. Magnetic Particle Inspection

1. Test appliances and media

1.1 Magnetic particle testing shall be carried out in accordance to ISO 17638:2016 or a recognized accepted standard and the specific requirement of BKI.

(IACS UR W33 6.4.1)

1.2 The magnetizing equipment shall be provided with markings or measuring devices which indicate the magnetizing current strength at any time. BKI may stipulate that measurements be performed to verify these data. Proof of the suitability of the test media shall be furnished on request.

1.3 Magnetic particles suspended in suitable, readily volatile vehicle liquids shall be used as test media for revealing the leakage flux due to discontinuities in the material. These magnetic particles may be black or fluorescent. Where black magnetic particles are used, the surface to be tested shall be coated with a permanent white paint, applied as thinly as possible, to provide a contrast.

1.4 The proportion of magnetic particles in the vehicle liquid shall conform to the manufacturer's instructions and shall be verified (e.g. by means of a test indicator or by a separation test using a glass centrifuge vessel to ASTM D 96-73, Fig. 6). Dry test media may only be used for tests at elevated temperatures (e.g. on root passes).

Table 10.7 Repair limit values

Quality level according to G.2.1	Wall thickness (weld thickness) [mm]	Longitudinal defects			Transverse defects		
		Number of defects per m of weld seam	Registration length [mm]	Max. Permissible excess echo height [dB]	Number of defects per m of weld seam	Registration length [mm]	Max. Permissible excess echo height [dB]
B	10 to15	10 and 3 and 1	10 20 10	6 6 12	3	10	6
	> 15 to 20	10 and 3 and 1	10 20 19	6 6 12	3	10	6
	> 20 to 40	10 and 3 and 1	10 25 10	6 6 12	3	10	6
	> 40	10 and 3 and 1	10 30 10	6 6 12	3	10	6
C	> 10 to 20	10 and 3 and 1	15 30 10	6 6 12	3	10	6
	> 20 to 40	10 and 3 and 1	15 30 10	6 6 12	3	10	6
	> 40	10 and 3 and 1	15 50 10	6 6 12	3	10	6

Table 10.7 Repair limit values *(continued)*

Quality level according to G.2.1	Wall thickness (weld thickness) [mm]	Longitudinal defects: Number of defects per m of weld seam	Longitudinal defects: Registration length [mm]	Longitudinal defects: Max. Permissible excess echo height [dB]	Transverse defects: Number of defects per m of weld seam	Transverse defects: Registration length [mm]	Transverse defects: Max. Permissible excess echo height [dB]
D	> 10 to 20	10 and 3 and 1	15 50 10	6 6 12	5	10	6
	> 20 to 40	10 and 3 and 1	15 50 10	6 6 12	5	10	6
	> 40	10 and 3 and 1	20 50 10	6 6 12	5	10	6

2. Magnetization method and field strength

2.1 The choice of the method of magnetization depends on the geometry of the component and is to be agreed with BKI. If possible, magnetization shall be effected by passing a current through the workpiece or, in the case of minor localized inspections, by yoke magnetization using electromagnets or, if no other possibilities are given, permanent magnets.

2.2 In special cases (e.g. where burn marks have to be avoided at all costs or for circumferential welds), it may be expedient to effect magnetization with a live conductor (a cable or coil). A combination of different methods of magnetization for the detection of variously orientated defects is allowed.

2.3 Where a current is passed through the workpiece, alternating, direct, impulse or surge current may be used. AC or DC magnets may be used for yoke magnetization. Where the magnetizing current is passed through the workpiece, fusible supply electrodes should be used to prevent burn marks. Where AC is used, fusible electrodes are obligatory.

2.4 The magnetizing field strength (effective tangential field strength) shall be at least 20 A/cm (25 Oe) but shall not exceed 50 A/cm (62,5 Oe). The adequacy of the magnetization shall be checked at the time of the test by suitable means (e.g. test indicator) or with a tangential field strength meter.

3. Preparation of testing surfaces, direction and duration of magnetization

3.1 The testing surfaces shall be free from loose scale, rust, weld spatter and other impurities. Notches, grooves, scratches, edges, etc. which may produce false indications are to be removed prior to inspection. Thin, dry layers of paint (e.g. shop primer, up to a coat thickness of 20 µm) may be left in place as long as they do not hinder the inspection.

3.2 Magnetization shall be effected, as shown in Fig. 10.4, in two different directions including an angle of not less than 60° and not more than 90° so as to enable variously orientated defects to be located.

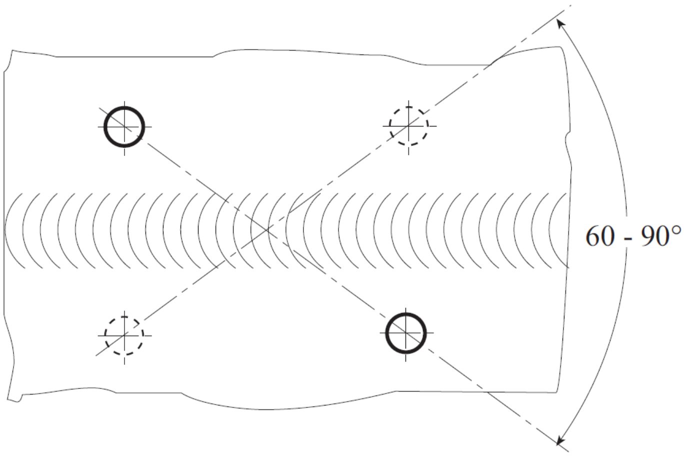

Fig. 10.4 Directions in which magnetization is to be effected

3.3 Magnetization shall be continued as long as the testing surface is sprayed with magnetic particle suspension and for as long thereafter as any movement of the magnetic particle suspension can be detected, subject to a minimum of 5 seconds. Testing under conditions of permanent magnetization is not permitted.

4. Evaluation, inspection reports

4.1 Every accumulation of magnetic particles not due to a false indication indicates a discontinuity or crack in the material which is to be registered in the inspection report and repaired. In the case of small cracks (e.g. end crater cracks) this may be done by grinding. Larger cracks are to be machined out and repair-welded; see I.1.2.

The acceptance levels and required quality levels for magnetic particle testing are provided in Table 10.8.

Table 10.8. Acceptance levels for magnetic particle testing

Quality levels in accordance with ISO 5817 or ISO 10042	Acceptance levels in accordance with ISO 23278:2015
B	2X
C	2X
D	3X

(IACS UR W33 7.7)

4.2 In addition to the items listed under D.2.1, inspection reports relating to magnetic particle inspections shall include the following details:

- Details of the component and weld concerned
- Details of magnetization, with amperage where appropriate
- Test arrangement (direction of magnetizing, distance between electrodes or poles)
- Test media
- Viewing conditions
- Demagnetization, if required
- Test results
- Place and time of the inspection, testing body and identification of the person performing the test.

(IACS UR W33 8.4)

N. Liquid Penetrant Inspection

1. Test media

Coloured or fluorescent penetrants shall be used as penetrant media. Penetrant removers and developers shall be compatible with the penetrant used. Proof of the suitability of the inspection system (penetrant, penetrant remover, developer) shall be furnished to BKI on request.

2. Preparation of testing surfaces, performance of inspection

2.1 Liquid penetrant testing shall be carried out in accordance to ISO 3452-1:2013 or a recognized accepted standard and the specific requirement of BKI.

(IACS UR W33 6.3.1)

2.2 To allow the penetrant to enter any defects present, the testing surfaces shall be completely free from scale, rust, greases, oils, paints or electro-deposits before the penetrant is applied. During this operation care should be taken to ensure that defects are not mechanically sealed by preliminary cleaning.

2.3 The testing surfaces shall be dry. The temperature of the work piece shall be between 5°C and 50°C, outside this temperature range special low/high temperature penetrant and reference comparator blocks shall be used.

(IACS UR W33 6.3.4)

2.4 Any method of applying the penetrant may be used. Care shall be taken to ensure that the testing surface is completely wetted throughout the entire penetration time. The penetration time shall be chosen in accordance with the manufacturer's instructions, but shall not be less than 15 minutes for work piece temperatures of 15°C and over or less than 30 minutes where the temperature is below 15°C. The penetrant shall not become dry during the penetration period.

2.5 Following penetration, the surplus penetrant shall be completely removed from the testing surface in such a way as to leave behind the penetrant lodged in any defects present. It is advisable first to wipe off the surplus penetrant with a cloth and quickly to remove only the remains with sparing use of the penetrant remover. The testing surface should then be dried as quickly as possible (max. 50°C).

2.6 The developer is to be applied evenly and as thinly as possible immediately after removal of the surplus penetrant and drying. The testing surface should be just covered. The developing time should be about the same as the time allowed for penetration. Visual inspection for defects shall begin as the developer is applied, but the final inspection can only take place after the expiry of the developing time. M.4.1 applies in analogous manner to the evaluation.

3. Evaluation, inspection reports

3.1 Should an unequivocal evaluation of the indications be impossible, the entire inspection procedure, starting with preliminary cleaning, shall be repeated. Where necessary, the surface quality shall also be improved. The repeat inspection shall be performed with the same test system as on the first occasion. The conditions specified in standard ISO 3452-1 are also applicable.

The acceptance levels and required quality levels for liquid penetrant testing are provided in Table 10.9.

Table 10.9 Acceptance levels for penetrant testing

Quality levels in accordance with ISO 5817 or ISO 10042	Acceptance levels in accordance with ISO 23277:2015
B	2X
C	2X
D	3X

(IACS UR W33 7.6)

3.2 In addition to the items listed under D.2.1, inspection reports relating to penetrant medium inspections shall include the following details:

- Details of the component and weld concerned
- Test media (type, brand name)
- Description of the test procedure (temperature of the work piece, penetrant acting time, development time, etc.)
- Test results
- Place and time of the inspection, testing body and identification of the person performing the test. Inspection reports shall conform to the form provided in Appendix A to DIN EN 571-1.

(IACS UR W33 8.3)

O. Advanced Non-Destructive Testing (ANDT)

Paragraphs of this sub section are based on IACS UR W 34.

1. General

This sub section gives minimum requirements on the methods and quality levels that are to be adopted for advanced non-destructive testing (ANDT) of welds during new building of ships. The advanced method intended for use under this sub section is in 2.1.

2. Applicability

2.1 Materials

This sub section applies to the following materials:

- Material and welding for gas tankers in accordance with Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) Sec.6
- Normal and higher strength hull structural steels in accordance with Rules for Materials (Pt.1, Vol.V) Sec.4
- High strength steels for welded structures in accordance with Rules for Materials (Pt.1, Vol.V) Sec.4
- Extremely Thick Steel Plates in Container Ships in accordance with Rules for Container Ships (Pt.1, Vol. XVIII) Sec.27
- Aluminium alloys for hull construction in accordance with Rules for Materials (Pt.1, Vol.V) Sec.10
- YP47 Steels and Brittle Crack Arrest Steels in accordance with Rules for Materials (Pt.1, Vol.V) Sec.4.L

2.2 Welding processes

This sub section applies to welding processes specified in Table 10.10 and also to Flash Welding (24).

2.3 Weld joints

2.3.1 This sub section applies to butt welds with full penetration. Variations of joint design, for example, tee, corner and cruciform joints (with or without full penetration) can be tested using Phased Array Ultrasonic Testing (PAUT). The constraints of joint design with respect to testing are to be recognized, documented, and agreed with BKI before application.

2.4 Timing of ANDT

For timing of ANDT see E.

2.5 Testing methods

2.5.1 The methods for detection of imperfections are Phased Array Ultrasonic Testing (PAUT) (only automated/semi-automated), Time of Flight Diffraction (TOFD), Digital Radiography (RT-D).

2.5.2 Applicable methods for testing of the different types of weld joints are given in Table 10.10.

Table 10.10 Applicable methods for testing of materials

Materials & Weld Joints	Parent Materials Thickness	Applicable Methods
Ferritic butt welds with full penetration	t < 6 mm	RT-D
	6 mm ≤ t ≤ 40 mm	PAUT, TOFD, RT-D
	t > 40 mm	PAUT, TOFD, RT-D*
Ferritic tee joints and corner joints with full penetration	t ≥ 6 mm	PAUT, RT-D*
Ferritic cruciform joints with full penetration	t ≥ 6 mm	PAUT*
Austenitic stainless steel butt welds with full penetration[1]	t < 6 mm	RT-D
	6 mm ≤ t ≤ 40 mm	RT-D, PAUT*
	t > 40 mm	PAUT*, RT-D*
Austenitic stainless steel tee joints, corner joints with full penetration[1]	t ≥ 6 mm	PAUT*, RT-D*
Aluminum tee joints and corner joints with full penetration	t ≥ 6 mm	PAUT*, RT-D*
Aluminum cruciform joints with full penetration	t ≥ 6 mm	PAUT*
Aluminum butt welds with full penetration	t < 6mm	RT-D
	6 mm ≤ t ≤ 40 mm	RT-D, TOFD, PAUT
	t > 40 mm	TOFD, PAUT, RT-D*

* Only applicable with limitations, need special qualification subject to acceptance by BKI

1 The ultrasonic testing of anisotropic material using advanced methods will require specific procedures and techniques. Additionally, the use of complementary techniques and equipment may also be required, e.g. using angle compression waves, and/or creep wave probes for detecting defects close to the surface.

3. Technique and procedure qualification

3.1 General

The shipbuilder shall submit to BKI the following documentation for review:

- The technical documentation of the ANDT.
- The operating methodology and procedure of the ANDT according to F.1.
- Result of software simulation, when applicable.

3.2 Software simulation

Software simulation may be required by BKI, when applicable for PAUT or TOFD techniques. The simulation may include initial test set-up, scan plan, volume coverage, result image of artificial flaw etc. In some circumstances, artificial defect modelling/simulation may be needed or required by the project.

3.3 Procedure qualification test

The procedure qualification for ANDT system shall include the following steps:

- Review of available performance data for the inspection system (detection abilities and defect sizing accuracy).
- Identification and evaluation of significant parameters and their variability.
- Planning and execution of a repeatability and reliability test programme[1] which including onsite demonstration.
- Documentation of results from the repeatability and reliability test programs.

Note [1]

The data from the repeatability and reliability test program is to be analysed with respect to comparative qualification block test report and onsite demonstration. The qualification block shall be in accordance with ASME V Article 14 MANDATORY APPENDIX II UT PERFORMANCE DEMONSTRATION CRITERIA or agreed by BKI, and at least the intermediate level qualification blocks shall be used. The high level qualification blocks shall be used when sizing error distributions and an accurate POD need to be evaluated. The demonstration process onsite shall be witnessed by BKI's surveyor.

3.4 Procedure approval

The testing procedure is to be evaluated based upon the qualification results, if satisfactory the procedure can be considered approved.

3.5 Onsite review

3.5.1 Supplementary NDT shall be performed on an agreed proportion of welds to be cross checked with other methods. Alternatively, other documented reference techniques may be applied to compare with ANDT results.

3.5.2 Data analyses shall be performed in accordance with the 3.3. Probability of Detection (PoD) and sizing accuracy shall be established when applicable.

3.5.3 When the result of inspection review does not conform to the approved procedure, the inspection shall be suspended immediately. Additional procedure review qualification and demonstration shall be undertaken to account for any nonconformity.

3.5.4 When a significant nonconformity is found, BKI has the right to reject the results of such activities.

4. Surface condition

4.1 Area to be examined shall conform to F.2.

4.2 Where there is a requirement to carry out PAUT or TOFD through paint, the suitability and sensitivity of the test shall be confirmed through an appropriate transfer correction method defined in the procedure. In all cases, if transfer losses exceed 12 dB, the reason shall be considered and further preparation of the scanning surfaces shall be carried out, if applicable. If testing is done through paint, then the procedure shall be qualified on a painted surface.

4.3 The requirement for acceptable test surface finish is to ensure accurate and reliable detection of defects. Where the test surface is irregular or has other features likely to interfere with the interpretation of NDT results, the weld is to be ground or machined.

5. General plan of testing: NDT method selection

5.1 The extent of testing shall be planned by the shipbuilder according to the ship design and ship or equipment type and welding process used. Particular attention shall be paid to highly stressed areas. The extent of testing shall be in accordance with the requirements applicable to weld examined.

6. Testing requirements

6.1 General

6.1.1 The methods considered within the application of this sub section are defined in 2.5.1.

6.1.2 PAUT techniques shall conform as a minimum to 6.2. Depending on the complexity of the item under test and the access to surfaces, there may be a requirement for additional scans and/or complementary NDT techniques to ensure that full coverage of the item is achieved.

PAUT of welds shall include a linear scan of the fusion face, together with other scans as defined in the specific test technique. Refer to linear scan requirements in section 6.2.2.4.

6.1.3 TOFD techniques shall conform as a minimum to 6.3. Depending on the complexity of the item under test and the access to surfaces, there may be a requirement for additional scans and/or complementary NDT techniques to ensure that full coverage of the item is achieved.

6.1.4 RT-D techniques shall conform as a minimum to 6.4. For the purpose of this subsection, RT-D comprises of two main RT methods; RT-S and RT-CR. Other methods may be included (e.g. radioscopy systems), however, then must conform to this sub section as applicable, and any specific requirements shall demonstrate equivalence to these requirements.

.1 In all RT-D methods, in addition to specific requirements, detector output quality control methods shall be described within the procedure.

.2 The procedure shall define the level of magnification, post-processing tools, image/data security and storage, for final evaluation and reporting.

6.2 Phased array ultrasonic testing

PAUT shall be carried out according to procedures based on ISO 13588:2019, ISO 18563-1:2015, ISO 18563-2:2017, ISO 18563-3:2015 and ISO 19285:2017 or recognized standards and the specific requirements of BKI.

6.2.1 Information required prior to testing

A procedure shall be written and include the following information as in minimum shown in Table 10.11. When an essential variable in Table 10.11 is to change from the specified value, or range of values, the written procedure shall require requalification. When a nonessential variable is to change from the specified value, or range of values, requalification of the written procedure is not required. All changes of essential or nonessential variables from the value, or range of values, specified by the written procedure shall require revision of, or an addendum to, the written procedure.

Table 10.11 Requirements of a PAUT Procedure

Requirement	Essential Variable	Nonessential Variable
Material type or weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)	X	-
The surfaces from which the examination shall be performed	X	-
Technique(s) (straight beam, angle beam, contact, and/or immersion)	X	-
Angle(s) and mode(s) of wave propagation in the material	X	-
Search unit type, frequency, element size and number, pitch and gap dimensions, and shape	X	-
Focal range (identify plane, depth, or sound path)	X	-
Virtual aperture size (i.e., number of elements, effective height[1], and element width)	X	-
Focal laws for E-scan and S-scan (i.e., range of element numbers used, angular range used, element or angle increment change)	X	-
Special search units, wedges, shoes, or saddles, when used	X	-
Ultrasonic instrument(s)	X	-
Calibration [calibration block(s) and technique(s)]	X	-
Directions and extent of scanning	X	-
Scanning (manual vs. automatic)	X	-
Method for sizing indications and discriminating geometric from flaw indications	X	-
Computer enhanced data acquisition, when used	X	-
Scan overlap (decrease only)	X	-
Personnel performance requirements, when required	X	-
Testing levels, acceptance levels and/or recording levels	X	-
Personnel qualification requirements	-	X
Surface condition (examination surface, calibration block)	-	X
Couplant (brand name or type)	-	X
Post-examination cleaning technique	-	X
Automatic alarm and/or recording equipment, when applicable	-	X
Records, including minimum calibration data to be recorded (e.g., instrument settings)	-	X
Environmental and safety issues	-	X
Note: [1] Effective height is the distance from the outside edge of the first to last element used in the focal law.		

6.2.2 Testing

.1 Testing levels

The testing levels specified in the testing procedure shall be in accordance with recognized standards accepted by BKI. Four testing levels are specified in ISO 13588:2019, each corresponding to a different probability of detection of imperfections.

.2 Weld Examinations

The weld examinations shall in accordance with ISO 13588:2019 and the additional special requirements of this sub section.

.3 Volume to be inspected

The purpose of the testing shall be defined by the testing procedure. Based on this, the volume to be inspected shall be determined.

A scan plan shall be provided. The scan plan shall show the beam coverage, the weld thickness and the weld geometry.

If the evaluation of the indications is based on amplitude only, it is a requirement that an 'E' scan (or linear scan) shall be utilized to scan the fusion faces of welds, so that the sound beam is perpendicular to the fusion face ± 5°. This requirement may be omitted if an 'S' (or sectorial) scan can be demonstrated to verify that discontinuities at the fusion face can be detected and sized, using the stated procedure (note, this demonstration shall utilize reference blocks containing suitable reflectors in location of fusion zone).

.4 Reference blocks

Depending on the testing level, a reference block shall be used to determine the adequacy of the testing (e.g. coverage, sensitivity setting). The design and manufacture of reference blocks shall be in accordance with ISO 13588:2019 or recognized equivalent standards and the specific requirements of BKI.

.5 Indication assessment

Indications detected when applying testing procedure shall be evaluated either by length and height or by length and maximum amplitude. Indication assessment shall be in accordance with ISO 19285:2017 or recognized standards and the specific requirements of BKI. The sizing techniques include reference levels, Time Corrected Gain (TCG), Distance Gain Size (DGS) and 6 dB drop. 6 dB drop method shall only be used for measuring the indications larger than the beam width.

6.3 Time of flight diffraction

TOFD shall be carried out according to procedure based on ISO 10863:2011, and ISO 15626:2018 or recognized standards and the specific requirements of BKI.

6.3.1 Information required prior to testing

A procedure shall be written and include the following information as shown in Table 10.12. When an essential variable in Table 10.12 is to change from the specified value, or range of values, the written procedure shall require requalification. When a nonessential variable is to change from the specified value, or range of values, requalification of the written procedure is not required. All changes of essential or nonessential variables from the value, or range of values, specified by the written procedure shall require revision of, or an addendum to, the written procedure.

Table 10.12 Requirements of a TOFD Procedure

Requirement	Essential Variable	Nonessential Variable
Weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)	X	–
The surfaces from which the examination shall be performed	X	–
Angle(s) of wave propagation in the material	X	–
Search unit type(s), frequency(ies), and element size(s)/shape(s)	X	–
Special search units, wedges, shoes, or saddles, when used	X	–
Ultrasonic instrument(s) and software(s)	X	–
Calibration [calibration block(s) and technique(s)]	X	–
Directions and extent of scanning	X	–
Scanning (manual vs. automatic)	X	–
Data sampling spacing (increase only)	X	–
Method for sizing indications and discriminating geometric from flaw indications	X	–
Computer enhanced data acquisition, when used	X	–
Scan overlap (decrease only)	X	–
Personnel performance requirements, when required	X	–
testing levels, acceptance levels and/or recording levels	X	–
Personnel qualification requirements	–	X
Surface condition (examination surface, calibration block)	–	X
Couplant (brand name or type)	–	X
Post-examination cleaning technique	–	X
Automatic alarm and/or recording equipment, when applicable	–	X
Records, including minimum calibration data to be recorded (e.g., instrument settings)	–	X
environmental and safety issues	–	X
environmental and safety issues	–	X

6.3.2 Testing

6.3.2.1 Testing levels

The testing levels specified in the testing procedure shall be in accordance with recognized standards accepted by BKI. Four testing levels are specified in ISO 10863:2011, each corresponding to a different probability of detection of imperfections.

6.3.2.2 Volume to be inspected

The purpose of the testing shall be defined by the testing procedure. Based on this, the volume to be inspected shall be determined.

A scan plan shall be provided. The scan plan shall show the locations of the probes, beam coverage, the weld thickness and the weld geometry.

6.3.2.3 Due to the nature of the TOFD method, there is a possibility that the scan plan may reveal weld volume zones that will not receive full TOFD coverage (commonly known as dead zones, either in the lateral wave, back wall, or both). If the scan plan reveals that these dead zones are not adequately inspected, then further TOFD scans and/or complementary NDT methods shall be applied to ensure full inspection coverage.

6.4 Digital radiography

Digital radiography shall be performed per procedure(s) based on ISO 17636-2:2013 and standards referenced therein, or recognized standards and additional specific requirements of BKI.

Any variation to applying the standard (e.g. IQI placement) shall be agreed with BKI. A procedure shall be written and include the following information as shown in Table 10.13.

Table 10.13 Requirements of a Digital radiography Procedure

Requirement
Material types or weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)
Digitizing System Description:
Manufacturer and model no. of digitizing system
Physical size of the usable area of the image monitor
Film size capacity of the scanning device
Spot size(s) of the film scanning system
Image display pixel size as defined by the vertical/horizontal resolution limit of the monitor
Illuminance of the video display
Data storage medium
Digitizing Technique:
Digitizer spot size (in microns) to be used
Loss-less data compression technique, if used
Method of image capture verification
Image processing operations
Time period for system verification
Spatial resolution used:
Contrast sensitivity (density range obtained)
Dynamic range used
Spatial linearity of the system
Material type and thickness range
Source type or maximum X-ray voltage used
Detector type
Detector calibration
Minimum source-to-object distance
Distance between the test object and the detector
Source size
Test object scan plan (if applicable)
Image Quality Measurement Tools

Table 10.13 Requirements of a Digital radiography Procedure *(continued)*

Requirement
Image Quality Indicator (IQI)
Wire Image Quality Indicator
Duplex Image Quality Indicator
Image Identification Indicator
Testing levels, acceptance levels and/or recording levels
Personnel qualification requirements
Surface condition
Records, including minimum calibration data to be recorded
Environmental and Safety issues

6.4.1 Testing levels

Regarding choice of testing level per ISO 17636-2:2013 this is referred to in 7.4.

7. Acceptance Levels

7.1 General

7.1.1 This sub section details the acceptance levels followed for the assessment of the NDT results. Methods include but are not limited to: Phased array ultrasonic testing (PAUT), Time of flight diffraction (TOFD), Digital radiography (RT-D).

7.1.2 It may be necessary to combine testing methods to facilitate the assessment of indications against the acceptance criteria.

7.1.3 Acceptance criteria shall be in accordance with 2.1.

7.2 Phased array ultrasonic testing

The relationship between acceptance levels, testing levels and quality levels is given in Table 10.14.

Quality levels and acceptance levels for PAUT of welds shall be in accordance with ISO 19285:2017 or recognized standard agreed with the BKI.

Table 10.14 Acceptance levels for PAUT

Quality levels according to ISO 5817:2014	Testing level according to ISO 13588:2019	Acceptance levels according to ISO 19285:2017
C, D	A	3
B	B	2
By agreement	C	1
Special application	D	By agreement

7.3 Time of flight diffraction

The relationship between acceptance levels, testing levels and quality levels is given in Table 10.15.

Quality levels and acceptance levels for TOFD of welds shall be in accordance to ISO 15626:2018 or recognized standard agreed with BKI.

Table 10.15 Acceptance levels for TOFD

Quality levels according to ISO 5817:2014	Testing level according to ISO 10863:2011	Acceptance levels according to ISO 15626:2018
B (Stringent)	C	1
C (Intermediate)	At least B	2
D (Moderate)	At least A	3

7.4 Digital radiography

The relationship between acceptance levels, testing levels and quality levels is given in Table 10.16.

Quality levels and acceptance levels for Digital Radiography of welds shall be in accordance with ISO 10675 or standard agreed with BKI.

Table 10.16 Acceptance levels for Digital radiography

Quality levels according to ISO 5817:2014 or ISO 10042:2018	Testing techniques/level(class) according to ISO 17636-2:2013	Acceptance levels according to ISO 10675-1:2016 & ISO 10675-2:2017
B (Stringent)	B (class)	1
C (Intermediate)	B* (class)	2
D (Moderate)	A (class)	3
* For circumferential weld testing, the minimum number of exposures may correspond to the requirements of ISO 17636-2:2013, class A		

8. Reporting

8.1 The test report shall include at least the following information:

1) a reference to standards of compliance;
2) information relating to the object under test:
   - identification of the object under test,
   - dimensions including wall thickness,
   - material type and product form,
   - geometrical configuration,
   - location of welded joint(s) examined,
   - reference to welding process and heat treatment
   - surface condition and temperature,
   - stage of manufacture;
3) information relating to equipment (see Table 10.17)
4) information relating to test technology (see Table 10.18)
5) information relating to test results (see Table 10.19)

Table 10.17 Information relating to equipment

Method	Information
All	manufacturer and type of instrument, including with identification numbers if required
PAUT	1) manufacturer, type, frequency of phased array probes including number and size of elements, material and angle(s) of wedges with identification numbers if required, 2) details of reference block(s) with identification numbers if required, 3) type of couplant used.
TOFD	1) manufacturer, type, frequency, element size and beam angle(s) of probes with identification numbers if required, 2) details of reference block(s) with identification numbers if required, 3) type of couplant used.
RT-D	1) system of marking used, 2) radiation source, type and size of focal spot and identification of equipment used, 3) detector, screens and filters and detector basic spatial resolution.

Table 10.18 Information relating to test technology

Method	Information
All	1) testing level and reference to a written test procedure, 2) purpose and extent of test, 3) details of datum and coordinate systems, 4) method and values used for range and sensitivity settings, 5) details of signal processing and scan increment setting, 6) access limitations and deviations from standards, if any
PAUT	1) increment (E-scans) or angular increment (S-scans), 2) element pitch and gap dimensions, 3) focus (calibration should be the same as scanning), 4) virtual aperture size, i.e. number of elements and element width, 5) element numbers used for focal laws, 6) documentation on permitted wedge angular range from manufacturer, 7) documented calibration, TCG and angle gain compensation, 8) scan plan.
TOFD	1) details of TOFD setups, 2) details of offset scans, if required.
RT-D	1) detector position plan, 2) tube voltage used and current or source type and activity, 3) time of exposure and source-to-detector distance, 4) type and position of image quality indicators, 5) achieved and required SNRN for RT-S or achieved and required grey values and/or SNRN for RT-CR, 6) for RT-S: type and parameters such as gain, frame time, frame number, pixel size, calibration procedure, 7) for RT-CR: scanner type and parameters such as pixel size, scan speed, gain, laser intensity, laser spot size, 8) image-processing parameters used, e.g. of the digital filters.

Table 10.19 Information relating to test results

Method	Information
All	1) acceptance criteria applied, 2) tabulated data recording the classification, location and size of relevant indications and results of evaluation, 3) results of examination including data on software used, 4) date of test, 5) reference to the raw data file(s), 6) date(s) of scan or exposure and test report, 7) names, signatures and certification of personnel.
PAUT	1) phased array images of at least those locations where relevant indications have been detected on hard copy, all images or data available in soft format, 2) reference points and details of the coordinate system.
TOFD	TOFD images of at least those locations where relevant TOFD indications have been detected.

8.2 Results of NDT are to be recorded and evaluated by the shipbuilder on a continual basis. These records are to be available to the Surveyor.

8.3 The shipbuilder is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDT. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued.

8.4 In addition to the above general reporting requirements, all specified NDT methods will have particular requirements and details that shall be listed in the report. Refer to the applicable method standards for specific requirements.

8.5 The shipbuilder is to keep the inspection records for the appropriate period deemed by BKI.

9. Unacceptable indications and repairs

All indications (discontinuities) exceeding the applicable acceptance criteria shall be classed as defects, and shall be eliminated and repaired as per requirements in relevant Sections.

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Section 11 Mechanical and Technological Tests

A. Scope

1. These Rules relate to the normal methods and forms of test specimens to be used in the mechanical and technological testing of welds, e.g. of test pieces for the welding procedure and workmanship tests, as well as to the metallographic inspections necessary for this purpose.

2. Special methods and forms of test specimens (e.g. for testing the manual skill of welders or testing of welding consumables, auxiliary materials and overweldable shop primers) are specified in the relevant sections.

3. The test methods and forms of specimens indicated in the standards mentioned in the following paragraphs shall be used wherever possible. Methods and forms of specimens conforming to other standards may be used by agreement with the Surveyor, provided that the same results can be achieved.

B. Preparation of Specimens and Testing

1. All tests are to be performed by trained personnel using calibrated testing machines. The testing machines shall be kept in good working order by their owners and are to be calibrated at regular intervals by an independent inspecting authority.

2. Before being cut out of the test piece, specimens are to be marked by the Surveyor. They shall then be cut out, wherever possible by a mechanical process, and machined to the required dimensions. Where specimens are cut from the test piece by a thermal process, they shall be wide enough to ensure that the heat-affected zone can be completely machined off.

3. All mechanical and technological tests are to be performed in the presence of the Surveyor, unless otherwise stipulated or agreed. The photographs of metallographic specimens are to be submitted to him for evaluation.

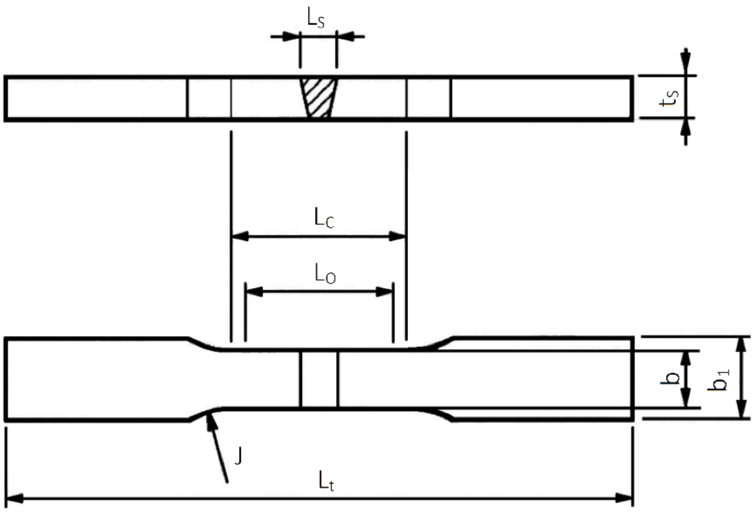
C. Tensile Tests

1. Tensile tests on flat tensile specimens (ISO 4136)

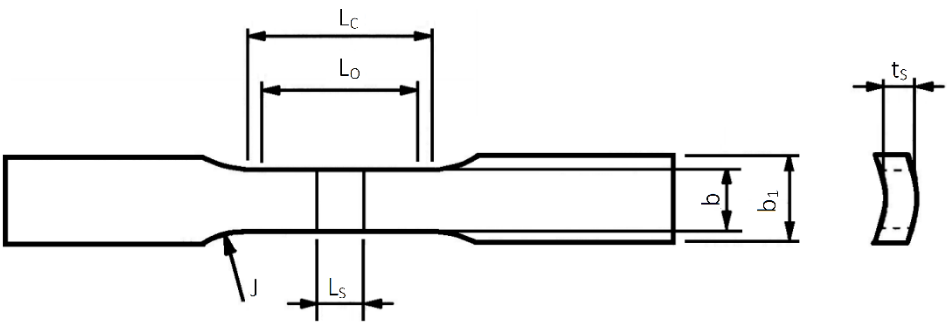
1.1 This test is carried out to determine the tensile strength, position, type of fracture and, where appropriate, the elongation of specimens located at right angles to the seam. The flat tensile specimen shown in Fig. 11.1 shall be used wherever possible.

1.2 The thickness of the specimen t_s shall be equal to the thickness of the parent metal near the welded joint. If this is greater than 30 mm several test specimens regularly spaced over the section may be taken to cover the full thickness of the joint, see Fig. 11.2.

1.3 For aluminium alloys the parallel length of tensile specimen (L_c) may not be less than L_s + 100 mm.



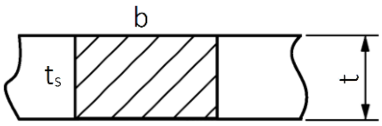
a) Test specimen for plate



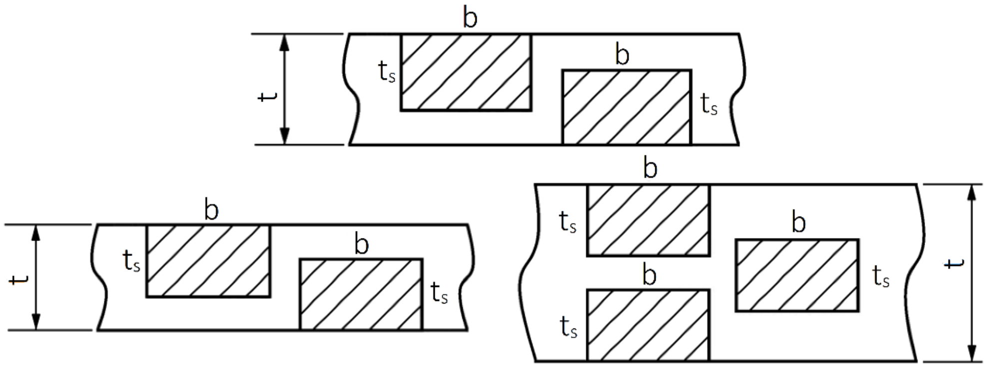
b) Test specimen for pipe

Denomination		Symbol	Dimensions [mm]
Total length of the specimen		L_t	to suit particular testing machine
Width of shoulder		b_1	b + 12
Width of the parallel length	Plates	b	12 for $t_s \le 2$
			25 for $t_s > 2$
	Pipes	b	6 for D ≤ 50
			12 for 50 < D ≤ 168,3
			25 for D 168,3
Parallel length		L_c	≥ L_s + 60
Radius at shoulder		r	≥ 25
Note: L_s = maximum width of the weld after machining t_s = thickness of the test specimen			

Fig. 11.1 Flat tensile specimen (welded joint)



a) Full section test



b) Multi specimen test

Fig. 11.2 Examples of the location of test specimens in joints

2. Tensile test on round tensile specimens (ISO 6892-1)

2.1 This test is carried out to determine the tensile strength, yield strength or 0,2% proof stress, reduction in area and elongation of the weld metal. Where necessary in the case of high-temperature steels, the 0,2 % proof stress at elevated temperatures shall also be established. Wherever possible, the test shall be performed on a 10 mm diameter round tensile specimen of the type depicted in Fig. 11.3, which is to be cut out of the weld metal with its longitudinal axis in the direction of the seam, see Fig. 11.4.

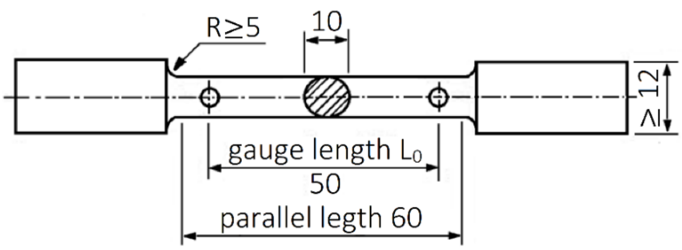


Fig. 11.3 Round tensile specimen (weld metal)

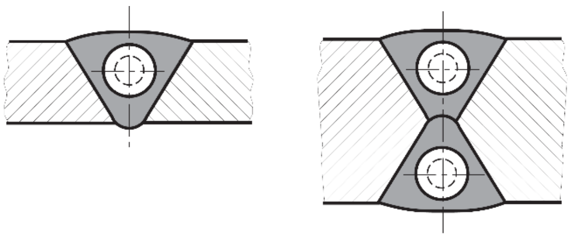


Fig. 11.4 Location of specimens in weld metal

2.2 If, in exceptional cases, the weld dimensions do not permit the preparation of a 10 mm diameter tensile specimen, specimens with a smaller diameter may be used, provided that the gauge length is 5 times and the parallel length at least 6 times the diameter of the specimen.

3. Tensile tests on cruciform tensile specimens

3.1 This test is carried out to determine the tensile shear strength Z_S of the weld metal. Three specimens with the dimensions shown in Fig. 11.5 shall be tested in each test.

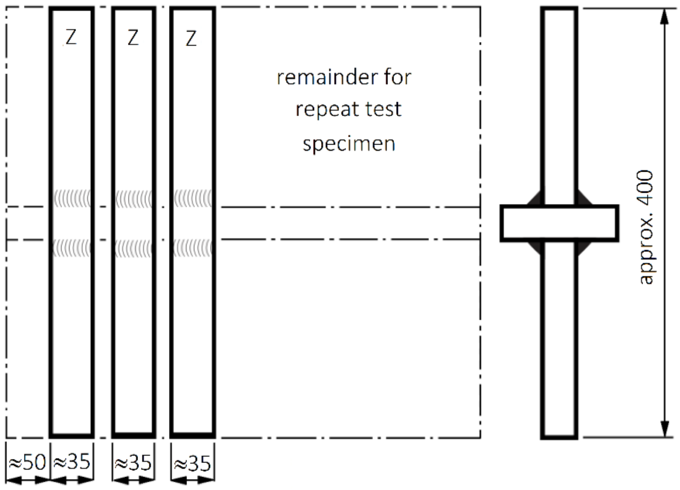


Fig. 11.5 Cruciform tensile specimens

3.2 The tensile shear strength Z_S is to be determined by the following formula (see Fig. 11.6):

$a_1 + a_2$ = fracture section $S_{1/2}$

$a_3 + a_4$ = fracture section $S_{3/4}$

Tensile shear strength Z_S:

$$Z_S = \frac{\text{Breaking load F}}{S_B \text{ x speciment width}} \quad [\text{N/mm}^2]$$

S_B = $S_{1/2}$ or $S_{3/4}$ depending on location of fracture

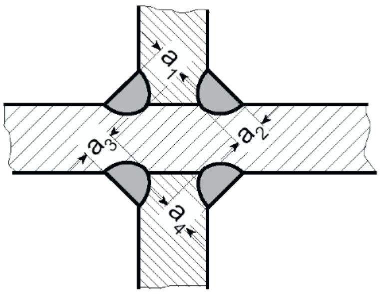
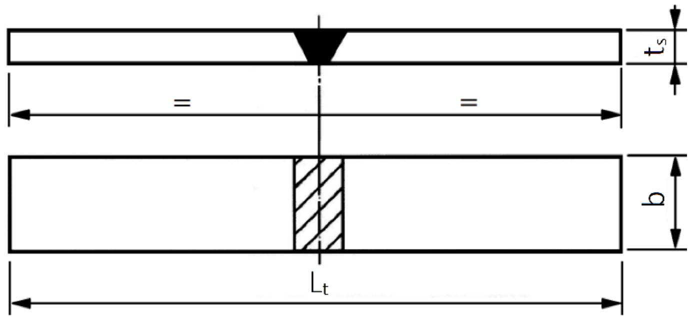


Fig. 11.6 Cruciform tensile specimen, section through welded joint

D. Bend Tests

1. Transverse bend test (ISO 5173)

1.1 This test is carried out to determine the ductility of the welded joint across the seam. For this purpose the specimen is bent over a mandrel or prescribed diameter and the angle achieved and, if specified, the bending elongation on the tension side of the specimen are measured. Specimens to Fig. 11.7 are to be prepared for the test.



Denomination			Symbol	Dimensions (mm)
Total length of the specimen			L_t	$\geq l + 2R$
Diameter of roller			R	≥ 20
Width of the specimen	Plates	Steel	b	$\geq 1{,}5\ t_s$ (min. 20)
		Al		$\geq 2\ t_s$ (min. 20)
	Pipes		b	t + 0,1D for D $\leq$ 50
				t + 0,05D for D > 50
Distance between roller			l	min. d + $2t_s$
				max. d + $3t_s$
Diameter former			d	according to requirements
t_s = thickness of the test specimen t = wall thickness of pipe				

Fig. 11.7 Specimen for transverse bend test

1.2 The thickness of the specimen shall be equal to the thickness of the base material adjacent to the welded joint. If this is greater than 30 mm several test specimens may be taken in order to cover the full thickness of the joint, see Fig. 11.2. On the side of the specimen which is in tension during the test, the edges may be rounded to the specified radius r.

1.3 Depending on the test specification, the specimens are to be mounted in the testing device in such a way that either the upper or the lower side of the weld is in tension during the test. The test rig is to be set up as shown in Fig. 11.8.

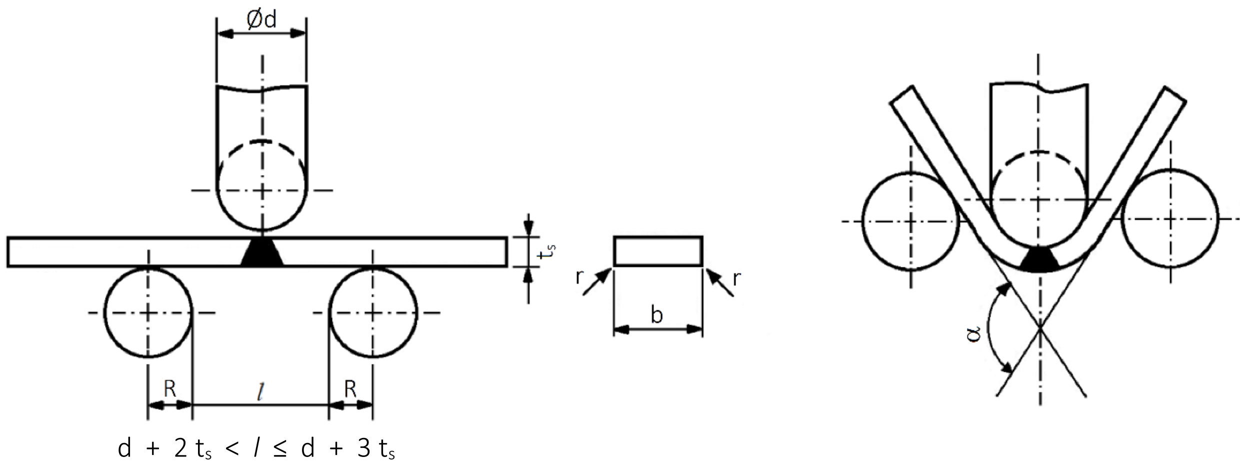


Fig. 11.8 Test rig for transverse face or root bend

1.4 If the bending elongation is to be determined, the deformation zone on the tension side of the specimen shall be provided prior to the test with gauge marks set 5 mm apart and these shall be used to measure the elongation when the prescribed bending angle has been reached.

The gauge length L_0 is the weld width + the wall thickness.

1.5 If the elongation behaviour of the base material and the weld metal differ greatly, e.g. in the case of welded aluminium test pieces, the test rig shown in Fig. 11.9 may be used in order to prevent premature incipient cracking of the specimen.

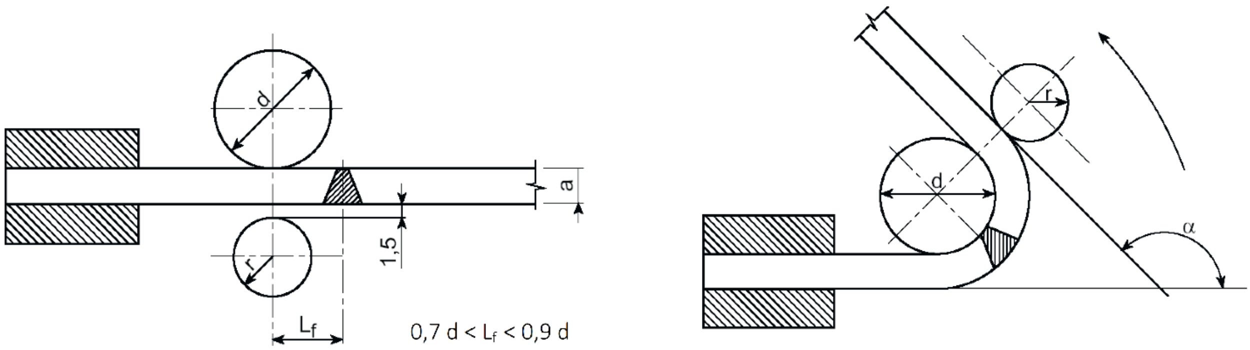


Fig. 11.9 Special test rig

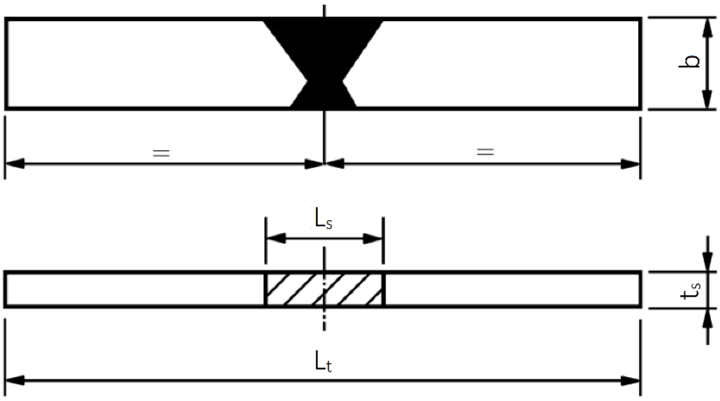
2. Side bend test (ISO 5173)

2.1 This test is carried out to determine the ductility of the welded joint in the cross-sectional plane. For this purpose the specimen is bent over a mandrel of specified diameter and the bending angle attained is measured. Specimens to Fig. 11.10 are to be prepared for the test.

2.2 When the joint thickness exceeds 40 mm, it is permissible to take several specimens from the welded joint, instead of one only, provided the width, b, of each test specimen is in the range from 20 mm to 40 mm. In these cases the location of the test specimen in the welded joint thickness shall be identified.

2.3 The specimens are to be mounted in the testing device shown in Fig. 11.8 in such a way that the testing load acts in the direction of the original longitudinal axis of the seam. On the side in tension during the test, the long edges of the specimen may be rounded to the specified radius r.

2.4 If welded clad plates are to undergo side bend tests, the form of specimen shown in Fig. 11.11 is to be used. The dimensions are as stated in the table in Fig.11.10.



Denomination	Dimensions (mm)
Specimen thickness, t_s	10 ± 0,5 [2)]
Specimen width, b	product thickness
Radius r, side in tension	#1 (# 3) [1)]
Specimen length, L_t	≥ l + 2R
Diameter of roller, R	≥ 20

1) The radius in the brackets applies to specimens where the reinforcements are not machined off.
2) The ratio between the width and thickness of specimen b/a shall be greater than and equal to 1,5.

Fig. 11.10 Specimen for side bend test

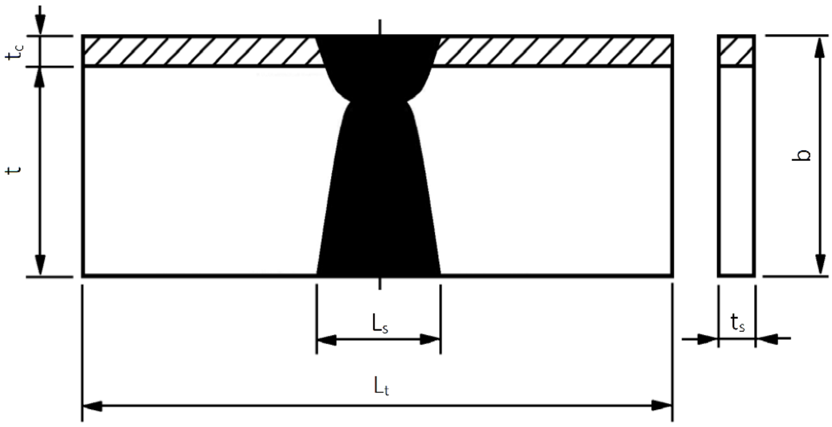


Fig. 11.11 Form of clad side bend test specimens

3. Bend test specimens from pipe joints

If bend test specimens are to be taken from circumferential pipe welds, the side faces shall be parallel. If necessary, the side of the specimen which is in compression shall be machined in accordance with Fig. 11.12.

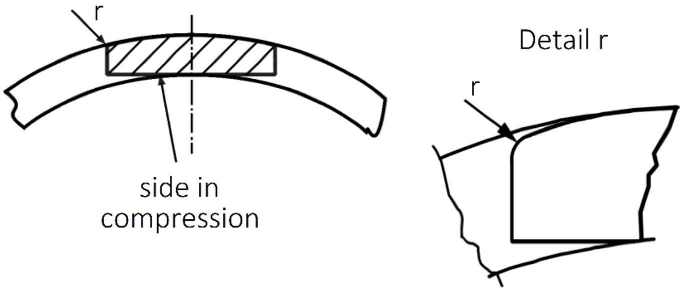


Fig. 11.12 Cross section through bend test specimen taken from a pipe

E. Notched Bar Impact Tests (ISO 9016)

1. The purpose of this test is to determine the impact energy in Joules (J). ISO V-notch specimens shall be used; their location in the test piece shall be such that the longitudinal axis of the specimen is perpendicular to the direction of the seam while the notch axis is at right angles to the surface of the product (see Fig. 11.13). In addition, determination of the crystalline portion of the fracture surface and/or of the lateral expansion of the specimen may be agreed.

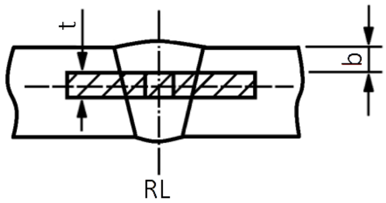
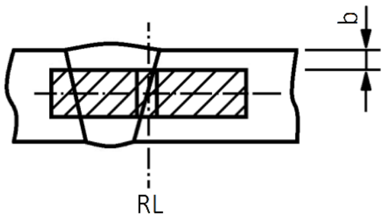
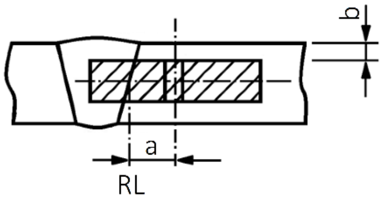
Location	Symbol	Representation
Centre of the weld	VWT 0/*b*	
Fusion line	VHT 0/*b*	
Heat-affected zone	VHT a/*b*	

Fig. 11.13 Locations of specimens for notched bar impact testing

2. Depending on the test specification, the notch shall be located either at the centre of the weld metal, on the fusion line or in the heat-affected zone of the base metal at a specified distance from the fusion line (see Fig. 11.13).

3. The test is to be carried out at the specified test temperature. Where the product thickness is < 10 mm, specimens measuring 7,5 x 10 mm, 5 x 10 mm should be used wherever possible. For these specimens the required impact energy E (J) in relation to the standard 10 x 10 mm test specimen shall be as indicated in the Table 11.1.

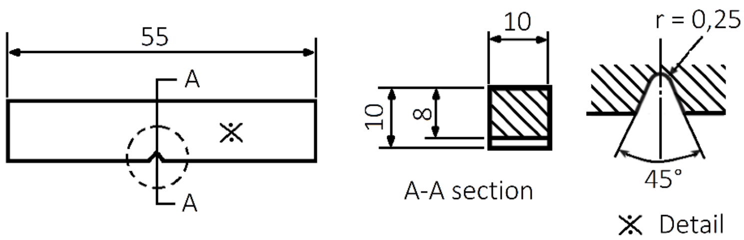
Table 11.1 Impact tests reduced section specimens

Cross section of specimen [mm]	Mean impact energy value required E
Standard specimen 10 x 10	E
Specimens of reduced section 10 x 7,5 10 x 5,0	 5/6 E 2/3 E

4. Where specimens are taken from only one side of a double-V weld, they shall be taken from the side of the seam which was welded last.

5. The specimens shall be machined down to the dimensions shown in Fig. 11.13 and compliance with the stipulated tolerances shall be verified.

6. If in technically justified exceptional cases specimens with forms or locations different from those described in 1 to 5 are to be used, the test requirements shall be specially agreed with BKI.



Dimension	Nominal size	Tolerance
Length	55 mm	± 0,60 mm
Width	10 mm	± 0,11 mm
Height	10 mm	± 0,06 mm
Notch angle	45°	2°
Height from bottom of notch	8 mm	0,06 mm
Notch radius	0,25 mm	0,025 mm
Distance between center of notch and ends of specimen	27,5 mm	0,42 mm
Angle between plane of symmetry of notch and longitudinal axis of specimen	90°	2°
Angle between adjacent longitudinal specimen surfaces	90°	2°

Fig. 11.14 ISO V-notch specimen

F. Hardness Testing of Welds (ISO 9015)

1. The hardness of welded joints shall be measured by Vickers hardness tester using a load of 49 or 98 N (HV 5 or HV 10) on polished and etched specimens whose test face is perpendicular to the weld axis. The choice of the test load depends on the grade of material concerned.

2. Normally, the test shall take the form of rows of hardness measurements, one row for fillet welds and at least two rows for butt welds, one of which is at the root and one in the area of the cover pass. Should this be insufficient for an adequate assessment of the hardness of the welded joint, a test with a further row of measurements shall be performed, e.g. in the area of the root and capping passes in the case of butt welds. The arrangement of the rows of hardness measurements shall be as shown in Fig. 11.15.

3. The impressions made by the hardness tester shall be close enough together to give an accurate picture of the hardness curve (see Fig. 11.16). The curve shall be plotted as a graph wherever possible.

4. If other test methods are to be used in exceptional cases, the requirements shall be converted in accordance with recognized standards, e.g. DIN 50150.

hO = distance from the surface
hG = distance from the underside
hW = distance of the row of hardness measurements for the root area from the surface

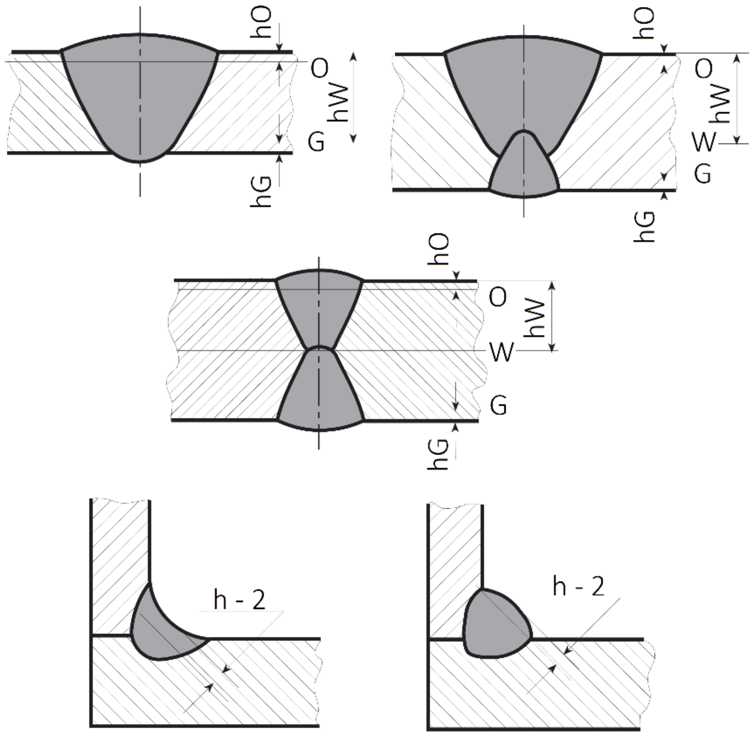


Fig. 11.15 Hardness testing with rows of hardness measurements

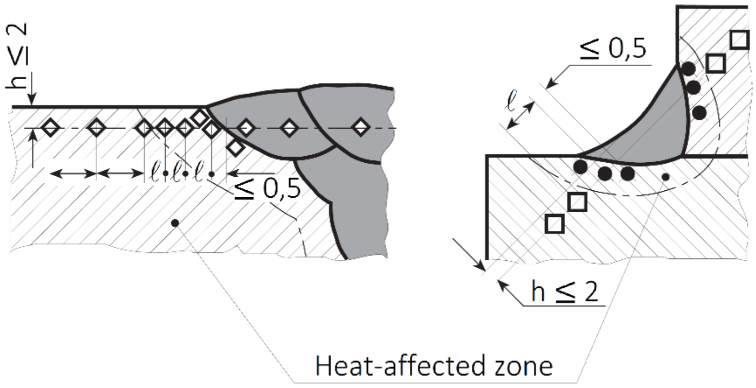
G. Metallographic Inspections

1. The macro- and micro-structure shall be evaluated by reference to polished sections. Unless otherwise agreed, the polished face of the sections shall be perpendicular to the weld axis (see also Fig. 11.15).

2. The metallographic specimens shall be of such a size and ground and etched in such a way as to reveal the nature and structure of the crystallization of the weld metal and the heat-affected zone as well as the texture of the base metal and, in the case of micrographs, the grain boundaries in the area under examination.

3. The polished sections shall be photographed and the photos appended to the inspection report. Macrographs shall normally be to a scale of 1:1 to 1:3; if the cross-sectional area of the weld is small, they may be magnified.

For assessment of the microstructure, at least 3 photographs shall be made of characteristic parts of the weld; these shall generally be the weld metal, the fusion line and the heat-affected zone. The magnification shall be at least 100:1.



Recommended distance ℓ between hardness test impressions in the heat-affected zone

Vickers hardness symbol	Distance between hardness test impressions P [mm]
HV 5	0,7
HV 10	1

Fig. 11.16 Location of hardness test impressions in the heat-affected zone

H. Inspection reports

1. The works shall prepare reports on the tests, which shall contain all the necessary details for assessing the method. These especially include:

- Type of inspection or test (e.g. welding procedure test)
- Dimensions and numbers of test pieces
- Base materials
- Weld preparation
- Welding processes and positions
- Welding consumables and their dimensions, auxiliary welding materials
- Welding current source
- Welding current strength and voltage
- Post-weld heat treatment
- Test methods and forms of specimens
- Test results.

2. The reports shall be submitted to the Surveyor in at least two copies for his perusal. He shall confirm the proper performance of the inspection and the correctness of the results by applying his stamp and signature.

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Section 12 Welding of Hull Structures

A. General

1. Scope

1.1 These Rules apply to all welding works carried out on the ship's hull, including the superstructure and deckhouses, its internal and external structures, and equipment components forming part of the ship's structure, e.g. hatch covers, masts, king posts or crane substructures welded to the ship's hull. See also Section 1, A.1 and A.2.

1.2 They also apply in analogous manner to cargo tanks which are not an integral part of the ship's hull and are not pressure vessels within the meaning of Sec. 14 (e.g. prismatic type A tanks, according to the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX)).

1.3 Welding work (such as relevant welder’s qualification, short bead, preheating, selection of welding consumable, etc.) for brittle crack arrest steels is to be in accordance with the relevant requirements for each steel grade excluding suffix “BCA1” or “BCA2” specified in Rules for Materials (Pt.1, Vol.V) Table 4.28.

2. Other relevant rules and regulations

The design and dimensioning of welded joints is also governed by the provisions of the Rules for Hull (Pt.1, Vol. II) Sec. 19 "Welded Joints" and 20 "Fatigue Strength" and the performance of the work is also subject to the provisions of Section 1, N. of the said Rules for Hull (Pt.1, Vol. II). For other relevant standards, see Section 1, B.

3. Weld performance

Welded joints in hull structures shall be prepared, made and inspected in such a way that their quality characteristics are equivalent to those of the base materials to be joined. This means that they may not deviate from the prescribed form and internal condition by more than the limits allowed by the prescribed weld quality grades according to Table 12.9 or by the evaluation categories used as a basis for the notch category classification for the proof of fatigue strength (see Rules for Hull (Pt.1, Vol. II) Sec. 20). The same applies in analogous manner to the other quality characteristics; see also C.

B. Approval of Shipyards and Welding Shops, Welding Personnel

1. Works and sub works

1.1 In the following paragraphs, the term "welding shop" refers to the shipyard or welding fabrication shop which may be considered an independent unit with regard to its physical and organizational situation.

1.2 Branches and subcontractors are thus generally deemed to be "independent" welding shops which have to satisfy the requirements prescribed below. In particular, every welding shop shall have a welding supervisor who is a permanent member of the welding shop staff (see Section 2).

1.3 Outside firms working in welding shops may be granted approval as independent welding shops. On this and on temporary workers, see also C.3. and Section 1, F.

2. Requirements, scope of approval

2.1 All shipyards and welding shops intending to perform welding work covered by these rules shall satisfy the requirements relating to the welding shop and its personnel set out in Section 2 and shall have been approved for this work by BKI. Applications for approval shall be submitted by the shipyards and welding shops in good time before starting the welding work, enclosing the information and documentation prescribed in Section 2, A.3.

2.2 Welding personnel (welders, operators and supervisors staff) and where applicable inspectors and test supervisors shall meet the requirements set out in Section 2, B.2, B.3 and B.4 and be recognized by BKI. For welder's qualification tests, see Section 3.

2.3 The scope of the approval is determined by the capabilities of the welding shop and by the intended range of application (materials, welding processes, welding positions, etc.). The intended range of application shall be specified in the application for approval; see the form "Description of Welding Shop" attached at Annex B. For the period of validity of the approval, see Section 2, A.4 and A.5.

C. Quality Inspection, Responsibility

1. Shipyards and welding shops shall ensure by means of regular in-house quality inspections during fabrication and on completion of the welding work that this work has been performed competently and satisfactorily (Section 1, F.). For the duties and responsibilities of the welding supervisor, see also ISO 14731.

2. The shipyards and welding shops are responsible for ensuring that the welding work conforms to these Rules, the approved manufacturing documents, any conditions stipulated in the approval documents, good shipbuilding practice and the latest state of welding practice. The inspections and checks to be performed by BKI Surveyor do not relieve the welding shops of this responsibility. The repair rate is to be recorded by the shipyard and any necessary corrective actions are to be identified in the builder’s QA system.

3. With regard to quality inspections and the responsibilities involved in awarding subcontracts to independent branches or suppliers or to approved or non-approved outside firms working in the welding shop (subcontractors), see, Section 1, F. Subcontracting of work or employment of temporary workers shall be notified to BKI.

4. The scope of the required quality inspections depends on the construction project in question. It is essential to ensure, however, that the intended materials, welding consumables and auxiliary materials are used and that the weld preparation, assembly, execution of the tack and final welds and the dimensional accuracy and completeness of the welded joints meets the requirements stated in 2. For non-destructive testing of the welded joints, see I.

5. Following inspection and, if necessary, repair by the welding shop, the components shall be presented to BKI Surveyor for checking at suitable stages of fabrication. For this purpose they shall be readily accessible and shall normally be uncoated. Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory workshop inspection and any necessary repair work has been performed.

6. If the quality or good working order of a component cannot be guaranteed or is in doubt due to inadequate or missing information in the manufacturing documents (e.g. production drawings), BKI may demand appropriate improvements. This applies in analogous manner to supplementary or additional components (e.g. reinforcements), even if these components were not stipulated when the drawings were scrutinized or could not be stipulated due to insufficiently detailed representation in the "class plans" (see the Rules for Hull (Pt.1, Vol. II) Sec. 1, G.).

7. BKI is not responsible for guaranteeing that all the components and welded joints inspected to the prescribed extent (generally on a random basis) by its surveyors have been fabricated in accordance with the conditions and meet the requirements in every respect. Components or welded joints which subsequently turn out to be defective may be rejected or their repair may be demanded even if acceptance testing has already been carried out.

D. Materials, Weldability

1. Welded structures may only be fabricated using base materials of proven weldability. Materials shall comply with the Rules for Materials (Pt.1, Vol. V). Other comparable materials (e.g. structural steels conforming to EN 10025) may only be used after BKI has given its approval in each individual case.

2. Any conditions relating to working and welding imposed by the approval certificate and the recommendations of the material producer shall be complied with. For the selection of materials for the ship's hull, see the Rules for Hull (Pt.1, Vol. II) Sec. 2.

3. The weldability of normal-strength hull structural steels of quality grades A, B, D and E tested by BKI is considered proven. No measures above and beyond the provisions of these Rules are necessary when welding these steels.

4. The weldability of the higher-strength hull structural steels of quality grades A 32 to F 40 approved and tested by BKI in accordance with the Rules for Materials (Pt.1, Vol. V), has been checked and can be taken for granted if the work is carried out in accordance with normal shipbuilding practice.

5. High-strength (quenched and tempered) fine-grained structural steels, steels tough at sub-zero temperatures, stainless structural steels and other (alloy) structural steels have to be specially approved by BKI. The weldability of the steel in question shall have been verified in combination with welding processes and welding consumables.

6. Steel castings and forgings shall comply with the Rules for Materials (Pt.1, Vol. V) and shall have been tested by BKI. The carbon content of components made from carbon and carbon-manganese steels/castings for welded structures shall not exceed 0,23% C at ladle analysis (product analysis: max. 0,25% C).

7. Light metal alloys shall have been tested by BKI in accordance with the Rules for Materials (Pt.1, Vol. V). Their weldability shall have been verified in combination with welding processes and welding consumables. It can generally be taken for granted in the case of the alloys mentioned in the Rules for Materials (Pt.1, Vol. V).

E. Welding Consumables and Auxiliary Materials

1. All the welding consumables and auxiliary materials used (e.g. covered electrodes, wire-gas combinations, wire-flux combinations, etc.) shall have been approved by BKI in accordance with Section 5. The quality grade required depends on the base materials to be welded and is shown in the relevant tables in Section 5, except for hull structural steels and other comparable structural steels, forged steels and cast steels.

2. The correlation of the required quality grades of welding consumables and auxiliary materials for welding hull structural steels to the respective hull structural steel quality grades is shown in Table 12.1. The correlation to other comparable structural steels, forged steels and cast steels shall be undertaken in analogous manner.

3. For welding of different quality grades of hull structural steel, welding consumables and auxiliary materials shall be correlated to the steels by their quality grades and added symbols as follows:

a) Normal-strength hull structural steels of different quality grades:

Welding consumables and auxiliary materials for whichever is the higher-quality (tougher) hull structural steel, e.g. A with D: quality grade 1 ....

b) Higher-strength hull structural steels of the same strength but with different quality grades:

Welding consumables and auxiliary materials for whichever is the higher-quality, (tougher) hull structural steel, e.g. A 36 with E 36: quality grade 3 Y ....

c) Normal-strength with higher-strength hull structural steels with comparable quality grades:

Welding consumables and auxiliary materials for the normal-strength hull structural steel quality grade in question, e.g. D with D 36: quality grade 2 .... (without added symbol Y).

d) Normal-strength with higher-strength hull structural steels with non-comparable quality grades:

Welding consumables and auxiliary materials having a quality grade for the higher-quality (tougher) hull structural steel but the strength of the normal-strength steel, e.g. A with D 36: quality grade 2 .... (without added symbol Y).

Table 12.1 Correlation of welding consumables and auxiliary materials to hull structural steel quality grades

Quality grades of welding consumables and auxiliary material (see also 3.)	Hull structural steel quality grades											
	A	B	D	E	A 32/36	D 32/36	E 32/36	F 32/36	A 40	D 40	E 40	F 40
1, 1S, 1T, 1M, 1TM, 1V	x											
1YS, 1YT, 1YM, 1YTM, 1YV	x	1)		x 2), 3)								
2, 2S, 2T, 2M, 2TM, 2V	x	x	x									
2Y, 2YS, 2YT, 2YM, 2YTM, 2YV	x	x	x		x 3)	x 3)						
2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V	1)	1)	1)		x 3)	x 3)			x 3)	x 3)		
3, 3S, 3T, 3M, 3TM, 3V	x	x	x	x								
3Y, 3YS, 3YT, 3YM, 3YTM, 3YV	x	x	x	x	x 3)	x 3)	x 3)					

Table 12.1 Correlation of welding consumables and auxiliary materials to hull structural steel quality grades *(continue)*

Quality grades of welding consumables and auxiliary material (see also 3.)	Hull structural steel quality grades											
	A	B	D	E	A 32/36	D 32/36	E 32/36	F 32/36	A 40	D 40	E 40	F 40
3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V	1)	1)	1)	x 3)	x 3)	x 3)		x 3)	x 3)	x 3)		
4Y, 4YS, 4YT, 4YM, 4YTM, 4YV	x	x	x	x	x 3)	x 3)	x 3)	x 3)				
4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V	1)	1)	1)	1)	x 3)	x 3)	x 3)	x 3)	x 3)	x 3)	x 3)	x 3)
5Y40, 5Y40S, 5Y40T, 5Y40M, 5Y40TM, 5Y40V	1)	1)	1)	1)	x 3)	x 3)	x 3)	x 3)	x 3)	x 3)	x 3)	x 3)

1) Not to be used if possible, otherwise only with BKI's approval; see Section 5, A.4.1 and A.4.2 apply in analogous manner.

2) For A 32/36, welding consumables and auxiliary material of quality grade 1Y.... should where possible only be used when welding thinners plate (up to 25 mm max.).

3) For plates over 50 to 70 mm thick, welding consumables and materials with one quality grade higher shall be used and for those over 70 and up to 100 mm thick those with two quality grades higher shall be used in each case in compliance with the higher base material requirements, see Rules for Materials (Pt.1, Vol. V).

Note:

For steels F 32, F 36 and A 40 to F 40, no provision is made in the Rules for Materials (Pt.1, Vol. V), for plates above 50 mm thick, but these shall be subject to special agreements where appropriate.

4. For welding very thick-walled, rigid components (approx. 30 mm and over) and welding of forgings and steel castings, hydrogen-controlled welding consumables and auxiliary materials of quality grade 3 H15 shall be used (for higher-strength hull structural steels, 3Y H10).

5. The use of hydrogen-controlled welding consumables and auxiliary materials is recommended for welding of higher-strength hull structural steels to one another (and to lower-strength steels) if the carbon equivalent of these steels is over to 0,41%. See also H.5.

6. Hydrogen-controlled welding consumables and auxiliary materials should also be used for components which are subjected to full load immediately after welding (e.g. lifting lugs or as a result of pressure tests) or where allowance has to be made for a high degree of residual stress due to the rigidity of the structure and, where applicable, a high yield strength or strength of a structure.

7. Hydrogen-controlled welding consumables and auxiliary materials shall always be used for welding high-strength (quenched and tempered) fine grained structural steels and steels tough at sub-zero temperatures, see Section 5, F.4. For steels with a yield strength or 0,2% proof stress of up to 500 N/mm^2, welding consumables and auxiliary materials with the maximum added symbol H10 should be used and for steels with a yield strength or 0,2% proof stress of over 500 N/mm^2 those with a maximum added symbol H5 should be used.

8. For welding of austenitic stainless steels to one another and to hull structural steels, welding consumables and auxiliary materials shall be selected in accordance with Tables 5.21 to 5.23 in Section 5 and the manufacturers' recommendations, taking the corrosion resistance and strength requirements and the welding metallurgy (including resistance to hot cracking) into account, and specified in a welding schedule, which is to be submitted for approval.

9. For welding of aluminium alloys, the welding consumables and auxiliary materials shall be selected according to the type and condition of the material (see Rules for Materials (Pt.1, Vol. V)) in accordance with Table 5.29 in Section 5, taking the required mechanical properties of the welded joints into account (see Rules for Hull (Pt.1, Vol. II) Sec. 19, C.2.8) and shall be indicated in the production documents to be submitted for approval.

10. Welding consumables and auxiliary materials specified in a welding shop or procedure approval (see F.) may only be replaced by equivalent consumables approved by BKI with an appropriate quality grade if this is explicitly stated in the respective approval document. Failing this, BKI's agreement shall be obtained.

11. The welding consumables and auxiliary materials may only be used in the approved welding positions. The manufacturer’s recommendations and instructions for welding (e.g. type of current and polarity) shall be followed.

12. The welding consumables and auxiliary materials (especially hydrogen-controlled, basic-covered electrodes and basic welding fluxes) shall be re-dried before use in accordance with the manufacturer's instructions (observed maximum drying time!) and stored in a dry place (in heated containers or the like) at the workplace.

F. Welding Procedures, Procedure Qualification Tests

1. General

1.1 Beneath the requirements for qualification tests of welding procedure intended for hull constructions are stated. Procedure qualification tests intended for other use like pipeline system, pressure vessel and steam boiler, machinery structures but also for the industrial sector, e.g. offshore or steel constructions, are not included in this Section. After BKI’s agreement, the following requirements can be applied in a corresponding manner.

1.2 The procedure qualification tests concerning special hull construction e.g. for liquid gas tanks are settled in the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX) Sec. 6.

1.3 Only those welding procedure are allowed to be applied, which qualification is proved by a qualification test and by the following requirements.

1.4 The following requirement are valid for the welding process commonly used in shipbuilding like manual metal arc welding, gas metal arc welding, flux cored arc welding, metal inert gas welding, submerged arc welding, tungsten inert gas welding and electrogas welding.

1.5 Procedure qualification test program concerning special welding processes and procedures respectively like e.g. laser welding, stud welding, friction welding, robotic welding have to be agreed with BKI.

1.6 BKI may additionally require welding procedure tests for specific (difficult) component shapes or combinations of materials, environmental conditions (e.g. under water welding), particular weld shapes, process variants or combinations, and also particular welding consumables and auxiliary materials. This is analogously valid for other joining process or (surface) finishing techniques such as thermal cutting or flame straightening.

1.7 The information in the preceding and following paragraphs, especially the information on test pieces, form of specimens, tests and requirements, applies to the normal materials, welding processes and weld shapes in current use in shipbuilding, which properties are proved under operating conditions and has been verified by test results. In case of doubt, BKI can require supplementary and/or other test pieces, forms of specimen and qualification tests showing that the properties of application are sufficient.

1.8 In the case of welding processes whose characteristics result in weld shapes other than those verified by test results (e.g. those with considerable notch effect), the influence of the weld shape on the fatigue strength behaviour of the welded joints may be investigated in addition to carrying out the prescribed tests. The same applies in analogous manner to other characteristics of the weld joints, e.g. corrosion resistance.

1.9 BKI may approve certain welding procedures such as vertical-down welding, build-up welding on rudder stocks or underwater welding (see. H.13.3), but make their application depending on an approval of every single case, e.g. after examination of the load conditions the use of which is, however, dependent upon authorization, for example following an examination of the load conditions, in each individual case. For welding processes or applications of this nature, BKI may also stipulate restrictions in the operation of the vessel (e.g. in the operating area).

1.10 In general welding procedure tests are to reflect fabrication conditions in respect to welding equipment, inside or outside fabrication, weld preparation, preheating and any post-weld heat treatment. It is to be the manufacturer’s responsibility to establish and document whether a procedure is suitable for the particular application.

1.11 For the welding procedure approval the welding procedure qualification test is to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

1.12 Welding procedure approvals are generally non-transferable. Exceptions are only possible after the acceptance by BKI and this only for workshops under the same technical and quality management. BKI may, however, require proof as to whether the welding processes are being applied correctly and the mechanical properties are adequate by means of non-destructive tests and/or production tests with mechanical-technological test specimens.

1.13 Welding procedure test performed according to other rule under the supervision of other independent testing bodies can be accepted on demand and after examination by BKI. For this purpose, test reports indicating the results, the welding procedure specification and the approval certificate of the other testing body have to be submitted to BKI.

2. Test schedule and welding procedure specifications

2.1 Preliminary welding procedure specification (pWPS) and welding procedure specifications (WPS)

The shipyard of the manufacturer has to prepare a welding procedure specification intended for the welding procedure qualification test. This welding procedure specification is also called preliminary welding procedure specification (pWPS). In the pWPS, all relevant welding and procedure variables have to be specified. If deemed necessary, the pWPS can be adjusted and completed during the welding procedure test.

2.2 The scope of welding procedure tests shall be laid down in an application and submitted for approval prior to the tests. Before starting the procedure test, a pWPS as well as copies of the base material certificates have to be submitted together with the application to BKI. The application for approval and for the performance of procedure test based upon the WPS has to be submitted to BKI Head Office, with simultaneous notification of the local Surveyor, giving the following details:

- Range of application (components, materials, plate/wall thickness, diameter of pipe)
- Welding process
- Welding positions
- Welding equipment, welding parameters
- Weld shapes, weld building up

- Welding consumables and auxiliary materials
- Joint preparations
- Cold-or hot-forming operations prior to welding
- Overweldable shop primer
- Welding jigs, weather protection
- Preheating and heat input during welding
- Post-weld heat treatment, other after-treatment
- Welder
- Date of the testing
- Location of the testing

If possible, a proposal of test schedule including sketch and dimension of the test pieces and scheduled test specimen and testing has to accompany the application. In case that the above required details and data are basing upon workshop standards or other (welding) specifications, these documents have to be also enclosed to the application.

2.3 If the test pieces, which are welded under the supervision of BKI according to the pWPS, show insufficient results, the shipyard or the manufacturer has to adjust and modify the pWPS considering the improvements. A new revised pWPS shall be prepared and the test pieces shall be welded again under the supervision of BKI and according to the new pWPS.

2.4 The final welding procedure specification (WPS) is the basis for the manufacturers welding production. If the test results of the test pieces welded in accordance with the pWPS comply with the requirements, BKI can approve the welding procedure specification (WPS) within the scope of welding procedure approval for the shipyard or the welding workshop respectively.

3. Qualification of the welding procedures

3.1 General

3.1.1 The preparation and welding of the test pieces have to be carried out in accordance with the preliminary welding procedure specification (pWPS) and under the general condition of production welding which it represent.

3.1.2 Welding of the test assemblies and testing of the test specimen are to be witnessed by BKI Surveyor.

3.1.3 If tack welds and/or start and stop points are a production condition of the weld they are to be fused into the joint and are to be included in the test assemblies.

3.1.4 If butt and fillet welding is applicable during production relevant welding procedure test pieces of butt and fillet weld have to be welded. Only in case of application and over welding of shop primer, test pieces of fillet weld are to be qualified separately from butt welds.

3.2 Base materials, welding consumables and auxiliaries

3.2.1 The base material used for welding procedures have to be identified by means of material marking and certificates.

3.2.2 In case of welding procedure test for high heat input welding, the weldability of the base material has to be proved to BKI concerning the maximum applied heat input by steel manufacturer.

3.2.3 The welding consumables and auxiliary materials shall if possible have already been tested and approved by BKI; however, they may be tested and approved at the same time as the welding procedure. Approvals of this type are generally restricted to the user's works and are valid for a maximum of one year, unless repeat tests are performed as required for the welding consumables.

3.2.4 Welding consumables and auxiliary materials used in the welding procedure tests may only be replaced in the subsequent fabrication work by others of the same kind which bear BKI approval if this is expressly stated in welding procedure approval certificate.

4. Welding procedure qualification tests for normal and higher strength hull structural steels, forgings and steel castings with a minimum specified yield strength of ReH ≤ 400 N/mm2, and YP47 steels

4.1 The following requirements are valid for normal and higher strength hull structural steels, forgings, steel castings, YP47 steels according to the Rules for Materials (Pt.1, Vol. V). Other comparable steels and materials respectively can only be used with previous consent of BKI.

The following requirements are also valid for brittle cracks arrest (BCA) steels specified in Rules for materials (Pt.1, Vol.V), Table 4.28 with heat input not more than 50kJ/cm.

4.2 Butt welds

The following provisions refer to butt welds on plates. For butt welds on pipelines, please refer to Section 15.

4.2.1 Assembly and dimension of test pieces

.1 The test assembly has to be great enough in order to ensure a reasonable heat distribution. The dimension of the test piece has to be adjusted to the welding procedure and to the number of the test specimens. Following minimum dimensions of test piece are required:

- manual or semi-automatic welding :
  - width = 2a, a = 3 x t, min. 150 mm
  - length b = 6 x t, min. 350 mm
- automatic welding :
  - width = 2a, a = 4 x t, min. 200 mm
  - length b = 1000 mm

The test assembly is represented in Fig. 12.1.

.2 Where, in order to establish the mechanical and technological characteristics of the welded joints, especially in fully mechanized and/or automatic welding processes, test piece lengths are selected which are considerably smaller than the weld lengths to be laid down during later fabrication, the first fabrication welds shall be included as part of the welding procedure tests and, as a minimum requirement, shall be subjected to a visual inspection and non-destructive testing to ensure a trouble-free welding procedure and to detect any imperfections in the weld.

For hull structural steel plates impact tested in the longitudinal direction (CVN-L), the butt weld of the test piece is perpendicular to the rolling direction of the two plates.

For high strength quenched and tempered steel plates impact tested in the transverse direction (CVN-T), the butt weld of the test piece is parallel to the rolling direction of the two plates.

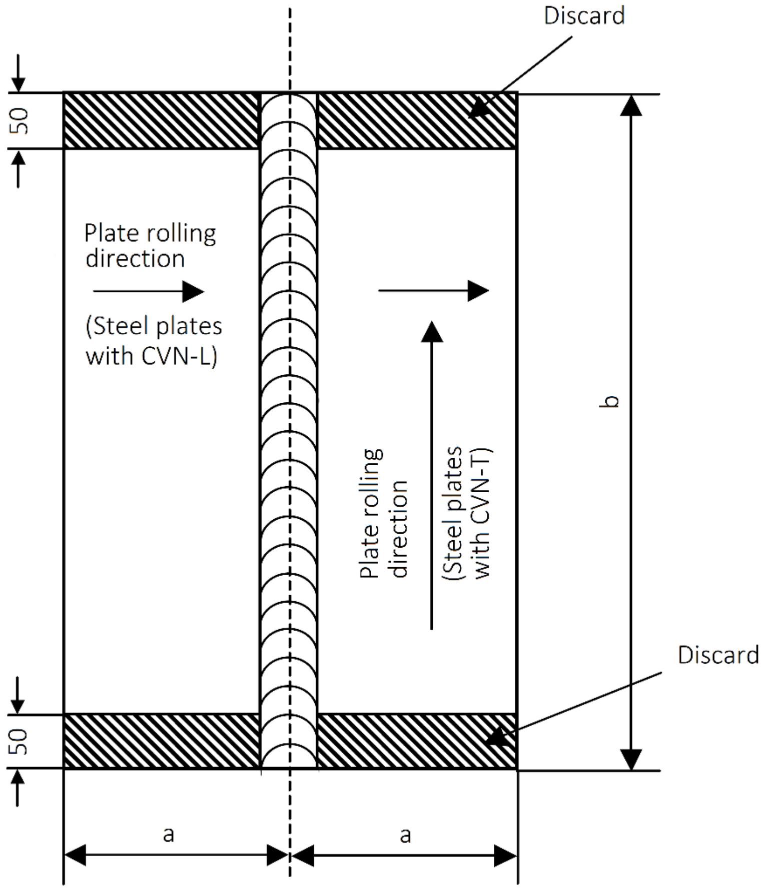


Fig. 12.1 Test assembly for Steels

4.2.2 Scope of testing and test specimens

The butt weld test assemblies are to be examined non-destructively and destructively in accordance with the following requirements and with Fig. 12.2:

–	Visual testing	100 %
–	Surface crack detection	100 % (dye penetrant testing or magnetic particle testing)
–	Radiographic or ultrasonic testing	100 %
–	Transverse tensile test	two specimens (see 4.2.2.2)
–	Longitudinal tensile test	one specimen (see 4.2.2.3)
–	Transverse bend test	four specimens (see 4.2.2.4)
–	Charpy V-notch impact test	required (see 4.2.2.5)
–	Macro examination	one specimen (see 4.2.2.6)
–	Hardness test	required (see 4.2.2.7)

.1 Non-destructive testing

Test assemblies have to be examined by visual and non-destructive testing prior to the cutting of test specimens. In case that any post-weld heat treatment is required or specified, the non-destructive testing has to be performed after the heat treatment. BKI may require specific testing intervals to be adhered to between completion of the welding work and performance of the crack test, unless a heat treatment has been executed. Imperfections detected by visual or non-destructive testing have to be assessed in accordance with ISO 5817 quality level "B" (except for excess weld metal and excess of penetration for which the quality level "C" applies).

.2 Transverse tensile test

The testing has to be carried out in accordance with ISO 4136. In case of great plate thicknesses more test specimens have to be intended for testing in order to cover the whole cross section. If not stated otherwise prior to the testing, the tensile strength recorded for each specimen has not to be less than the minimum required for the base material. The welding procedure minimum tensile test requirement for hull structural steels are shown in Table 12.2. When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength.

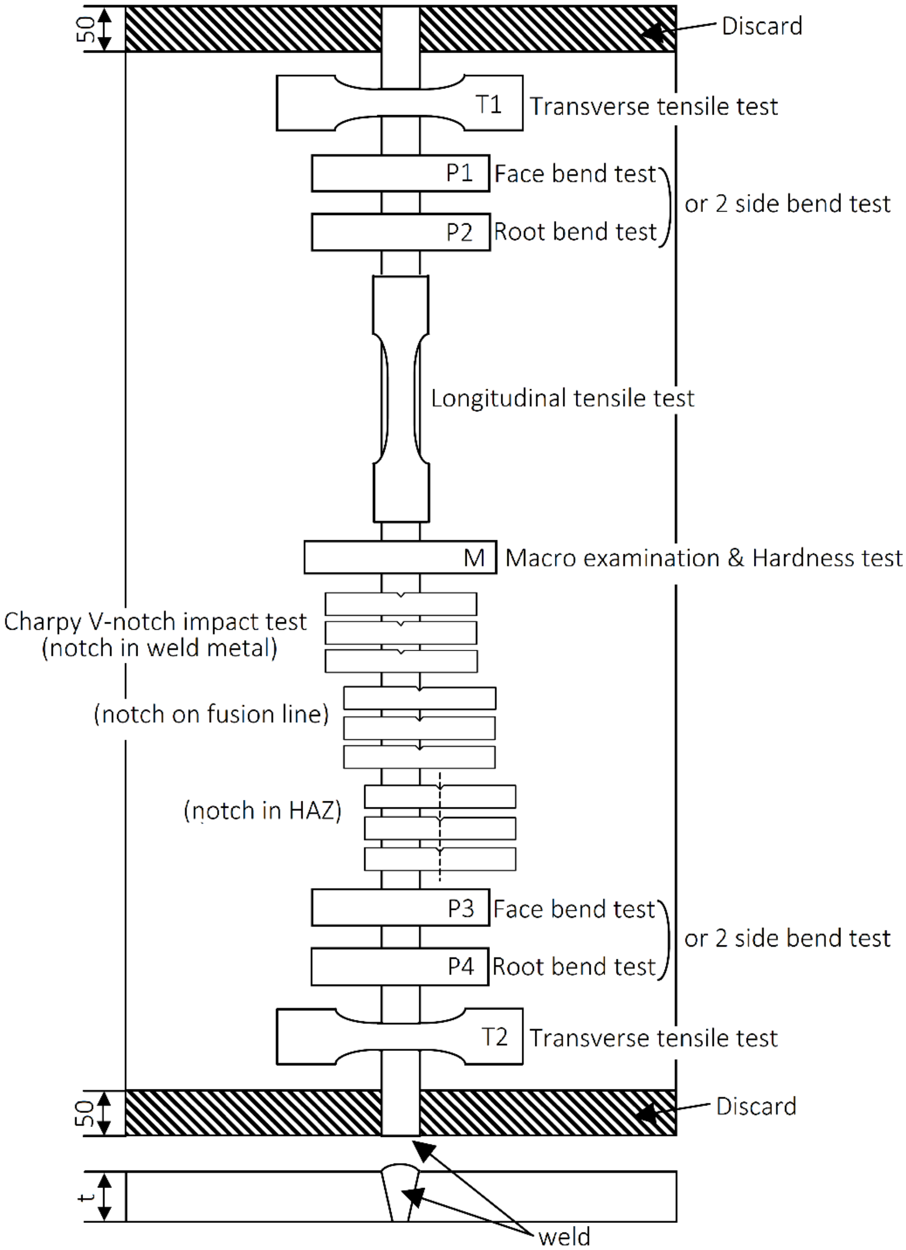


Fig. 12.2 Test sampling

.3 Longitudinal tensile test

The testing has to be carried out in accordance with Section 11, C.2. Longitudinal tensile test of deposited weld metal taken lengthwise from the weld is required for cases where the welding consumable or auxiliaries is not BKI approved or that a greater influence on the weld metal is expected due to the character of the procedure. Tensile strength, yield strength and elongation of the specimen has not to be less than the minimum tensile strength, minimum yield strength and minimum elongation of the required quality/strength grade of the welding consumable. Table 12.2 shows the requirements for the minimum tensile strength, yield strength and elongation of the weld metal.

Where more than one welding process or type of consumable has been used to make the test weld, test specimens are to be taken from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

Table 12.2 Requirements applicable to welded hull structural steel in the scope of welding procedure tests

<table>
<tr><th rowspan="3">Grade</th><th rowspan="3">Yield strength (weld metal)
[N/mm^2] (min.)</th><th rowspan="3">Tensile strength
[N/mm^2] (min.)</th><th rowspan="3">Elongation (weld metal $L_0 = 5\ d_0$)
[%] (min.)</th><th colspan="4">Impact energy [1), 3), 4)]
(J)</th><th rowspan="3">Bending angle (D = 4t)</th><th rowspan="3">Bending Elongation gauge length 2 Ls [2)]
[%]</th></tr>
<tr><th rowspan="2">Temp.
[°C]</th><th colspan="2">Manual and semi-mechanised</th><th rowspan="2">Full mechanised</th></tr>
<tr><th>PA, PC, PE</th><th>PF, PG</th></tr>
<tr><td>A[5)]</td><td rowspan="3">305</td><td rowspan="3">400</td><td rowspan="3">22</td><td>+ 20</td><td rowspan="3">47</td><td rowspan="3">34</td><td rowspan="3">34</td><td rowspan="3">180°</td><td rowspan="3">22</td></tr>
<tr><td>B[5)], D</td><td>± 0</td></tr>
<tr><td>E -</td><td>20</td></tr>
<tr><td>A32</td><td rowspan="4">335</td><td rowspan="4">440</td><td rowspan="4">22</td><td>+ 20</td><td rowspan="4">47</td><td rowspan="4">34</td><td rowspan="4">34</td><td rowspan="4">180°</td><td rowspan="4">22</td></tr>
<tr><td>D32</td><td>± 0</td></tr>
<tr><td>E32</td><td>- 20</td></tr>
<tr><td>F32</td><td>- 40</td></tr>
<tr><td>A36</td><td rowspan="4">375</td><td rowspan="4">490</td><td rowspan="4">22</td><td>+ 20</td><td rowspan="4">47</td><td rowspan="4">34</td><td rowspan="4">34</td><td rowspan="4">180°</td><td rowspan="4">22</td></tr>
<tr><td>D36</td><td>± 0</td></tr>
<tr><td>E36</td><td>- 20</td></tr>
<tr><td>F36</td><td>- 40</td></tr>
<tr><td>A40</td><td rowspan="4">400</td><td rowspan="4">510</td><td rowspan="4">22</td><td>+ 20</td><td rowspan="4">47</td><td rowspan="4">39</td><td rowspan="4">39</td><td rowspan="4">180°</td><td rowspan="4">22</td></tr>
<tr><td>D40</td><td>± 0</td></tr>
<tr><td>E40</td><td>- 20</td></tr>
<tr><td>F40</td><td>- 40</td></tr>
<tr><td>E47[6)]</td><td>460</td><td>570</td><td>19</td><td>- 20</td><td>64</td><td>64</td><td>64</td><td>180°</td><td>19</td></tr>
</table>

1) Charpy V- notch specimen, average value of three specimens.
2) The gauge length (L_0) = weld width (L_S) + half of the plate thickness on each side adjacent to the weld; see EN 910 / ISO 5173
3) In the case of plate thickness > 50 mm, the requirement of the impact energy have to be agreed with BKI prior to testing.
4) The impact requirement are valid for test pieces with weld perpendicular to the rolling direction of the plates.
5) For grade A/B, the minimum value of impact energy is 27 J in the fusion line (FL) and in the heat affected zone (HAZ).
6) For grade E47, diameter of mandrel (D) = 5 t.

.4 Bend test

Transverse bend tests have to be carried out in accordance with ISO 5173. Two of the four test specimens have to be bent with final pass in tension and the other two have to be bent with the root pass in tension. In case of specimen thicknesses ≥ 12 mm, four side bend test specimens can be alternatively tested. For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

The bending tests are to be performed using a mandrel with a diameter equal to 4 times the thickness of the specimen. The required bending angle of 180° under the test conditions specified in ISO 5173 is deemed to have been attained when the specimen has been thrust between the supporting rolls to the minimum distance indicated in this standard. The required bending elongation shall be attained before the first incipient crack appears. Minor pore exposures or the like up to a maximum length of 3 mm may be tolerated. The fracture surfaces of ruptured test specimens shall be evaluated.

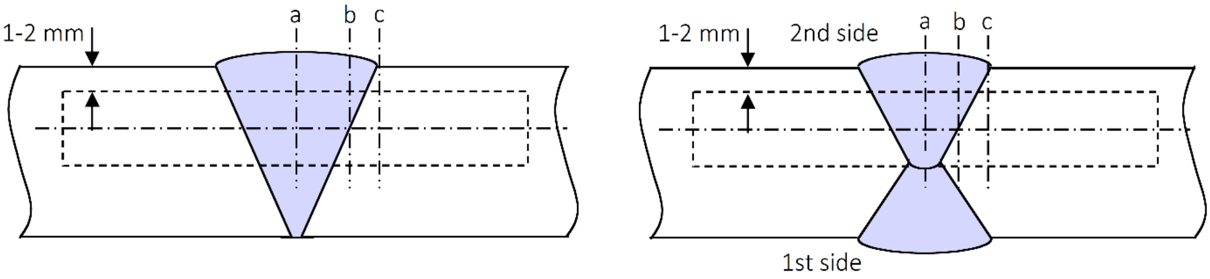
.5 Impact tests

The specimen position, the test temperature and the requirements of the notched-bar impact tests have to be in line with the following requirements. The dimensions of the specimens and the tests have to follow ISO 9016. Charpy V-specimens with the notch perpendicular to the surface of the plate in accordance with ISO 9016 transversal to the weld are required. The notched bar impact test specimens shall be taken from the last side welded and this 1-2 mm below the surface of the base material, in case of larger plate thicknesses they have to be taken from both sides. In case of very great plate thicknesses or welding procedure tending to centre segregation, additional notched-bar impact specimens have to be taken from the middle of the plate thickness. Fig. 12.3 and Fig. 12.4 show the position of specimen depending on heat input, plate thickness and weld preparation. Table 12.2 presents the impact requirements.

For the impact tests the average value out of three impact test specimens (for each notch location, weld metal, fusion line, HAZ) applies.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

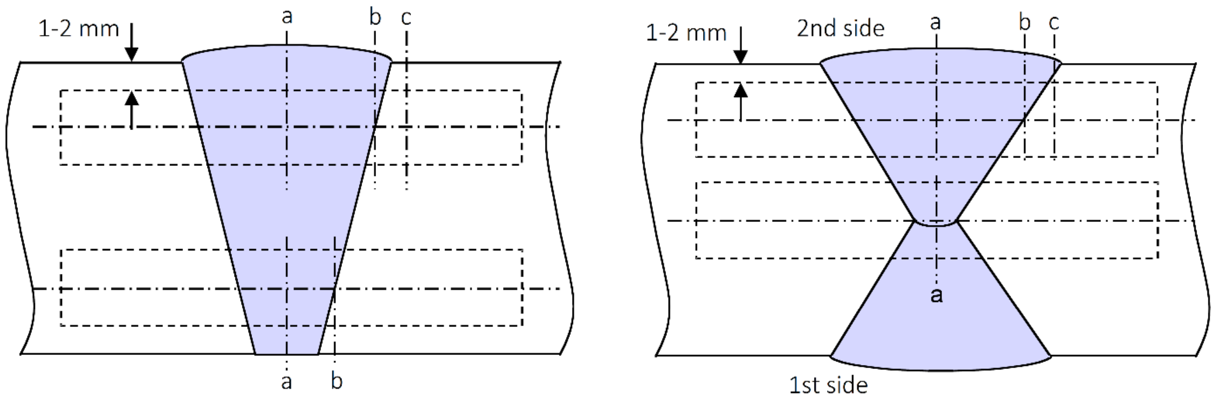
a) $t \leq 50$ mm [1]



Note:

(1) For one side welding with thickness over 20 mm notch locations "a" is to be added on root side.

b) $t > 50$ mm



Notch locations:

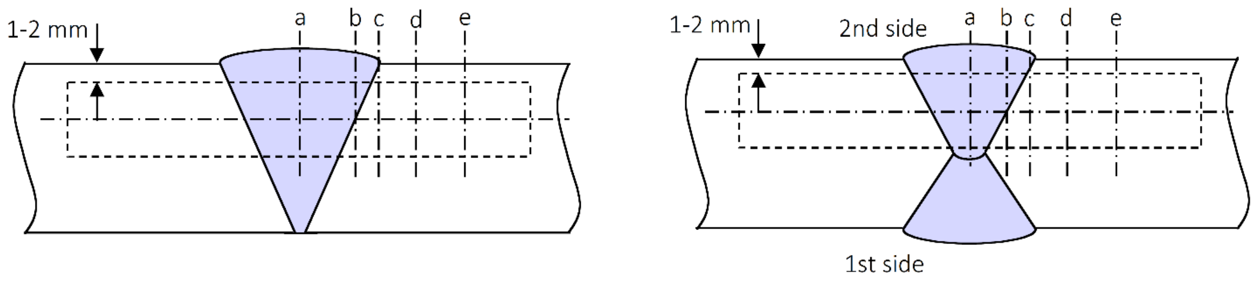
a : center of weld "WM"

b : on fusion line "FL"

c : in HAZ, 2 mm from fusion line

Fig 12.3 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

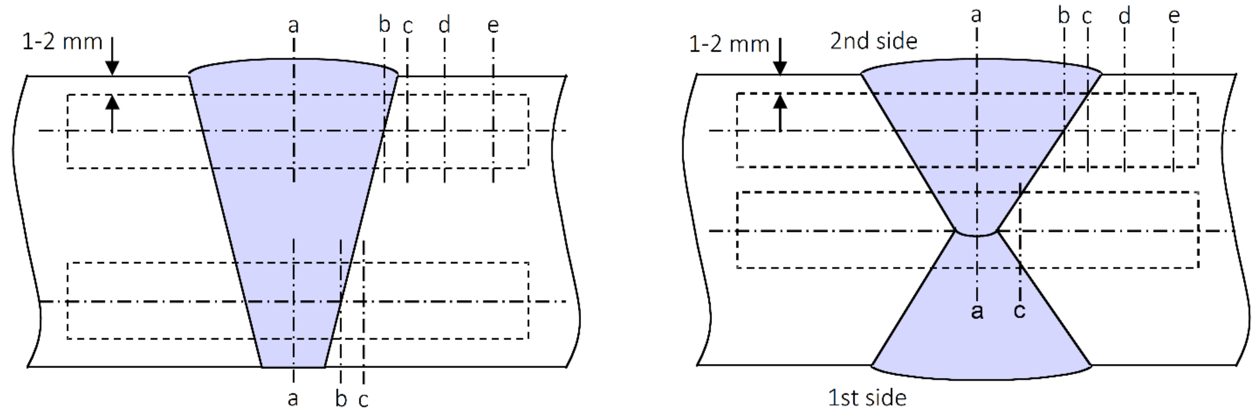
a) t ≤ 50 mm [1]



Note:

(1) For one side welding with thickness over 20 mm notch locations "a", "b" and "c" are to be added on root side.

b) t > 50 mm



Notch locations:

a : center of weld "WM"
b : on fusion line "FL"
c : in HAZ, 2 mm from fusion line
d : in HAZ, 5 mm from fusion line
e : in HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm

Fig 12.4 Locations of V-notch for butt weld of normal heat input (heat input > 50 kJ/cm)

Where the plate thickness is less than 10 mm, notched bar impact test specimens with a width corresponding to the plate thickness, and wherever possible 7,5 mm or 5 mm, may be used. In such cases the impact energy values specified in Table 12.2 shall be reduced in accordance with Table 12.3.

The notched bar impact test is generally dispensed with for plates less than 5 mm thick. However, other tests of resistance to brittle fracture may be stipulated.

Table 12.3 Required impact energy values with specimens of reduced width

Cross section of specimen [mm x mm]	Fraction of the required minimum impact
10 × 7,5	5/6
10 × 5,0	2/3

.6 Macro examination

The examination of the macro-structure has to be executed on minimum one polished section. The polished surface of the section has to be taken perpendicular to the weld axis.

The macro specimen shall be of such a size and treated by grinding and etching in such a way as to reveal the nature and structure of the crystallization of the weld metal and the heat-affected zone as well as the texture of the base metal and the absence of defects such as cracks, lack of fusion etc. For the macro examination, minimum 10 mm out off the heat affected zone from the base material has to be considered.

The polished sections shall be photographed and the photos appended to the inspection report. Macrographs shall normally be to a scale of 1:1 to 1:3; if the cross-sectional area of the weld is small, they may be magnified.

The specimen have to be assessed in accordance with ISO 5817, quality level "B", except for excess weld metal and excess of penetration for which the quality level "C" applies.

.7 Hardness test

The hardness test is required for steels with specified minimum yield strength of $R_{eH} \geq 355$ N/mm^2 and in general for steel cast and forgings. The Vickers method with a test strength of 98N (HV10) has normally to be used. The hardness has to be verified on ground and etched specimens, with test surface perpendicular to the weld axis. Other test methods have to be agreed with BKI prior to testing. Two test rows are necessary in accordance with Fig. 12.5. At least three individual indentations in the weld metal, the heat affected zones (both sides of the weld) and the base metal (both sides of the weld) are required in accordance with Fig. 12.6. In addition, for YP47 steels, measurement points are to include mid-thickness position. The distance between the indentations is 1 mm in case of Vickers HV10.

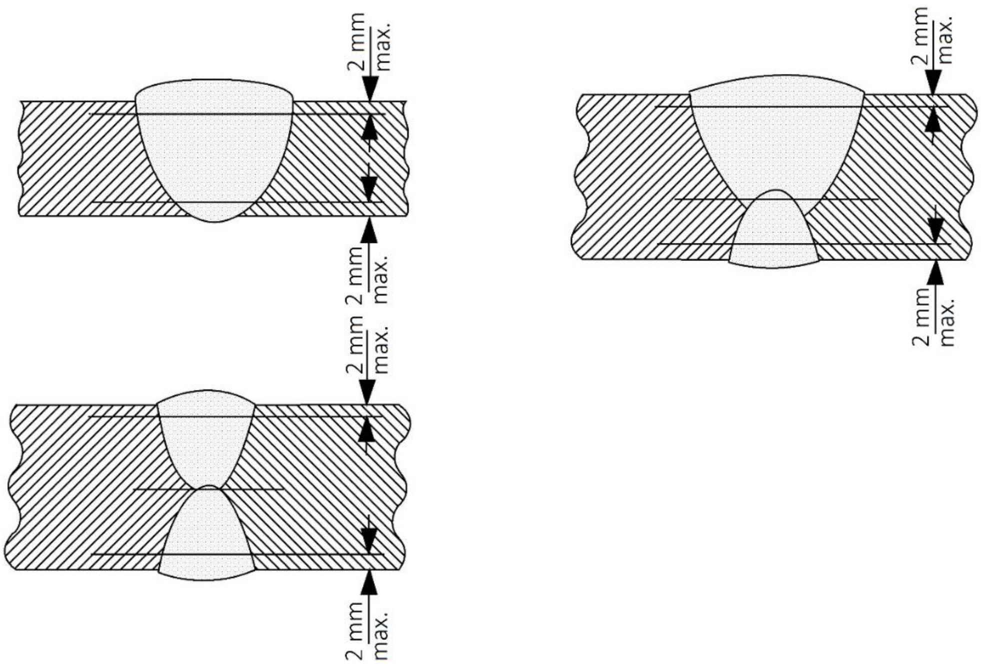


Fig. 12.5 Examples of hardness test with rows of indentations in butt welds

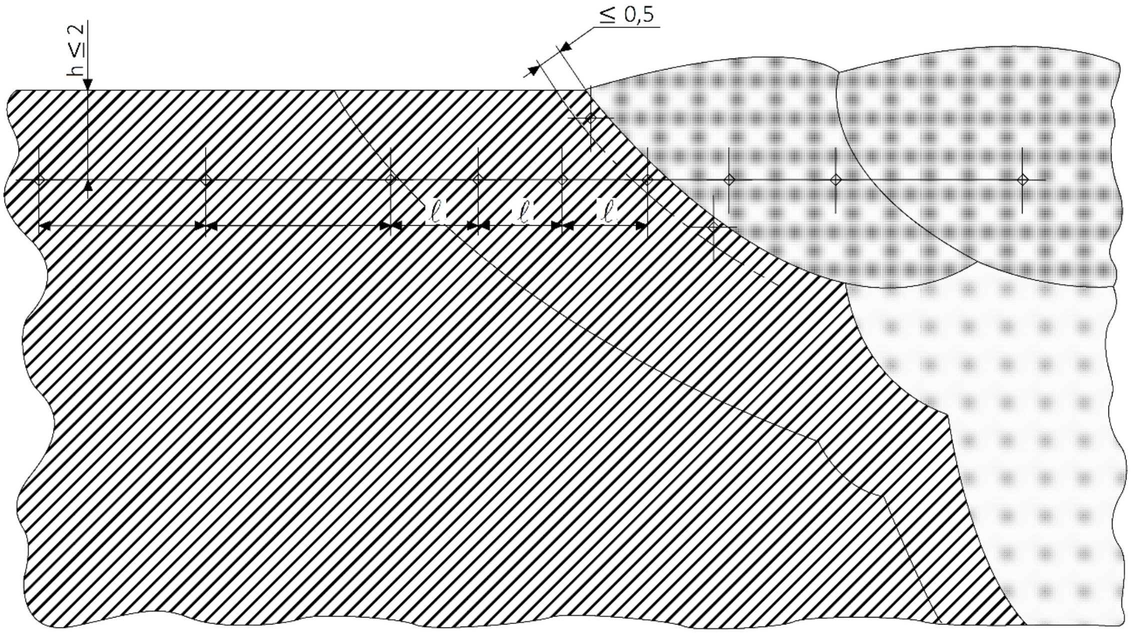


Fig. 12.6 Example of hardness indentations in butt weld

More examples concerning hardness indentations are presented in ISO 9015-1/ ISO 6507-1.

The results from the hardness test have not to exceed a hardness of 350 HV10 in case of higher strength steel, steel casting and forgings with a specified minimum yield strength of R_{eH} ≤ 400 N/mm^2 and YP47 steels. The results from the hardness test have not to exceed 380 HV10 in case of brittle crack arrest (BCA) steels.

.8 Additional Tests

CTOD test may be required for YP47 steels. The tests shall be carried out according to ISO 15653 using 3-point bend specimens (SENB), or another recognized standard as agreed with BKI. Both B x 2B and B x B specimens may be used, although B × 2B specimens are recommended.

One set of CTOD specimens is required for each of the notch locations given below for each test assembly:

– Grain Coarsened HAZ
– weld metal.

CTOD testing shall be carried out at –10°C or design temperature, whichever is lower. Minimum single CTOD value of 0,18 mm and minimum average CTOD value of 0,20 mm for notch position in GCHAZ and weld metal shall be fulfilled. The average CTOD is calculated as average of three valid CTOD test results.

4.3 Fillet welds

The following requirements refer to fillet welds on plates and sections. Concerning fillet weld on pipelines, see Section 15. In case that a fillet welding procedure shall be used for plates and sections, coated with an overweldable shop primer, similarly coated plates have to be used during the procedure test for fillet welds in the same manner. The kind of the shop primer and dry-film thickness have to be indicated in the report.

Fillet weld test pieces [T- joint and/or double T-joint (cruciform) test pieces] have to be welded with root gaps not greater than 0,5 mm. Depending on the subsequent practice, tacks shall also be included in the test (and overwelded where applicable). The throat thickness of the fillet shall correspond to those used in subsequent fabrication, but shall not be greater than 0,5 times the plate thickness.

4.3.1 Test assembly and dimension

Depending on the welding position to be qualified, T- joint and/or double T-joint (cruciform) test pieces are always required for plates coated with shop primer and also for plates without shop primer. In case of the other welding positions (PA, PB, PD, PF) T-joint test pieces are sufficient but only for plates coated with shop primer. The evaluation of fillet welds on plates without shop primer coating in welding positions (PA, PB, PD, PF) can take place in the scope of butt weld procedure test after BKI's agreement.

.1 T-joint test pieces

The test assembly has to be great enough in order to ensure a reasonable heat distribution. The dimension of the test piece has to be adjusted to the welding procedure and to the number of test specimens. Following minimum dimensions of test piece are required:

- manual and semi-automatic welding:
  - width a = 3 × t, min. 150 mm
  - length b = 6 × t, min. 350 mm
- automatic welding:
  - width a = 3 × t, min. 150 mm
  - length b = 1000 mm

The test assembly is represented in Fig. 12.7.

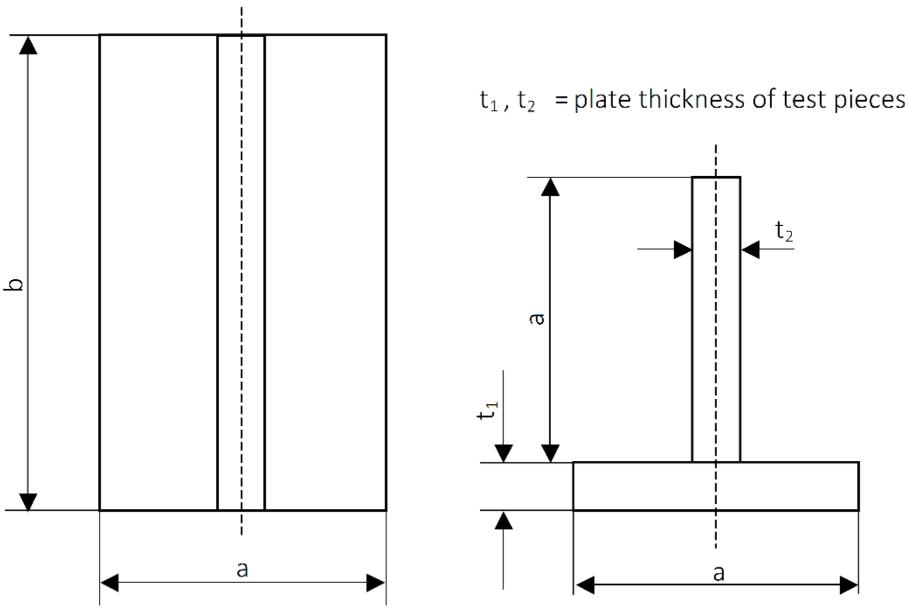


Fig. 12.7 Test assembly for fillet weld in welding positions PA, PB, PD, PF

.2 Where, in order to establish the mechanical and technological characteristics of the welded joints, especially in fully mechanized and/or automatic welding processes, test piece lengths are selected which are considerably smaller than the weld lengths to be laid down during later fabrication, the first fabrication welds shall be included as part of the welding procedure tests and, as a minimum requirement, shall be subjected to a visual inspection or production tests shall be arranged to ensure a trouble-free welding procedure and to detect possible imperfections in the weld.

.3 Double T- joint (cruciform) test pieces

The test assembly has to be great enough in order to ensure a reasonable heat distribution. The dimension of the test piece has to be adjusted to the welding procedure and to the number of test specimens. The minimum dimensions of test piece and the test assembly are shown in Fig. 12.8 concerning manual and semi-automatic welding procedures and in Fig. 12.9 concerning automatic welding procedures.

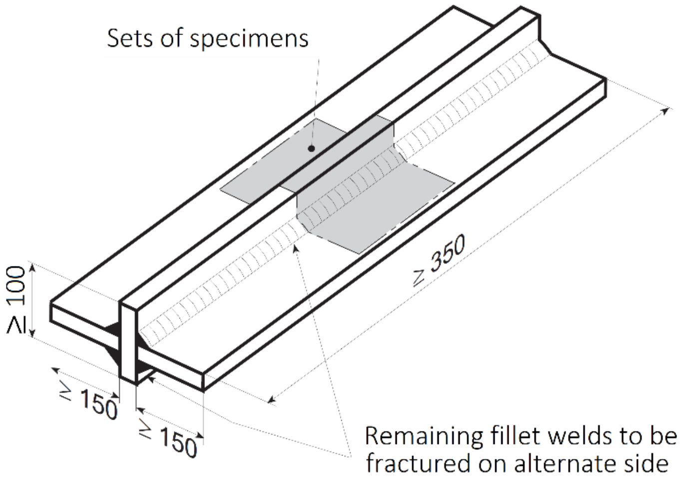


Fig. 12.8 Double T- joint (cruciform) test pieces for manual and semi-automatic welding procedures (welding position PG)

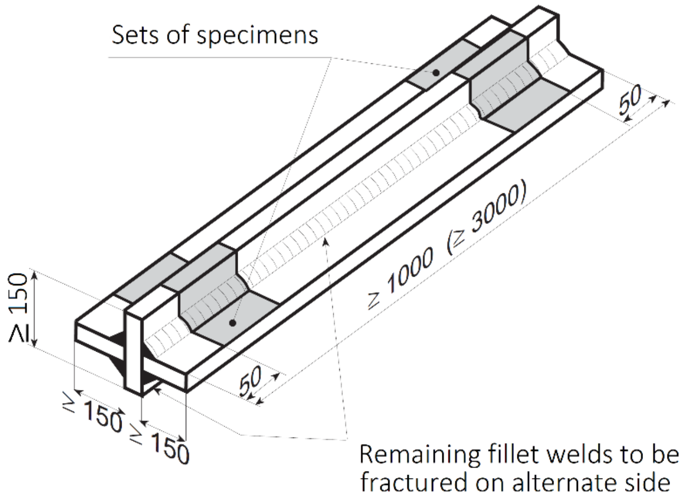


Fig. 12.9 Double T- joint (cruciform) test pieces for automatic welding procedures

4.3.2 Welding of test pieces

For single run manual and semi-automatic fillet welding, a stop/restart has to be included in the test length and its position is to be clearly marked for subsequent examination. If tack welds are intended to be overwelded in the subsequent production, they have to be considered in the test piece as well. T-joint test pieces have to be welded on one side only. Only one welding position shall be used per test piece.≥

4.3.3 Examinations and tests

Test assemblies have to be examined non-destructively and destructively in accordance with the following:

.1 Examinations and tests of T-joint test pieces

- Visual testing 100 %
- Surface crack detection 100 % (dye penetrant testing or magnetic particle testing)
- Macro examination 2 specimens (see 4.3.3.4)
- Hardness test required (see 4.3.3.5)
- Fracture test required (see 4.3.3.5)

.2 Examinations and tests of double-T joint (cruciform) test pieces

- Visual testing 100 %
- Surface crack detection 100 % (dye penetrant testing or magnetic particle testing)

As shown in Figs. 12.8 and 12.9, one or more sets of test specimens shall be taken from the (cruciform) fillet-welded test pieces in accordance with Fig. 12.10.

A set of (cruciform) fillet weld test specimens shall include the following specimens. The specimen shapes and dimensions have to be in line with Section 11. One set of test specimens has to include the following specimens:

- Cruciform tensile 3 specimen test specimens (Z) (see 4.3.3.7)
- Macrographic 2 specimen examination (M) (see 4.3.3.4)
- Hardness test required (see 4.3.3.5)
- Fracture test required, from the remaining test piece on alternate side (see 4.3.3.6)

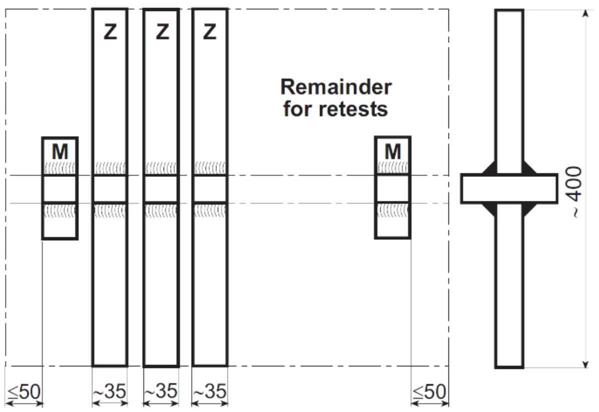


Fig. 12.10 Set of double-T (cruciform) test specimens

.3 Non-destructive testing

Test assemblies have to be examined by visual and non-destructive testing prior to the cutting of test specimens. In case that any post-weld heat treatment is required or specified, the non-destructive testing has to be performed after the heat treatment. BKI may require specific testing intervals to be adhered to between completion of the welding work and performance of the crack tests, unless a heat treatment has been executed. Imperfections detected by visual or non-destructive testing have to be assessed in accordance with ISO 5817, quality level "B" (except for excess convexity and excess throat thickness for which the quality level "C" applies).

.4 Macro examination

The examination of the macro-structure has to be executed on minimum two polished section. For single run manual and semi-automatic fillet welds one macro-section is necessary in the stop/restart area. The polished surface of the section has to be taken perpendicular to the weld axis.

The macro specimen shall be of such a size and treated by grinding and etching in such a way as to reveal the nature and structure of the crystallization of the weld metal and the heat-affected zone as well as the texture of the base metal and the absence of defects such as cracks, lack of fusion etc. For the macro examination, minimum 10 mm out off the heat affected zone from the base material has to be considered.

The polished sections shall be photographed and the photos appended to the inspection report. Macrographs shall normally be to a scale of 1:1 to 1:3; if the cross-sectional area of the weld is small, they may be magnified.

The specimens have to be assessed in accordance with ISO 5817, quality level "B", except for excess convexity and excess throat thickness for which the quality level "C" applies.

.5 Hardness tests

The hardness test is required for steels with specified minimum yield strength of $R_{eH} \geq 355$ N/mm^2 and in general for steel cast and forgings. The Vickers method with a test strength of 98N (HV10) has normally to be used. The hardness has to be verified on ground and etched specimens, with test surface perpendicular to the weld axis. Other test methods have to be agreed with BKI prior to testing. Two test rows are necessary in accordance with Fig. 12.11. At least three individual indentations in the weld metal, the heat affected zones (both sides of the weld) and the base metal (both sides of the weld) are required in accordance with Fig. 12.12. The distance between the indentations is 1 mm in case of Vickers HV10.

Further examples for hardness tests with indentations are given in ISO 9015-1 / ISO 6507-1.

The results from the hardness test have not to exceed a hardness of 350 HV10 in case of higher strength steel, steel casting and forgings with a specified minimum yield strength of $R_{eH} \leq 400$ N/mm^2.

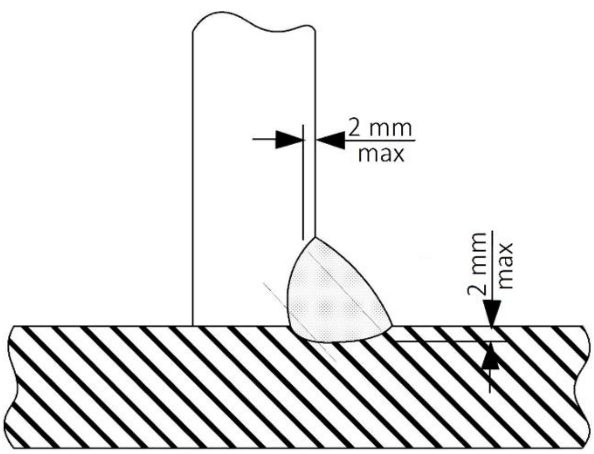


Fig. 12.11 Example of hardness test with row indentation in fillet welds

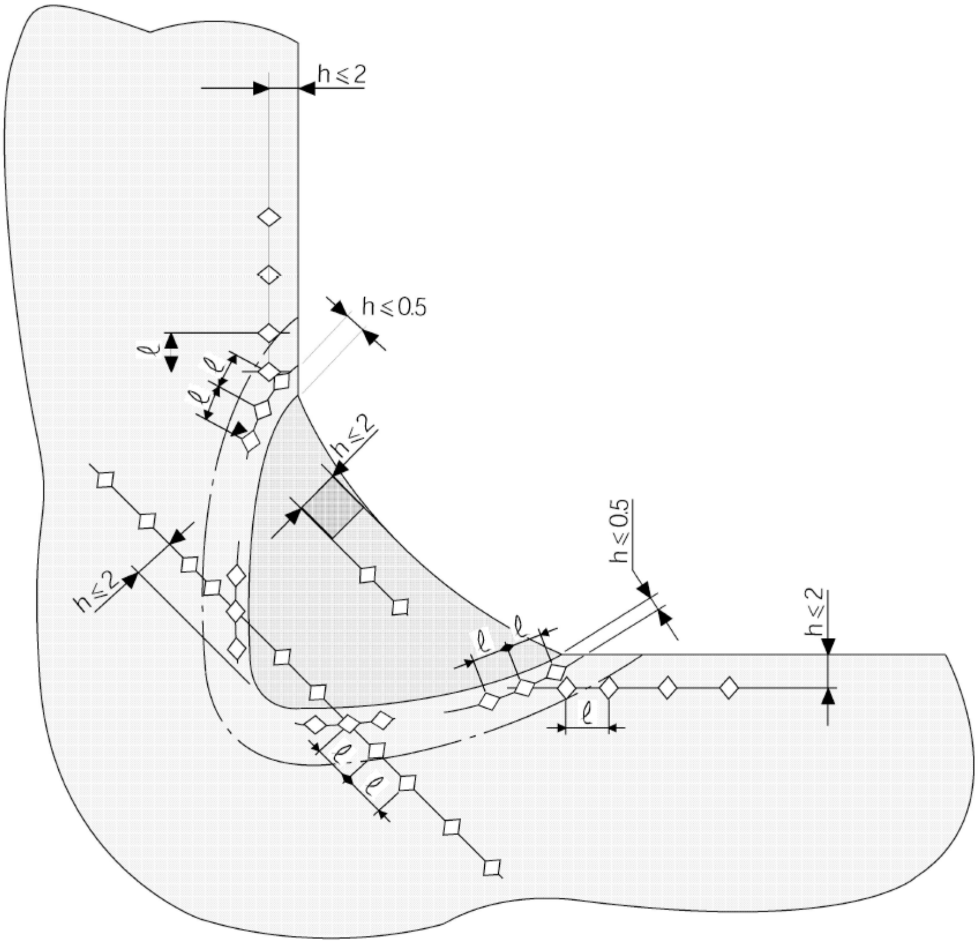


Fig. 12.12 Example of hardness indentations in fillet weld

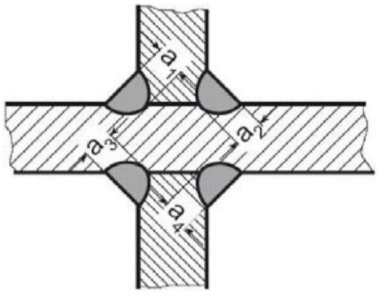
.6 Fracture test

The fracture test has to be performed in accordance with ISO 9017. Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration (penetration of the theoretical root point), to be assessed in accordance with ISO 5817, quality level "B".

.7 Cruciform tensile test

The cruciform tensile test specimens have to be evaluated in order to determine the tensile-shear strength of the weld metal according to Fig. 12.13. Before the performance of cruciform tensile tests, the fillet weld throat thicknesses and the width of the specimens have to be measured. The width of the specimen should be about 35 mm.

Measured on cruciform tensile test specimens, the minimum tensile (tensile-shear) strength of the weld section (fracture section in accordance with Fig. 12.13) shall meet the requirements stated in Table 12.4.



$a_1 + a_2$ = fracture section $S_{1/2}$
$a_3 + a_4$ = fracture section $S_{3/4}$

$$\text{Tensile-shear strength} = \frac{\text{Breaking load F}}{S_B \times \text{width of specimen}} \quad [\text{N/mm}^2]$$

S_B = $S_{1/2}$ or $S_{3/4}$ according to position of fracture

Fig. 12.13 Cruciform tensile test specimen (weld cross section)

Table 12.4 Requirements applicable to cruciform tensile specimens

Grades	Tensile-shear strength [N/mm^2]
A – E	350
A 32 – F 36	430
A 40 – F 40	450

4.4 Re-testing

If the test specimen fails to comply with any of the requirements for visual or non-destructive testing one further test piece is to be welded and subjected to the same examination. If this additional test piece does not comply with the relevant requirements, the pWPS has to be regarded as not capable of complying with the requirements without modification.

If any test specimen fails to comply with the relevant requirements for destructive testing due to weld imperfections only, two further test specimens have to be obtained for each one that failed. These specimens can be taken from the same test specimen if there is sufficient material available or from a new test specimen, and have to be subjected to the same test. If one of these additional test specimens does not comply with the relevant requirements, the pWPS has to be regarded as not capable of complying with the requirements without modification.

If a tensile test specimen fails to meet the requirements, two more tensile tests may be performed. If both additional specimens comply with the requirement, the tensile test is passed. If one or both of the additional specimens do not comply with the requirement, the tensile test and thus the procedure test has been failed.

If there is a single hardness value above the maximum values allowed, additional hardness tests are to be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

When the average value of the three initial Charpy V-notch impact specimens fails to meet the stated requirement or the value for more than one specimen is below the required average value or when the value of any one specimen is below 70% of the specified average value, three additional specimens from the same test piece may be tested and the results added to those previously obtained to form a new average. However, of the six individual values only two may be below the required average value, of which only one individual value may be less than 70% of the prescribed average value. Otherwise the impact test and thus the procedure test has been failed.

Where there is insufficient welded assembly remaining to provide additional test specimens, a further assembly has to be welded using the same procedure to provide the additional specimens.

4.5 Test record

Welding conditions for test assemblies and test results have to be recorded in a welding procedure test record and submitted to BKI. Forms of welding procedure test records can be taken from these Rules (see Annex D) or from relevant standards. The relevant items listed for the WPS of these requirements have to be included.

The welding procedure test record has to be signed by the Surveyor witnessing the test and submitted to BKI together with the welding procedure specification for the final approval of the welding procedure.

5. Welding procedure qualification tests for high-strength (quenched and tempered) finegrained steels with a specified minimum yield strength R_{eH} > 400 N/mm^2

Unless no further statements to the procedure tests are made in the following, the requirements given in the previous sections apply. For welding procedure tests on high-strength steels intended for hull structures BKI acceptance on a case by case decision is necessary. The requirements will be defined separately.

5.1 The following requirements apply for high strength (quenched and tempered) fine-grained steels for welded structures according to the Rules for Materials (Pt.1, Vol. V). Comparable high-strength steels, suitable for welding, can only be used with BKI's agreement.

5.2 For high-strength and quenched and tempered steels with a specified minimum yield strength R_{eH} > 400 N/mm^2, the non-destructive test has to be carried out at least 48 hours after the welding, unless heat treatment has been carried out.

5.3 A round tensile test specimen is to be prepared in every case where the mechanical properties of the weld metal are inferior to those of the base material.

5.4 The bending tests have to be performed, depending of the specified minimum yield strength in the range of 420 N/mm^2 up to 500 N/mm^2 using a mandrel with a diameter of 5 × the specimen thickness, and in the range above 500 N/mm^2 up to 690 N/mm^2 using a mandrel with a diameter of 6 × the specimen thickness. The required bending angle is 180°.

5.5 For high-strength and quenched and tempered steels, where the impact energy has been demonstrated in transverse direction (CVN-T), the welding seam has to be arranged parallel to the rolling direction of both plates. The requirements for the impact energy and the test temperature are the same as for the base material.

5.6 The results of the hardness test for high strength and quenched and tempered steels of a specified minimum yield strength R_{eH} > 400 N/mm^2 and $R_{eH} \leq$ 690 N/mm^2 shall not exceed a hardness of 420 HV10.

5.7 For fillet welds on high-strength and quenched and tempered steels with a specified minimum yield strength R_{eH} > 460 N/mm^2 separately fillet weld procedure tests are required using double-T joint (cruciform) test specimens. If the fracture occurs in the base material, at least the minimum tensile strength of the base material is to be achieved. If the fracture occurs in the cross-section of the weld seam, the tensile-shear strength is to be determined, taking into consideration the actual cross-section of the weld seam. Where necessary, the melting depth has to be considered which exceeds the theoretical root point. The mean tensile-shear strength determined in the weld seam cross-section shall be at least 80% of the tensile strength of the base material used.

5.8 For the range of application see Section 9.

6. Austenitic stainless (clad) and austenitic-ferritic (duplex) steels

If no further statements are made regarding welding procedure tests in the following, Section 4 or respectively the standards of series ISO 15614 are applicable.

6.1 For welding procedure tests for austenitic stainless steels for liquefied natural gas tanks see Rules for Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX).

6.2 The minimum properties specified in Section 5, for the testing of welding consumables and auxiliary materials shall be met for butt weld specimens. In the case of joints between different types of steels, the strength values of the base material which has the lower strength, shall be used.

6.3 Unless otherwise agreed in an individual case, a bending mandrel diameter of 3 times the specimen thickness may be used for the bending test and a test temperature of minus 30°C for the notched bar impact test performed on austenitic-ferritic (duplex) steels. For austenitic stainless materials normally no notched bar impact tests have to be performed unless the qualification of the welding procedures is necessary for a low temperature application. Hardness test for austenitic stainless materials have normally not to be performed as well. For such materials, dye penetration tests have to be carried out.

6.4 Depending on the field of application or if required for the base material, additional corrosion protection tests have to be performed within the scope of welding procedure tests, e.g. testing of resistance against intergranular corrosion.

6.5 For test specimens of austenitic-ferritic (duplex) steels a determination of the ferrite content is additionally necessary, which should not be less than 30% in both the welding material and in the heat affected zone.

7. Aluminium alloys

7.1 Butt Weld

7.1.1 Assembly and dimension of test pieces

The test pieces shall be of sufficient size to ensure a reasonable heat distribution during welding and to provide for the required test specimens, after sufficient discard at the ends, see Fig.12.14. The edge preparation and fit up shall be in accordance with the pWPS. If tack welds are to be fused into the production joint they shall be included in the test pieces.

The test assembly shall have the following minimum size:

- manual and semiautomatic welding:
  - length L = 350 mm
  - width W = 300 mm
- automatic welding
  - length L = 1000 mm
  - width W = 400 mm

The cleaning of the parts to be welded shall be carried out in accordance with the welding procedure. The welding shall be carried out in accordance with the pWPS and under the general conditions of production welding which it represents. Location of test specimens is represented in Fig. 12.15.

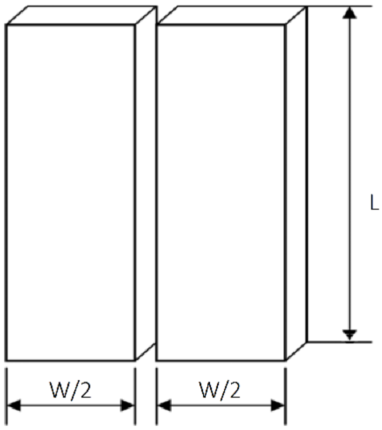


Fig. 12.14 Test assembly for Aluminium Alloys

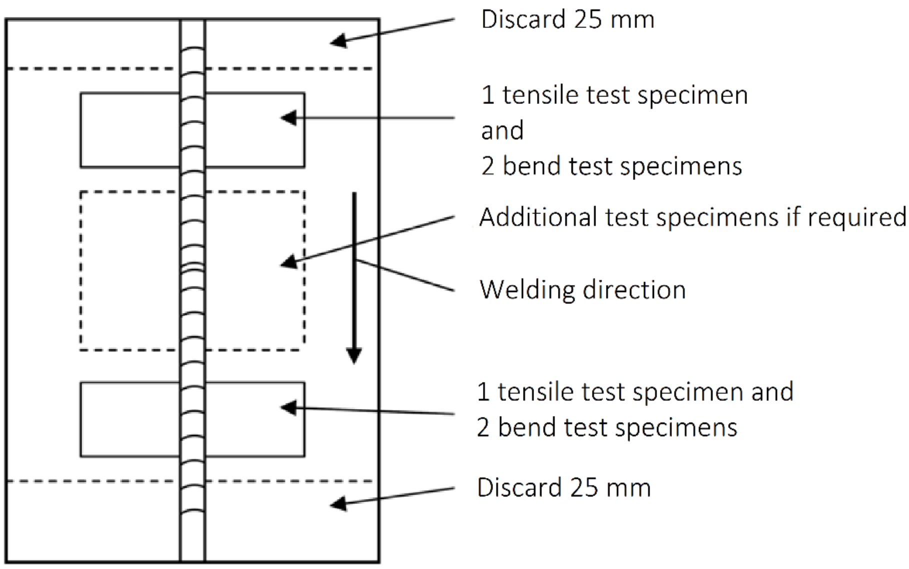


Fig. 12.15 Location of test specimens for a butt joint in plate

7.1.2 Scope of testing and test specimens

The butt weld test assemblies are to be examined non-destructively and destructively in accordance with the following requirements:

– Visual testing	100 %
– Surface crack detection	100 % (dye penetrant testing or magnetic particle testing)
– Radiographic or ultrasonic testing	100 %
– Transverse tensile test	two specimens
– Transverse bend test	two root and two face specimens
– Macro examination	one specimen

.1 Non-destructive testing

Test assemblies have to be examined by visual and non-destructive testing prior to the cutting of test specimens. In case that any post-weld heat treatment is required or specified, the non-destructive testing has to be performed after the heat treatment. BKI may require specific testing intervals to be adhered to between completion of the welding work and performance of the crack test, unless a heat treatment has been executed. Imperfections detected by visual or non-destructive testing have to be assessed in accordance with ISO 10042 quality level B except for excess weld metal and excess of penetration for which the quality level C applies.

.2 Transverse tensile test

The testing has to be carried out in accordance with ISO 4136. The stipulated tensile strength values apply to test specimens by retaining the weld reinforcement. In case of great plate thicknesses more test specimens have to be intended for testing in order to cover the whole cross section. In no case the tensile strength of the specimens shall not be less than the minimum stipulated value for the base material in its "soft" condition. For welding procedure tests and tests on production specimens relating to aluminium alloys, the values specified in Table 12.5 shall be used as standard values for butt weld specimens.

Table 12.5 Requirements applicable to aluminium alloys

Base material		Welded joints [1]			
Alloy No.	Material designation	0,2 %-proof stress [2] [N/mm^2]	Tensile strength [N/mm^2]	Bending angle [3] [degree]	Bending elongation [%]
5754	AlMg3	80	190	180	18
5086	AlMg4	100	240		
5083	AlMg4,5Mn0,7	125	275		
5383	AlMg4,5Mn0,7mod.	145	290		
5456	AlMg5	130	290		
5059	AlMg5,5Mn0,8ZnZr	160	330		
6005A	AlSiMg(A)	115	170		10
6061	AlMgSilCu	115	170		
6082	AlSilMgMn	125	185		

[1] Using a weld consumable of a quality grade in accordance with the base material according to Section 5, J.
[2] As far as established (on additional samples which are to be agreed).
[3] Bending mandrel-i to be selected depending on the material group and condition according EN ISO 15614-2.

.3 Bend test

Transverse bend tests have to be carried out in accordance with ISO 5173. Two of the four test specimens have to be bent with final pass in tension and the other two have to be bent with the root pass in tension. In case of specimen thicknesses ≥ 12 mm, four side bend test specimens can be alternatively tested. For butt joints in heterogeneous or dissimilar, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

The bend test specimens shall be bent on a mandrel with maximum diameter as given in the formula below. The bending angle shall be 180° under the test conditions specified in ISO 5173.

$$d = \frac{(100 \cdot t_s)}{A} - t_s$$

Where:

d = the maximum former diameter

t_s = the thickness of the bend test specimen (this includes side bends)

A = the minimum tensile elongation required by the alloy grade, temper condition and thickness (for combination between different alloys, the lowest individual value shall be used).

After testing the test specimens shall not reveal any open defect in any direction greater than 3 mm. Defects appearing at the corner of the specimens may be disregarded, unless there is evidence that they result from lack of fusion.

.4 Macro examination

The test specimen shall be prepared and etched on one side to clearly reveal the fusion line, the HAZ and the build up of the runs and the unaffected base metal. The examination shall reveal a regular weld profile, thorough fusion between adjacent layers of weld and base metal and the absence of defects such as cracks and lack of fusion. The acceptance levels specified in 7.1.2.1 apply

7.2 Fillet Weld

7.2.1 Test assembly, dimension and welding

.1 T-joint test pieces

The minimum size of the test assemblies shall be as follows:

- manual and semiautomatic welding:
  - length L = 350 mm
  - width W = 150 mm,
- automatic welding:
  - length L = 1000 mm
  - width W = 150 mm.

The two plates shall be positioned and tack welded edgewise so as to constitute a T assembly without clearance. Welding on one or both sides and fit up shall be as detailed in the pWPS. In general for manual and semiautomatic welding a stop/restart position shall be included in the test length and shall be clearly marked for subsequent examination. The cleaning of the parts to be welded shall be carried out in accordance with the welding procedure.

.2 Double T- joint (cruciform) test pieces

The test assembly and dimensions are as shown in Fig.12.8 and 12.9.

7.2.2 Examinations and tests

Non-destructive examination and destructive test shall be carried out in accordance with these requirements

.1 Examinations and tests of T-joint test pieces

- Visual testing 100 %

– Surface crack detection 100 % (dye penetrant testing or magnetic particle testing)
– Macro examination 2 specimens (One of macro section shall be taken at the position of the stop/restart (see 7.2.1)
– Fracture test required

.2 Examinations and tests of double-T joint (cruciform) test pieces

Examinations and tests of double-T joint (cruciform) test pieces should be carried out in accordance with 4.3.3.2. The hardness test maybe omitted

7.2.3 Cruciform test

In addition to examination and test required for T joint test piece (see 7.2.2.1), one or more sets of test piece shall be taken from the cruciform test piece in accordance with Fig. 12.10. The test specimens are as shown in Fig.12.13.

If the rupture occurs in the base material, at least the minimum tensile strength of the base material in its "soft" condition has to be achieved. If the rupture occurs in the cross-section of the weld seam, the tensile shear strength has to be determined, taking the actual cross-section of the weld seam into consideration. Where necessary, the melting depth which exceeds the theoretical root point has to be considered. The mean tensile-shear strength determined in the weld seam cross-section shall be at least 60 % of the tensile strength of the used base material. Necessary margins (if this value is not attained) have to be considered for the dimensioning of fillet joints.

7.2.4 Macro examination and Fracture test

The fracture test as well as the macro examination shall, in general, satisfy the acceptance level specified in 7.1.2.1. Dimension of leg size, throat and penetration shall in general be reported.

8. Other materials or welding processes

The requirements applicable to other materials or other test methods will be determined on a case-by-case basis in a manner analogous to that applied to the materials covered earlier, on the basis of their chemical composition, mechanical properties and other characteristics of the base materials and with due regard for the anticipated operating conditions, such as the lowest anticipated service temperature (design).

9. Scope of application

9.1 General

All the conditions of validity stated below have to be met independently of each other.

9.2 Changes outside of the ranges specified and approved by BKI require a new welding procedure test.

9.3 Shop primers may have an influence on the quality of fillet welds. Therefore they have to be taken into account for the testing. Welding procedure qualification with shop primer will qualify those without shop primer, but not vice versa.

9.4 Base metal

9.4.1 Normal- and higher strength hull structural steels

The strength level (--, …32, …36, …40) and the toughness grade (A/A…, B, D/D…, E/E…, F…) of the specimen are decisive for the scope of application.

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as the tested one.

b) For each toughness grade, welding procedures are considered applicable to the same and two lower strength levels as the tested one.

c) For applying the above a) and b) to high heat input processes above 50 kJ/cm, e.g. the two-run technique with either submerged arc or gas shielded metal arc welding, electro slag and electro gas welding, welding procedure is applicable to that toughness grade tested and one strength level below.

If steels used for construction are supplied with different delivery conditions as those tested, BKI may require additional tests. Welding procedure tests of thermo-mechanically rolled (TM) steels do not include normalised steels, however vice versa.

9.4.2 YP47 steel

Welding procedures are considered applicable to weld steels in grade A40, D40, and E40. The approval only qualifies for thermo-mechanically rolled (TM) steels.

9.4.3 High strength (quenched and tempered) steels with R_{eH} > 400 N/mm^2

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as the tested one.

b) For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as the tested one.

c) The approval of quenched and tempered steels does not qualify thermo-mechanically rolled (TM) steels and vice versa.

9.4.4 Weldable C and C-Mn hull steel forgings

a) Welding procedures are considered applicable to the same and lower strength level as the tested one.

b) The approval of quenched and tempered hull steel forgings does not qualify other delivery conditions and vice versa. These have to be tested and qualified separately.

9.4.5 Weldable C and C-Mn hull steel castings

a) Welding procedures are considered applicable to the same and lower strength level as the tested one.

b) The approval of quenched and tempered hull steel castings does not qualify other delivery conditions and vice versa. These have to be tested and qualified separately.

9.4.6 Aluminium Alloys

The aluminium alloys are grouped into three groups:

Group A : aluminium-magnesium alloys with Mg content ≤ 3.5% (alloy 5754)

Group B : aluminium-magnesium alloys with 4% ≤ Mg ≤ 5.6% (alloys 5059, 5083, 5086, 5383 and 5456)

Group C : aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082)

For each Group, the qualification made on one alloy qualifies the other alloys of the same Group with equal or lower specified tensile strength after welding.

The qualification made on Group B alloy qualifies alloys in Group A.

9.5 Thickness

9.5.1 The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.6 for steels and Table 12.7 for aluminium.

9.5.2 In addition to the requirements of Table 12.6 and Table 12.7, the range of approval of throat thickness "a" for fillet welds is to be as follows:

a) Steel

- single-run : 0,75 × a to 1,5 × a
- multi-run : as for butt welds with multi-run (i.e. a = t)

b) Aluminium alloys

- a < 10 mm : 0,75 × a to 1,5 × a
- a ≥ 10 mm : ≥ 7,5

9.5.3 For the vertical-down welding, the test piece thickness "t" is always taken as the upper limit of the range of application.

9.5.4 For unequal plate thickness of butt welds, the lesser thickness is the ruling dimension.

9.5.5 Notwithstanding the above, the approval of maximum thickness of base metal for any technique has to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated in 4.2.2.7, 4.3.3.5 and 5.6.

9.6 Welding positions

Approval for a test made in any position is restricted to that position, except for aluminium alloys, approval for a test in any one position qualifies for welding in all positions. To qualify a range of positions, test assemblies have to be welded for highest heat input position (normally vertical-up position (PF)) and lowest heat input position (normally horizontal-vertical (PC)). The vertical-down welding position (PG), in general, has to be tested separately.

Table 12.6 Approval range of thickness for steels

Thickness of test piece t [1)] [mm]	Range of approval [4)]	
	Butt welds with single-run or single-run from both sides	Butt welds with multi-run and fillet welds [2)]
3 < t ≤ 12	0,7 x t to 1,1 x t	3 to 2 x t
12 < t ≤ 100	0,7 x t to 1,1 x t [3)]	0,5 x t to 2 x t (max. 150 mm)

1) For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval for the individual welding process.
2) For fillet welds, the range of approval is to be applied to both base metals (web and flange thickness).
3) For high heat input processes over 50 kJ/cm, the upper limit of range of approval is to be 1,0 H t.
4) T-butt welds are in general qualified by butt welds. BKI may additionally require welding procedure tests as T- joint welds, e.g. for particular weld shapes.

Table 12.7 Approval range of thickness for aluminium alloys

Thickness of the test piece, t (mm)	Range of approval
t ≤ 3	0,5 to 2 t
3 < t ≤ 20	3 to 2 t
t > 20	≥ 0,8 t

9.7 Welding process

9.7.1 The approval is only valid for the welding process(es) used in the welding procedure test. A change from a multi-run to a single run is not allowed.

9.7.2 For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process. It is also possible to make the welding procedure test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

9.7.3 In general, full mechanized and automatic (robot) welding procedures have to be qualified separately from the semi-automatic welding procedures.

9.8 Welding consumables

Welding consumables and auxiliary materials may be replaced by other equivalent (and higher strength for aluminium alloys), suitable, with corresponding quality grade and with BKI approval, if this is explicitly stated in the welding procedure approval.

The qualification given to shielding gas and backing gas is restricted to the gas/gas mixture used in the welding procedure test, see ISO 14175 or other recognized standards for gas designations.

9.9 Type of current

Changes in the type of current (AC, DC, pulsed) and polarity require a new welding procedure qualification. For process 111 (SMAW) alternating current also qualifies direct current (both polarities) when impact testing is not required.

9.10 Heat input

9.10.1 The upper limit of heat input approved is 25% greater than that used in welding the test piece or 55 kJ/cm whichever is smaller, except that the upper limit is 10% greater than that for high heat input processes over 50 kJ/cm.

9.10.2 The lower limit of heat input approved is 25 % lower than that used when welding the test piece.

9.11 Preheating and interpass temperature

9.11.1 The minimum preheating temperature has not to be less than that used in the beginning of the welding of the test piece. If necessary, for the higher range of thicknesses, the specification of the preheating temperature may be increased. For the necessity and amount of preheating see Section 9.

9.11.2 The maximum interpass temperature has not to be higher than that used when welding the test piece. The standard values for the maximum interpass temperature according to Section 9 have to be observed.

9.12 Post-weld heat treatment

The heat treatment used in the qualification test has to be maintained during manufacture. The holding time may be adjusted as a function of thickness. Further notes with reference to post-weld heat treatment see Section 9.

9.13 Type of joint

9.13.1 The range of approval depending on type of welded joints for test assembly is shown in Table 12.8.

Table 12.8 Range of approval for type of welded joints

<table>
<tr><th colspan="4" rowspan="2">Type of welded joint for assembly</th><th colspan="2">Range of approval</th></tr>
<tr><th>Steel</th><th>Al alloys</th></tr>
<tr><td rowspan="4">Butt welding</td><td rowspan="2">one side</td><td>with backing</td><td>A</td><td colspan="2">A, C, D</td></tr>
<tr><td>without backing</td><td>B</td><td colspan="2">A, B, C, D</td></tr>
<tr><td rowspan="2">both side</td><td>with gouging</td><td>C</td><td colspan="2">C</td></tr>
<tr><td>without gouging</td><td>D</td><td>C, D</td><td>A, C, D</td></tr>
</table>

9.13.2 A qualification test performed on a butt weld, if no shop primers are overwelded, will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 9.5.2 above. Additional qualification tests, e.g. for T-joints, may be required by BKI, e.g. if the edge preparation (root gap, included angle) has been changed and a lack of fusion, insufficient penetration or a negative influence on the mechanical-technological properties cannot be excluded.

G. Design, Dimensioning

Preliminary remark:

The contents of this section are largely identical to the provisions of the Rules for Hull (Pt.1, Vol. II) Sec. 19 "Welded Joints". Because of the time separating the reissues of the different rules, some temporary divergences may arise and in such circumstances the more recent rules shall prevail.

1. General

1.1 The general design principles described in Section 7 shall be followed.

1.2 Welded joints shall be designed to ensure that the proposed weld type and quality (e.g. complete root fusion in the case of single- and double-bevel butt welds) can be satisfactorily achieved under the given fabricating conditions. Failing this, provision shall be made for welds which are easier to execute and the (possibly lower) load-bearing capacity of these welds shall be allowed for in the dimensional design.

1.3 Severely stressed welded joints, which are therefore normally subject to compulsory inspection, shall be designed such that the most appropriate inspection technique for the detection of defects (radiography, ultrasonic or surface crack inspection) can be applied without restriction so that tests offering reliable results can be carried out.

2. Characteristics related to materials, corrosion

2.1 Characteristics related to materials, e.g. the (inferior) strength of rolled products in the thickness direction (see 7.) or the softening of hardened aluminium alloys when welded, are to be allowed for when designing and dimensioning the components and the welded joints.

2.2 Clad plates where the efficiency of the bond between the support and the superimposed material is proven may generally be treated as solid plates (up to medium plate thicknesses with mostly fillet welds).

2.3 In thermally stressed composite structures made of different materials (e.g. hull structural and stainless steels in the case of tank heating systems), due allowance shall be made for the differences in the thermal conductivities and especially the rates of thermal expansion of the different steels.

2.4 Where pairs of different materials are exposed to seawater or other electrolytes, e.g. the welded joints between unalloyed and stainless steels in the wear linings of rudder nozzles and in build-up welds on rudder stocks, attention is to be paid to the increased tendency towards corrosion, especially at the weld, due to the differences in electrochemical potential.

2.5 If welded joints of this kind cannot be avoided, they shall whenever possible be located at points where there is less danger of corrosion (e.g. outside tanks) or special corrosion protection shall be provided (e.g. coating or cathodic protection).

3. Stress flow, transitions

3.1 All welded joints on primary supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to expansion (see also the Rules for Hull (Pt.1, Vol. II) Sec.3, H.).

3.2 This applies in analogous manner to the welding of subordinate components onto primary supporting members whose exposed plate or flange edges should, as far as possible, be kept free from notch effects due to welded attachments. Regarding the inadmissibility of weldments to the upper edge of the sheer strake, see the Rules for Hull (Pt.1, Vol. II) Sec.6, C.3.3. This applies in analogous manner to weldments to the upper edge of continuous hatchway side coamings.

3.3 Butt joints in long or continuous external structures, such as bilge keels, fenders, slop coamings, crane rails, hatchway cover running rails, compression bars, etc. attached to primary supporting members are therefore to be welded over their entire cross section. Their ends shall be designed in analogous manner to the ends of the doubling plates (see 6.4) with "smooth" transitions into the component underneath.

3.4 Wherever possible, welded joints (especially site joints) in girders and sections shall not be located in areas of high bending stress. Joints at the buckling points of flanges are to be avoided. Full penetration welds uniting three plates with additional fillet welds applied from the rear side in analogous manner to Fig. 12.27 on buckle stiffeners are generally acceptable.

3.5 The transition between differing component dimensions shall be smooth and gradual. Where the depth of web of girders or sections differs, the flanges or bulbs are to be bevelled and the web slit and expanded or pressed together to equalize the depth of the members so that the flange or bulbs, as applicable, may be satisfactorily welded together. The length of the transition should equal at least twice the difference in depth.

3.6 Where the plate thickness changes at joints running perpendicular to the direction of the main stress, differences in thickness greater than 4 mm (greater than 3 mm where the thickness of the thinner plate is less 10 mm) shall be accommodated by bevelling the proud edge in the manner shown in Fig. 12.16 at a ratio of at least 1 : 3 or less according to the notch category (see the Rules for Hull (Pt.1, Vol. II) Sec.20, Table 20.3). Differences in thickness up to the values stated above may be accommodated within the weld.

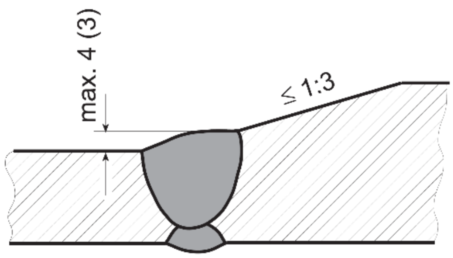


Fig. 12.16 Accommodation of differences in thickness

3.7 For the welding on of plates or other relatively thin-walled elements, steel castings and forgings shall be appropriately tapered or provided with integrally cast or forged welding flanges in accordance with Fig. 12.17. Failing this, BKI may approve a correspondingly thicker transition piece welded over its entire cross-section to the steel casting or forging in a manner analogous to that for shaft brackets (see Fig. 12.35 and 12.36) or to that for the horizontal rudder coupling flanges (see Fig. 12.37)

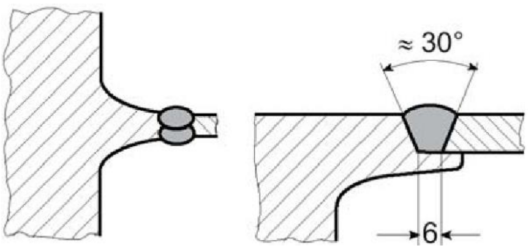


Fig. 12.17 Welding flange on steel castings and forgings

3.8 For the connection of shaft brackets to the hub and the shell plating, see 13. and the Rules for Hull (Pt.1, Vol. II) Sec.13, D.1.; for the connection of horizontal coupling flanges to the rudder body, see 14. For the thickened rudder stock collar required with build-up welds and for the connection of the coupling flange, see 9. and 14. respectively and the Rules for Hull (Pt.1, Vol. II) Sec.14, D.2.4. The connection between the rudder stock and the coupling flange shall be welded over the entire cross section.

4. Local clustering of welds, minimum spacing, socket weldments

4.1 Local clustering of welds and short distances between welds are to be avoided. Where account has to be taken of higher residual welding stresses due to thicker plates or welds and corresponding rigidity of the components, the preparation should allow for the fact that adjacent butt welds should be separated from each other by a distance of at least 50 mm + 4 x plate thickness Fillet welds should be separated from each other and from butt welds by a distance of at least 30 mm + 2 x plate thickness In this case, the applicable dimensions are edge of fillet weld to edge of fillet weld or edge of fillet weld to centre of butt weld. The width of interchangeable sections (strips) of plates should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater. Other dimensions shall be subject to approval by BKI in each individual case as part of the examination of the drawings.

Note:

In special cases, for example where plating bends over its length (e.g. the inner bottom plating in the fore section of the hull or lateral longitudinal bulkheads in the fore and aft sections of the hull), especially in the lower plate thickness range (up to approx. 20 mm) it may be advisable, in order to improve buckle stiffening - or where the weld throat thicknesses are not too large (up to about 5 mm) - to reduce the distances stated above or even position the buckle stiffening section or the like directly on the plate weld causing the buckling.

Although the extra fillet welds on the butt joint produce an additional clustering of welds and thus residual welding stresses, this is relatively minor compared with the residual welding stresses which occur in larger plate thicknesses and the correspondingly larger number of passes and may therefore be acceptable as a way of increasing the strength properties of the design. For permitted tolerances, see H.3.

4.2 Reinforcing plates, welding flanges, drain unions, mountings and similar components socket-welded into plating should be of the following minimum size:

$$D_{min.} = 170 + 3\,(t - 10) \geq 170 \text{ mm}$$

Where,

D = Diameter of round or length of side of angular socket weldments [mm]

t = Plating thickness [mm]

With angular socket weldments, the corner radii should be at least 50 mm or the "longitudinal seams" should be extended beyond the "transverse joints". Socket weldments shall be welded to the surrounding plating over the entire cross-section. For the provisions relating to the increase in stresses due to possible differences in thickness, see the Rules for Hull (Pt.1, Vol. II) Sec. 20, B.1.3.

5. Welding apertures

5.1 Welding apertures for the (later) execution of butt or fillet welds following the positioning of transverse members should be rounded (minimum radius 25 mm or twice the plate thickness, whichever is the greater) and (especially where the loading is mainly dynamic) should be shaped to provide a gentle transition to the adjoining surface and adequately notch-free welding should be carried out around the end faces as shown in Fig. 12.18.

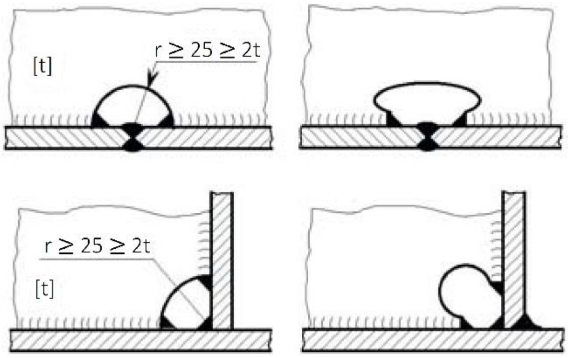


Fig. 12.18 Welding apertures

5.2 Where the welds are completed prior to the positioning of transverse members, no welding apertures are needed. Any weld reinforcements present are to be machined off prior to positioning the transverse member, or the members to be positioned are to be notched accordingly.

6. Local reinforcements, plate doublings

6.1 Where platings (including girder plates and tube walls) are subjected locally to increased stresses, thicker plates should be used wherever possible in preference to plate doublings. Bearing bushes, hubs, etc. shall invariably take the form of thicker sections welded into the plating (see 4.2).

6.2 Where doublings cannot be avoided, the thickness of the doubling plate should not exceed twice the plating thickness. Doubling plates whose width is greater than approximately 30 times their thickness shall be plug-welded to the underlying plating in accordance with 10.5 at intervals not exceeding 30 times the thickness of the doubling plate.

6.3 Along their (longitudinal) edges, doubling plates shall be continuously fillet welded with a throat thickness "a" of 0,3 x the doubling plate thickness. At the ends of doubling plates, the throat thickness "a" at the end faces shall equal 0,5 x the doubling plate thickness t, but shall not exceed the plating thickness (see Fig. 12.19).

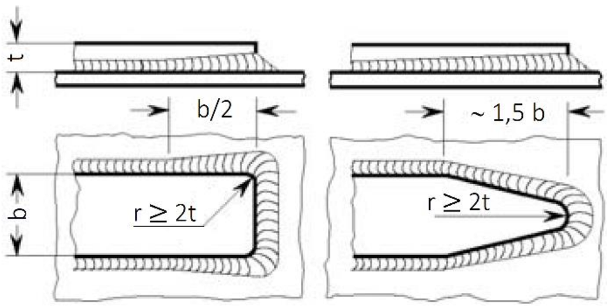


Fig. 12.19 Welds at the ends of doubling plates

6.4 The weld joining the end faces to the plating should make a smooth transition with the latter at an angle of 45° or less.

Where proof of fatigue strength is demanded, (see Section 20 of the Rules for Hull (Pt.1, Vol. II)) the ends of the doubling plates shall be designed so that they comply with the detail category selected.

6.5 Doubling plates are not acceptable in tanks for flammable liquids, gases or chemicals.

7. Transverse members, stress in the thickness direction

7.1 Where, in the case of members lying transverse to each other, plates or other rolled products are stressed in the thickness direction by residual stresses due to the welding and/or by applied loads, suitable measures shall be taken in the design and fabrication of the structures to prevent lamellar tearing (stratified fractures) due to the anisotropy of the rolled products.

7.2 Such measures include the use of suitable weld shapes with a minimum weld volume and an appropriate welding sequence designed to reduce transverse shrinkage. Other measures are the distribution of the stresses over a larger area of the plate surface by using a build-up weld or the "joining together of several layers" of members stressed in the thickness direction, as exemplified by the deck stringer/sheer strake joint shown in Fig. 12.28.

7.3 Where there are very severe stresses in the thickness direction (due, for example, to the aggregate effect of the shrinkage stresses of bulky single- or double-bevel welds plus high applied loads), plates with guaranteed through thickness strength properties are to be used (higher degree of purity and guaranteed minimum reductions in area of ≥ 20% of tensile test specimens taken in the thickness direction[1].

7.4 Sandwiched flat bar steel positioned transversely to the direction of force (e.g. for use as backings for plug welding or to accommodate excessive air gaps) are not permitted where components intersect.

8. Welding of cold-formed sections, bending radii.

8.1 In structural steels with a tendency towards strain ageing, welding of the cold-formed sections with more than 5% permanent elongation[2] and the adjacent areas with 5 H plate thickness should be avoided wherever possible. In case of doubt BKI may demand proof (e.g. in the form of notched bar impact tests) that cold forming and subsequent welding have not caused any unacceptable reduction in toughness characteristics.

8.2 Welding of the cold-formed sections and adjacent areas of hull structural steels and comparable structural steels (e.g. quality groups S.....J.... or S....K..... conforming to EN 10025) may be performed, provided that the minimum bending radii are not less than those specified in Table 12.9.

Table 12.9 Minimum bending radii for welding of cold-formed sections

Plate thickness t	Minimum inner bending radius r
4 mm or less	1 x t
8 mm or less	1,5 x t
12 mm or less	2 x t
24 mm or less	3 x t
over 24 mm	5 x t

Note:

1 See the Rules for Materials (Pt.1, Vol. V) Sec. 4, I.
2 Elongation ε in the outer tensile-stressed zone :

$$\varepsilon = \frac{100}{1 + 2 \cdot r/t} \quad \%$$

r = inner bending radius [mm]
t = plate thickness [mm]

The bending capacity of the material may necessitate a larger bending radius.

8.3 For other steels and, where applicable, other materials, the necessary minimum bending radius shall, in case of doubt, be established by test. Proof of adequate toughness after welding may be stipulated for steels with minimum yield strengths of more than 355 N/mm^2 and plate thicknesses of 30 mm and above which have undergone cold forming resulting in 2% or more permanent elongation.

9. Build-up welds on rudderstocks and pintles

9.1 Wear-resistant and/or corrosion-resistant build-up welds on the bearing surfaces of rudderstocks, pintles, etc. shall be applied to a thickened collar exceeding by at least 20 mm the diameter of the adjoining part of the shaft.

9.2 Where a thickened collar is impossible for design reasons, the build-up weld may be applied to the smooth shaft provided that relief-turning in accordance with 9.3 is possible (leaving an adequate residual diameter).

9.3 After welding, the transition areas between the welded and non-welded portions of the shaft shall be relief-turned with large radii, as shown in Fig. 12.20, to remove any base material whose structure close to the concave groove has been altered by the welding operation and in order to effect the physical separation of geometrical and "metallurgical" notches.

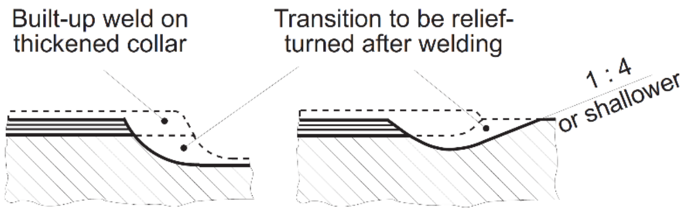


Fig. 12.20 Build-up welds applied to rudderstocks and pintles

9.4 If, during a repair, a build-up weld is exceptionally to be applied to the smooth shaft without relief turning with the special permission of BKI, this weld shall be made in analogous manner to 9.3 (at an adequate distance beyond the zone of maximum bending stress) as shown in Fig. 12.21 in such a way that at least two passes of weld metal remain in the smooth part of the shaft after machining. The transition between the build-up weld and the shaft shall be machined cleanly and free of notches.

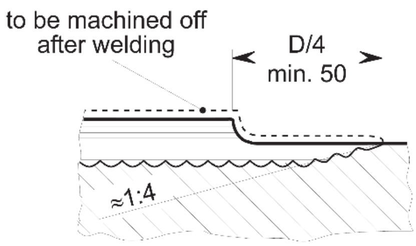


Fig. 12.21 Repair made by build-up welding

9.5 Build-up welding may only be carried out using a fully mechanized process approved by BKI (e.g. 12, submerged-arc welding) in the circumferential direction on a rotating fixture.

10. Weld shapes and dimensions

10.1 Butt joints

10.1.1 Depending on the plate thickness, the welding process and the welding position, butt joints shall take the form of square, V or double-V welds (double V butt joints) conforming to the standards (e.g. ISO 2553, EN 29629, ISO 9692-2, ISO 9692 or ISO 9692-4). The weld shapes shall be illustrated in the drawings or in other production documents, together with the standard symbols.

10.1.2 Where weld shapes are proposed other than those specified in the standards, these are to be specially described in the drawings. Weld shapes for special welding processes (e.g. submerged-arc, single-side welding, electrogas or electroslag welding) shall have been tested and approved in the context of a welding procedure test.

10.1.3 As a matter of principle, the rear sides of butt joints shall be grooved and welded with at least one backing run (capping pass). Exceptions to this rule, as in the case of submerged-arc welding or the welding processes mentioned in 10.1.1, require testing and approval in the context of a welding procedure test.

10.1.4 Where the aforementioned conditions cannot be met (e.g. where the welds are accessible from one side only), the joints shall be executed as lesser bevelled welds with an open root and an attached or an integrally machined or cast permanent weld pool support (backing), as shown in Fig. 12.22.

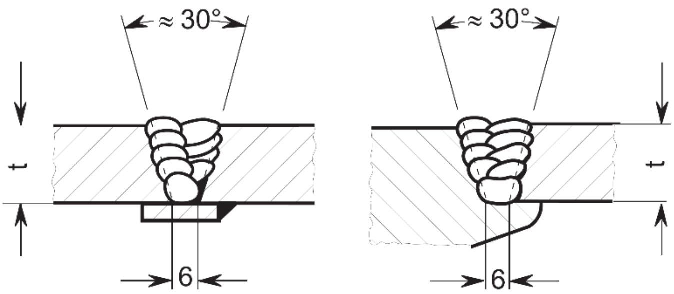


Fig. 12.22 Single-side welds with permanent weld pool supports (backings)

10.1.5 The effective weld thickness is deemed to be the plate thickness or, where the plate thicknesses differ, the lesser plate thickness. Where proof of fatigue strength is required (see 15.3), the detail category depends on the workmanship (geometry and quality) of the weld.

10.1.6 The weld shapes illustrated in Fig. 12.23 shall be used for clad plates. These weld shapes shall be used in analogous manner for corner joints and for joining clad plates to (unalloyed and low- alloy) hull structural steels.

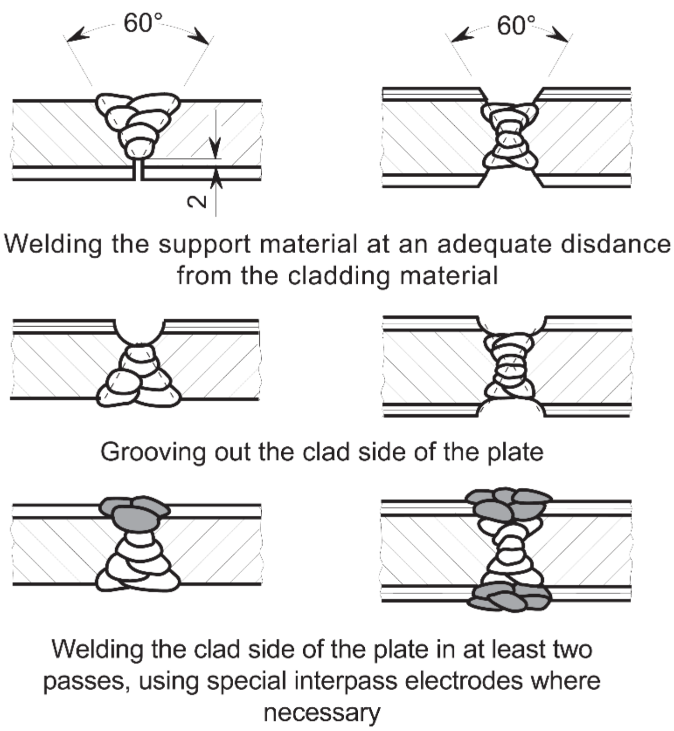


Fig. 12.23 Weld shape for welding of clad plate

10.2 Corner, T and double-T (cruciform) joints

10.2.1 Corner, T and double-T (cruciform) joints with full root penetration connection of the abutting plates shall be executed as single- or double-bevel welds with a minimum root face and adequate air gap, as shown in Fig. 12.24, and with grooving of the root and capping from the opposite side.

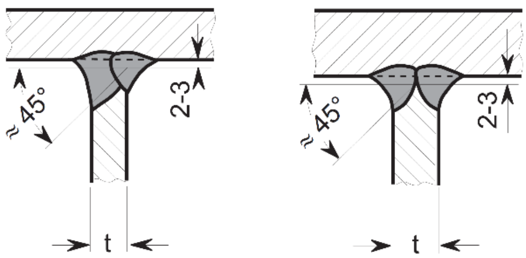


Fig. 12.24 Single-and double-bevel welds with full root penetration

The effective weld thickness is deemed to be the thickness of the abutting plate. Where proof of fatigue strength is required (see 15.3), the detail category depends on the workmanship (geometry and quality) of the weld. These welds are to be classified according to type D1 in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 20, Table 20.3.

10.2.2 Corner, T and double-T (cruciform) joints with a defined incomplete root penetration "f", as shown in Fig. 12.25 shall be executed as single- or double-bevel welds, as described in 10.2.1, with capping from the rear side but without grooving of the root.

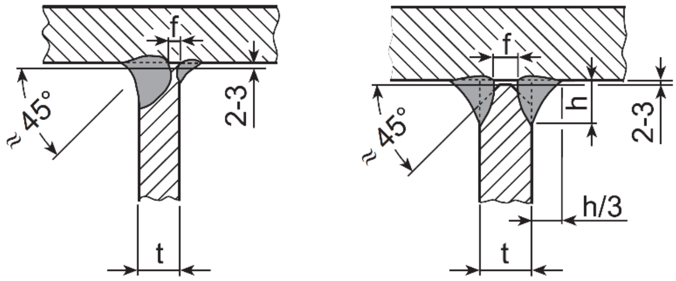


Fig. 12.25 Single-and double-bevel welds with defined incomplete root penetration

The effective weld thickness may be deemed to be the thickness t (- f) of the abutting plate, the assumed incomplete root penetration f = 0,2 t, max. 3 mm, being compensated for by means of additional fillet welds of at least equal size applied to each side. As a practical dimension, a leg length of z = h/3 at the root of the weld may be prescribed where h is the depth of the weld as shown in the figure. If proof of fatigue strength is required (see 15.3), these welds may also be placed in detail category no. D1 in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 20, Table 20.3.

10.2.3 Corner, T and double-T (cruciform) joints with an unwelded root face "c" and an incomplete root penetration "f" which is also to be allowed for shall be executed in accordance with Fig. 12.26.

The effective weld thickness is deemed to be the thickness of the abutting plate t - (c + f), where f is to be assigned a value of 0,2 t subject to a maximum of 3 mm. Where proof of fatigue strength is required (see 15.3), and depending on the plate thickness to weld thickness ratio, these welds are to be classified according to type D2 or D3 in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 20, Table 20.3.

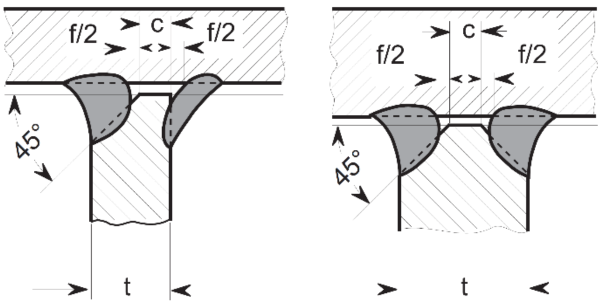


Fig. 12.26 Single- and double-bevel welds with unwelded root face and defined incomplete root penetration

10.2.4 Corner, T and double-T (cruciform) joints which are accessible from one side only may be executed in accordance with Fig. 12.27 in a manner analogous to the butt joints referred to in 10.1.4 using a weld pool support (backing) or as single-side single-bevel welds laid down in a manner similar to that prescribed in 10.2.2.

The effective weld thickness shall be determined by analogy with 10.1.5 or 10.2.2, as appropriate. Wherever possible, these joints should not be used where proof of fatigue strength is required (see 15.3).

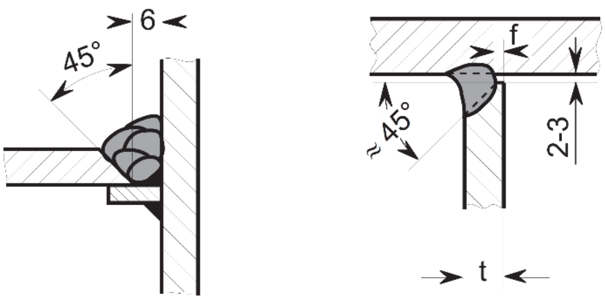


Fig. 12.27 Single-side welded T-joints

10.2.5 Where corner joints are flush, i.e. with neither of the plates standing proud, the weld shapes shall be as shown in Fig. 12.28 with bevelling of the perpendicularly juxtaposed plates to avoid the danger of lamellar tearing (stratified fracture, see 7). A similar procedure is to be followed in the case of fitted T-joints (uniting three plates) where the perpendicular plate illustrated is to be socketed (between two horizontal plates).

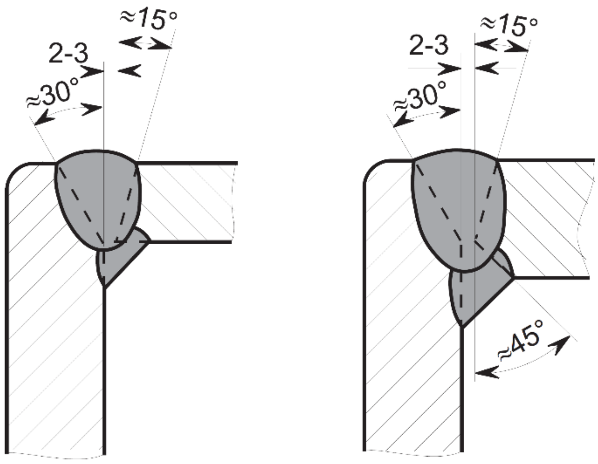


Fig. 12.28 Flush fitted corner joints

10.2.6 Where, in the case of T-joints (uniting three plates), the direction of the main stress lies in the plane of the horizontal plates (e.g. the plating) shown in Fig. 12.29 and the connection of the perpendicular (web) plates is of secondary importance, welds uniting three plates may be made in accordance with Fig. 12.29 (with the exception of those subjected mainly to dynamic loads).

The effective thickness of the weld uniting the horizontal plates shall be determined by analogy with 10.1.5. The requisite "a" dimension is determined by the joint uniting the vertical (web) plates and shall, where necessary, be determined in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 19, Table 19.3 or by calculation as for fillet welds.

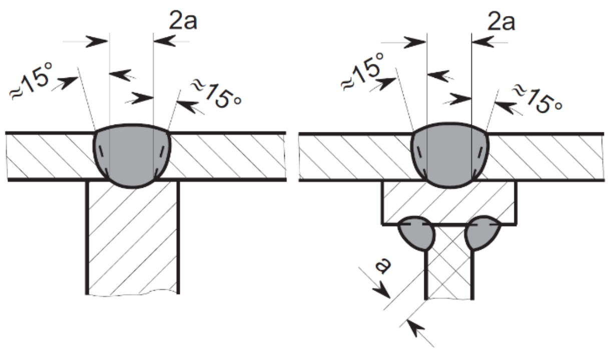


Fig. 12.29 Welding together three plates

10.3 Fillet weld joints

10.3.1 Fillet welds shall normally be made on both sides, and exceptions to this rule (as in the case of closed box girders and predominant shear stresses parallel to the weld) are subject to approval in each individual case. The throat thickness "a" of the weld (the height of the inscribed isosceles triangle) shall be determined in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 19, Table 19.3 or by calculation in accordance with 15. The leg length "z" of a fillet weld is to be not less than 1,4 H the throat thickness "a". For fillet welds at doubling plates, see 6.3 for the welding of deck stringer to sheer strakes, see the Rules for Hull (Pt.1, Vol. II) Sec. 7, A.2.1, and for bracket plate connections, see Sec. 19, C.2.7.

10.3.2 The relative fillet weld throat thicknesses specified in the above-mentioned Table 19.3 relate to normal- and higher-strength hull structural steels and comparable structural steels. They may also be applied to high-strength structural steels and non-ferrous metals provided that the tensile-shear strength of the weld metal used is at least equal to the tensile strength of the base material. Failing this, the "a" dimension shall be increased accordingly and the necessary increment shall be established during the welding procedure test. Alternatively, proof by calculation taking account of the properties of the weld metal may be presented.

Note:

In the case of higher-strength aluminium alloys (e.g. AlMg 4,5 Mn), such an increment may be necessary for cruciform joints subject to tensile stresses, as experience shows that in the welding procedure tests the tensile-shear strength of fillet welds (made with matching filler metal) often fails to attain the tensile strength of the base material. See F.7.3.

10.3.3 The throat thickness of fillet welds shall not exceed 0,7 times the lesser thickness of the parts to be welded (the web thickness, for instance). The minimum weld thickness is defined by the expression:

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \text{ [mm], but not less than 3 mm}$$

where

t_1 = lesser (e.g. the web) plate thickness [mm]

t_2 = greater (e.g. the flange) plate thickness [mm]

See Section 7, E.2.

10.3.4 It is desirable that the fillet weld section should be flat faced with smooth transitions to the base material. Where proof of fatigue strength is required (see 15.3), machining of the weld (grinding to remove notches) may be required depending on the detail category. The weld should penetrate at least close to the theoretical root point (see Fig. 12.30).

10.3.5 Where mechanized welding processes are used which ensure deeper penetration extending well beyond the theoretical root point and where such penetration is uniformly and dependably maintained under production conditions, approval may be given for this deeper penetration to be allowed for in determining the throat thickness. The effective dimension:

$$a_{deep} = a + \frac{2 \min e}{3} \quad [mm]$$

shall be ascertained in accordance with Fig. 12.30 and by applying the term "min e", which is to be established for each welding process by a welding procedure test. The throat thickness shall not be less than the minimum throat thickness related to the theoretical root point.

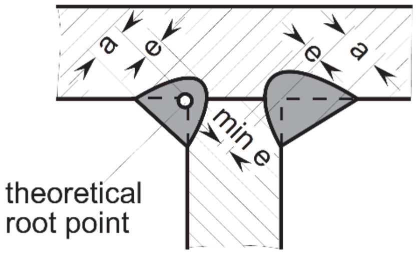


Fig. 12.30 Fillet welds with increased penetration

Note:

In the case of welding processes where there is a particularly deep, narrow penetration, as occurs for example in laser welding without welding consumable in which no significant fillet weld is produced but the entire welded joint is virtually shifted "inwards", the above requirement for a specific minimum fillet weld thickness may be difficult or impossible to meet. In such cases the extent of the effect of the weld shape (if any) on the characteristics of the welded joint (e.g. resistance to cracking, strength) shall be assessed and/or verified in the welding procedure test, taking into consideration any fatigue strength requirements which may be stipulated. The details of this shall be agreed with BKI on a case-by-case basis.

10.3.6 When welding on top of shop primers which are particularly liable to cause porosity, an increase of the "a" dimension by up to 1 mm may be stipulated depending on the welding process used. This is especially applicable where minimum fillet weld throat thicknesses are employed. The size of the increase shall be decided on a case-by-case basis allowing for the nature and the severity of the loading according to the results of the examination of the shop primer in accordance with Section 6 or of the welding procedure tests or production test, as applicable. This applies in analogous manner to welding processes where provision has to be made for inadequate root penetration.

10.3.7 Strengthened fillet welds continuous on both sides are to be used in areas subjected to severe dynamic loads (e.g. for joining the longitudinal and transverse girders of the engine base to top plates close to foundation bolts, see the Rules for Hull (Pt.1, Vol. II) Sec. 8, C.3.2.5 and Sec. 19, Table 19.3) unless single- or double-bevel welds are stipulated in these locations. In these areas the fillet weld throat thickness "a" shall equal 0,7 times the lesser thickness of the parts to be welded.

10.3.8 Intermittent fillet welds may be located opposite each other (chain intermittent welds, possibly with scallops) or may be offset (staggered welding), in accordance with the Rules for Hull (Pt.1, Vol. II) Table 19.3 (see Fig.12.31). The use of different scallop shapes and dimensions may be agreed on for very small sections.

In water and cargo tanks, in the bottoms of fuel tanks and of rooms where pools of condensation or spray water may collect, and in hollow components (e.g. rudders) threatened by corrosion, only continuous fillet welds or intermittent welds with scallops shall be used. The same applies in analogous manner to areas, components or compartments which are exposed to extreme weather conditions or to a corrosive cargo.

There shall be no scallops in areas where the plating is subjected to severe stresses (e.g. in the bottom section of the fore ship) and continuous welds are to be preferred where the loading is chiefly dynamic.

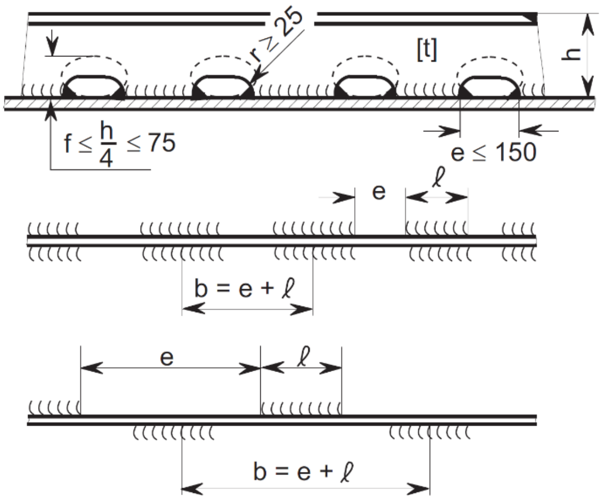


Fig. 12.31 Scallop, chain and staggered welds

10.3.9 The throat thickness au of intermittent fillet welds is to be determined according to the selected pitch ratio b/ℓ by applying the following formula:

$$a_u = a \times \frac{b}{\ell} \times 1{,}1 \quad [mm]$$

where

a	=	necessary fillet weld throat thickness for a continuous weld conforming to the Rules for Hull (Pt.1, Vol. II), Table 19.3, or determined by calculation [mm]
b	=	pitch = e + ℓ [mm]
e	=	interval between the welds [mm]
ℓ	=	length of fillet weld [mm]

The pitch ratio b/ℓ may not be greater than 5. The maximum unwelded length ($b - \ell$ with scallop and chain welds or $b/2 - \ell$ with staggered welds) shall not exceed 25 times the lesser thickness of the parts to be welded. However, the length of the scallops shall not exceed 150 mm.

10.4 Lapped joints

10.4.1 Lapped joints running transversely to the main direction of load should be avoided wherever possible and may not be used for heavily loaded components. Lapped welds may be accepted for components subject to low loads (excluding, however, tanks for chemicals, combustible liquids or gases) provided that wherever possible, they are orientated parallel to the direction of the main stress.

10.4.2 The width of the lap shall be 1,5 t + 15 mm (t = thickness of the thinner plate). Except where another value is determined by calculation, the fillet weld throat thickness "a" shall equal 0,4 times the thickness of the thinner plate, subject to the requirement that it shall not be less than the minimum throat thickness prescribed in 10.3.3. The fillet weld shall be continuous on both sides and shall meet at the ends.

10.5 Plug welding

10.5.1 In the case of plug welding, the plugs should, wherever possible, take the form of elongated holes lying in the direction of the main stress. The distance between the holes and the length of the holes may be determined by analogy with the pitch "b" and the fillet weld length "ℓ" in the intermittent welds covered by 10.3. The fillet weld throat thickness "a_u" may be established in accordance with 10.3.9.

10.5.2 The width of the holes shall be equal to at least twice the thickness of the plate and shall not be less than 15 mm. The ends of the holes shall be semi-circular.

10.5.3 Plates or sections placed underneath should at least equal the perforated plate in thickness and should project on both sides to a distance of 1,5 x the plate thickness subject to a maximum of 20 mm. Wherever possible, only the necessary fillet welds shall be made, while the remaining void is packed with a suitable filler.

10.5.4 **Lug-joint welding is not permitted.**

11. Welding at the ends of girders and stiffeners

11.1 As shown in Fig. 12.32, the web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance at least equal to the depth "h" of the girder or stiffener subject to a maximum of 300 mm. Regarding the strengthening of the welds at the ends, normally extending over 0,15 of the span, see the Rules for Hull (Pt.1, Vol. II) Sec. 19, Table 19.3.

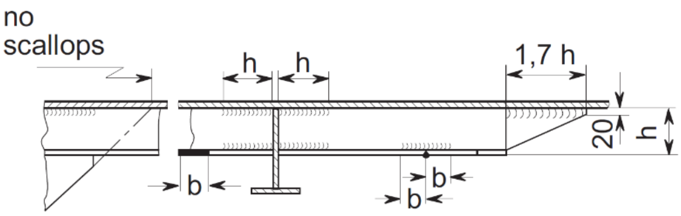


Fig. 12.32 Welds at the ends of girders and stiffeners

11.2 The areas of bracket plates should be continuously welded over a distance at least equal to the length of the bracket plate. Scallops shall be located only beyond a line imagined as an extension of the free edge of the bracket plate.

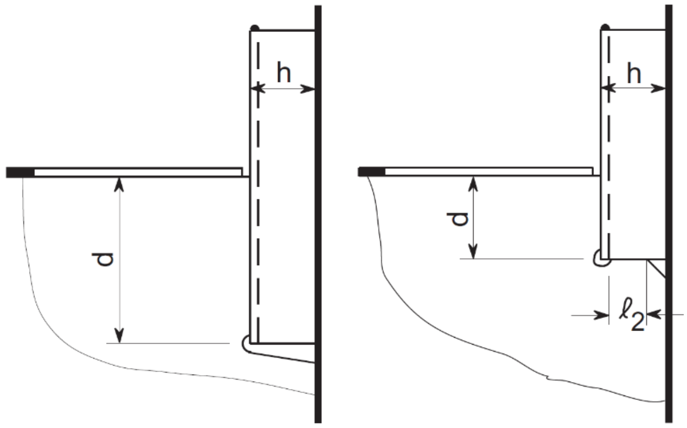
11.3 Wherever possible, the free ends of stiffeners shall abut against the transverse plating or the webs of sections and girders so as to avoid stress concentrations in the plating. Failing this, the ends of the stiffeners shall be cut off obliquely and shall be continuously welded in accordance with Fig. 12.32 over a distance of at least 1,7 h, subject to a maximum of 300 mm. Different dimensions may be agreed for very small sections.

11.4 Where butt joints occur in flange plates, the flange shall be continuously welded to the web on both sides of the joint over a distance "b" at least equal to the width of the flange.

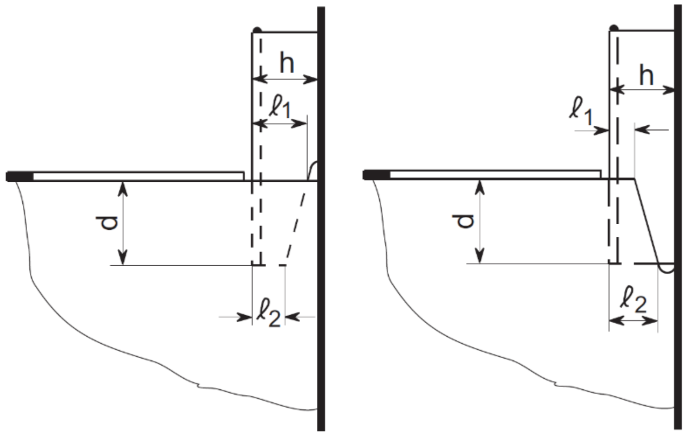
11.5 In the case of girders lying transversely to each other, e.g. as shown in Fig. 12.32, and section passages, a continuous weld shall also be made, by analogy with 11.1, on the girder depicted in section in the figure on both sides of the point where the girders cross.

12. Joints between section ends and plates

12.1 Welded joints uniting section ends and plates (e.g. at lower ends of frames) may be made in the same plane or lapped. Where no design calculations have been carried out or stipulated for the welded connections, the joints may be made analogously to those shown in Fig. 12.33.



d ≥ 1,75 | h d ≥ h
$\ell_2 \geq$ 0,67 h



d ≥ 1,5 h | d ≥ 1,5 h
$\ell_1 \geq$ 0,75 h | $\ell_1 \geq$ 0,5 h
$\ell_2 \geq$ 0,33 h | $\ell_2 \geq$ 0,75 h

Fig. 12.33 Joints uniting section ends and plates

12.2 Where the joint lies in the plane of the plate, it may conveniently take the form of a single-bevel butt weld with fillet. Where the joint between the plate and the section end overlaps, the fillet weld shall be continuous on both sides and shall meet at the ends. The necessary "a" dimension is to be calculated in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 19, C.2.6. The fillet weld throat thickness shall not be less than the minimum specified in 10.3.3.

13. Welded shaft bracket joints

13.1 Unless cast in one piece or provided with integrally cast welding flanges analogous to those prescribed in 3.7 (see Fig. 12.34), strut barrel and struts are to be joined to each other and to the shell plating in the manner shown in Fig. 12.35.

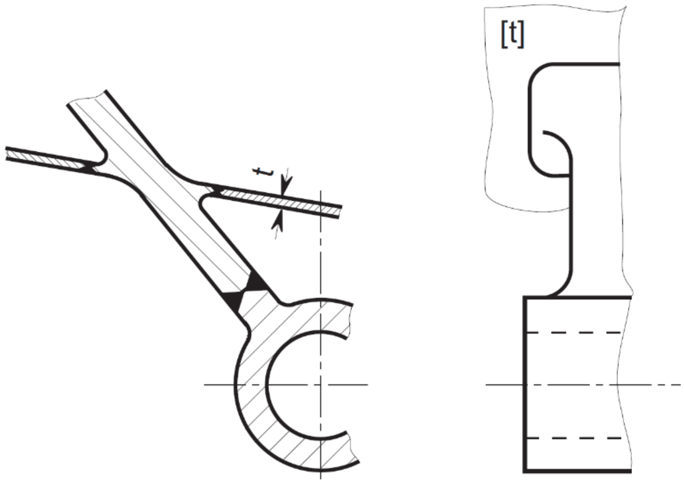
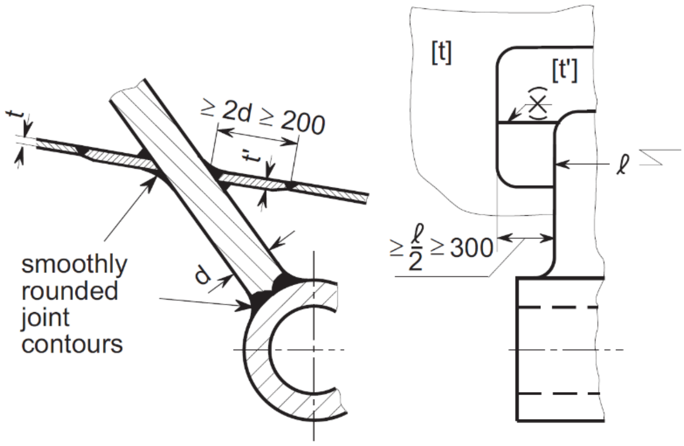


Fig. 12.34 Shaft bracket with integrally cast welding flanges



t = plating thickness in accordance with the Rules for Hull (Pt.1, Vol. II) Sec.6, F. [mm]

t' = $\frac{d}{3} + 5$ [mm] for d < 50 mm

t' = $3\sqrt{d}$ [mm] for d ≥ 50 mm

Fig. 12.35 Shaft bracket without integrally cast welding flanges

13.2 In the case of single-strut shaft brackets no welding may be performed on the arm at or close to the position of constraint. Such components shall be provided with integrally forged or cast welding flanges. Alternatively, a design in accordance Fig.12.36 may be used, subject to the consent of BKI in each individual case. If so, it is essential to keep the concave groove free from welds or other notches.

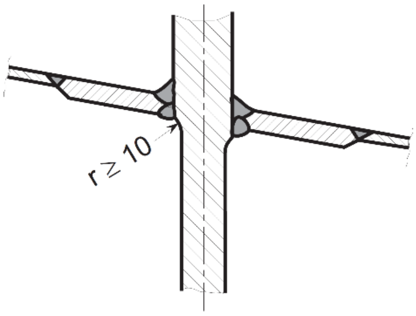
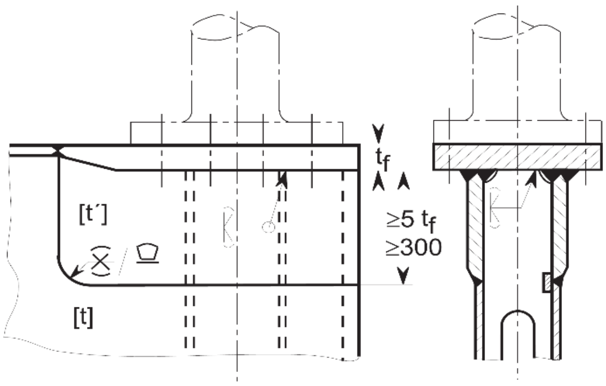


Fig.12.36 Single-strut shaft bracket

14. Rudder coupling flanges

14.1 Unless forged or cast steel flanges with integrally forged or cast welding flanges in conformity with 3.7 are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single- or double-bevel welds as prescribed in 10.2.1 (see Fig. 12.37) See also the Rules for Hull (Pt.1, Vol. II) Sec. 14, D.1.4 and 2.4.



t = plating thickness in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 14, E.3.1 [mm]

t_f = actual flange thickness

$t' = \frac{t_f}{3} + 5$ [mm] for $t_f < 50$ mm

$t' = 3\sqrt{t_f}$ [mm] for $t_f \geq 50$ mm

Fig. 12.37 Horizontal rudder coupling flanges

14.2 Allowance shall be made for the reduced strength of the coupling flange in the thickness direction (see 2.1 and 7.). In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

14.3 The use of horizontal couplings for spade rudders is permitted only if the specified thickness of the coupling flanges is less than 50 mm. If this is not the case, taper couplings shall be used. Taper couplings are the only type permitted for high-performance spade rudders. See also Rules for Hull (Pt.1, Vol. II) Sec. 14, D.1.4 and 2.4.

14.4 The welded joint between the rudder shaft (with, generally, thickened collar, see 3.8) and the flange shall be made in accordance with Fig. 12.38 in such a way that the concave groove at the transition to the thickened collar remains absolutely free of welds. Where necessary, the transition shall be machined to remove notches. For larger flange thicknesses, it is advisable to carry out a single-U weld preparation instead of a double-bevel butt weld.

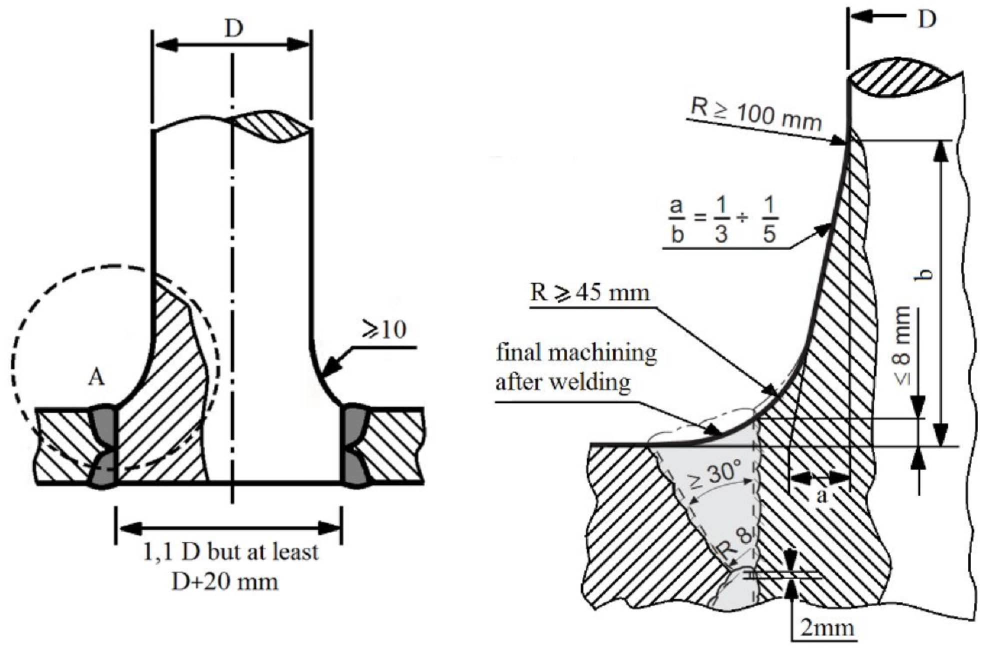


Fig. 12.38 Welded joint between rudder shaft and coupling flange.

For small stock diameter welded joint in accordance with Fig 12.39 may be applied.

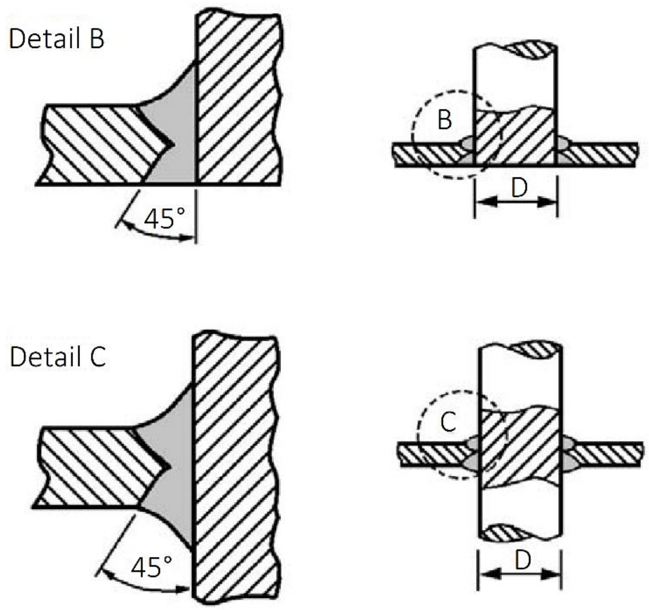


Fig.12.39 Welded joint between rudder shaft and coupling flange for small stock diameter.

15. Design calculation applied to welded joints

15.1 Any calculation relating to welded joints which is stipulated in the Rules or prescribed as an alternative to the rules governing dimensions shall be performed in accordance with the Rules for Hull (Pt.1, Vol. II) Sec. 19, C. Calculations conforming to other rules, standards or code (e.g. EN 13001-3-1, EN 1993 Part 1-1 s/d 1-10) are subject to the prior consent of BKI.

15.2 Proof by calculation of adequate dimensioning with mainly static loading (a general stress analysis) is required where the thickness of butt welds, T-joints or double-T (cruciform) joints cannot be regarded as equal to the plate thickness (see 10.1.5, 10.2.1 to 10.2.4, 10.2.6 and elsewhere) or the throat thickness of fillet welds do not conform to the tables (see the Rules for Hull (Pt.1, Vol. II) Sec.19, Table 19.3).

15.3 For welded joint subjected to mainly dynamic loads, the permissible loading shall be determined by reference to the number of load alternations, the global loading conditions, the mean stress and the notch category (proof of fatigue strength). The notch category is a function of the geometrical configuration of the welded joint. It is also associated with (graduated degrees of) proof of the absence of serious internal and external notches (welding defects). See the notch category catalogue in the Rules for Hull (Pt.1, Vol. II) Sec. 20.

H. Execution of Welds

1. General

1.1 The general rules prescribed and the instructions given in Section 8 for the execution of welds shall be complied with.

1.2 For the necessary approvals, inspections and tests of welding shops, welders, welding procedures, welding consumables and auxiliary materials, overweldable shop primers, etc., see the relevant sections and also A. to F. of this section.

2. Welders and supervisors

2.1 Welding work on components governed by these Rules may only be performed by qualified welders who have been approved by BKI and hold valid qualification certificates. Welders and operators (see 2.3 and 2.4) shall be adequately experienced in the practice of the craft.

2.2 Welders for manual and semi-mechanized welding of normal-strength hull structural steels shall be qualified for the relevant welding processes and welding positions on both butt welds and fillet welds in accordance with Section 3. Welders for vertical-down welding shall also be qualified for this position.

2.3 Welders working with higher-strength hull structural steels, special structural steels, stainless steels or aluminium alloys shall be qualified for welding these materials in analogous manner to the provisions of Section 3.

2.4 Operators for fully mechanized and automatic welding equipment shall have received instruction and training in the use of the equipment and shall be qualified in accordance with the provision of Section 3, A.1.3. BKI may demand that the operators' qualifications be verified in the course of the welding procedure test (see Section 4) or by means of production tests during fabrication.

2.5 Every workshop which performs welding work shall have a welding supervisor who is an employee of the workshop, proof of whose technical qualifications shall be furnished (see Section 2). BKI is to be automatically informed of any changes to the welding supervisors.

2.6 The welding supervisor shall supervise the preparation and performance of the welding work in a responsible manner (see C.). Wherever these differ from the preceding and following conditions, requirements, etc., he shall take steps to ensure that the quality of the welded joints is consistent and adequate in consultation with BKI.

3. Weld preparation and assembly

3.1 Overweldable shop primers

3.1.1 Only those overweldable shop primers may be used for which BKI has issued a confirmation of acceptability based on a porosity test. See also Section 6 and the list of welding consumables and auxiliary materials approved by BKI.

3.1.2 By means of suitable checks carried out in the course of production (e.g. measurements of coat thickness, production tests), workshops using shop primers shall ensure that the conditions of use on which the confirmation of acceptability was based are adhered to and that, in fillet welding, no excessive pore formation occurs which adversely affects the application. See also Section 6 (notes).

3.2 Weld shapes, root openings (air gaps)

3.2.1 When preparing and assembling components, care shall be taken to ensure compliance with the weld shapes and root openings (air gaps) specified in the manufacturing documents. With single- and double-bevel welds especially, attention shall be paid to an adequate root opening in order to achieve sufficient root penetration (see G.10.2.1 and 10.2.2).

3.2.2 The root opening shall not exceed twice the specified gap. If the size of the gap permitted by this rule is exceeded locally over a limited area, the gap may be reduced by build-up welding of the sidewalls, subject to the prior consent of the Surveyor. With fillet welds, the "a" dimension shall be increased accordingly, or a single-or double-bevel weld shall be used if the air gap is large. See also the note to 3.3.2.

3.2.3 With the Surveyor's agreement, large gaps may be closed by means of a strip of plate with a width of at least ten times the plate thickness or 300 mm, whichever is the greater (see G.4.).

3.3 Alignment of components, edge misalignment

3.3.1 Components which are to be united by butt joints shall be aligned as accurately as possible. Sections etc. welded to plating shall be left unfastened at the ends for this purpose. Special attention shall be paid to the alignment of (abutting) girders etc. which are interrupted by transverse members. If necessary, such alignment shall be facilitated by drilling check holes in the transverse member which are later seal-welded.

3.3.2 The permissible edge misalignment depends on the importance and loading of the component concerned (weld quality, see I.6.1). With heavily loaded seams (weld quality grade [1]) running transversely to the main direction of loading, the edge misalignment of butt welds shall not exceed 10% of the thickness of the plate or section, subject to a maximum of 3 mm.

Note:

A serviceable guide to permissible fabricating tolerances is provided in the standards ISO 5817 (Annex F) relating to steel and EN 30042/ISO 10042 (Annex G) relating to aluminium and also in the IACS "Shipbuilding and Repair Quality Standards". In the case of the standards, the assessment category or the individual evaluative criteria to be applied to components or welded joints have to be determined by reference to their loading (see Table 12.9).

BKI has agreed to the "Manufacturing Standard" subject to the reservation that in particular instances, e.g. where important, highly stressed components are concerned or where there is an accumulation of deviations from nominal dimensions, it may also impose decisions which differ from the Standard and may call for improvements to be carried out. Where BKI raises no objection, the provisions of the Manufacturing Standard may therefore be considered to represent the maximum permissible upper limit for deviations from the stipulated dimensions.

3.4 Tack welds, auxiliary fixtures

3.4.1 Tack welds should be used as sparingly as possible and should be made by trained operators. Where their quality does not meet the requirements applicable to the subsequent welded joint, they are to be carefully removed before the permanent weld is made. Cracked tack welds may under no circumstances be welded over.

3.4.2 Clamping plates, temporary ties, aligning pins, etc. shall be made of (hull structural) steel of good weldability and should not be used more than necessary. When the components have been permanently welded, they are to be carefully removed to prevent damage to the surfaces of the components.

3.4.3 Clamping plates, temporary ties, aligning pins, etc. may not be welded to components subject to particularly high stresses (e.g. hatchway corners), nor shall they be welded to the edges of flange plates or, especially, to the upper edges of sheer strakes and continuous hatchway side coamings. The same applies to the welding of handling lugs and other auxiliary fixtures.

3.4.4 Particularly with mechanized welding processes, and invariably when end craters and defects at the start and end of the weld have to be avoided, run-in and run-off plates of adequate section shall be attached to components and cleanly removed on completion of the weld.

4. Weather protection, welding at low temperatures

4.1 The area in which welding work is performed, particularly outside, is to be sheltered from wind, damp and cold. Where gas-shielded arc welding is carried out, special attention is to be paid to ensuring adequate protection against draughts. When working in the open in unfavourable weather conditions, it is advisable always to dry welding edges by heating.

4.2 At low temperatures (below 5°C), suitable measures shall be taken to ensure the satisfactory quality of the welds. Such measures include the shielding of components, extensive preliminary heating and preheating, especially when welding with a relatively low heat input, e.g. when laying down thin fillet welds or welding thick-walled components. Wherever possible, welding work should be suspended if the temperature falls below - 10°C.

5. Preheating

5.1 The need for and the degree of preheating necessary for welding (see Section 9, D.) are governed by a series of factors. These factors differ in their effect in the manner indicated in Section 9, D.2.5 (Table 9.4), i.e. they raise or lower the necessary preheating temperature. For information on the measurement of the preheating temperature and the interpass temperatures to be maintained, see also, Section 9, D.

5.2 Apart from the measures prescribed in 4.1 and 4.2, normal-strength hull structural steel do not normally require preheating. However, with large cross section (e.g. steel castings or forging) and where difficult conditions with regard to design or welding practice apply (e.g. severe distortion of components), it is advisable to carry out uniform preliminary heating of the areas surrounding the welded joints. See 4.1 and 4.2.

5.3 Higher-strength hull structural steels and YP47 steel shall generally be preheated if the temperature of the workpiece is less than 5°C (for YP47 steels, preheating is to be 50°C or over), in the case where P_{cm} value of the steel is less than or equal to 0,19, the temperature of 0°C or below may be adopted with approval of BKI. If it is higher than this, preheating shall be carried out upwards of a specific threshold wall thickness, paying due regard to the other factors described in Section 9, D.2.5 (Table 9.4). For an average carbon equivalent and an average heat input (energy applied per unit length of weld), the threshold wall thicknesses "t" and preheating temperatures "T" shown in Fig. 12.40 may be used as an initial guide. These values, however, are governed by the influencing factors shown in the abovementioned Table 9.4 and have to be adjusted in line with the prevailing conditions. Where necessary, the need for and degree of preheating shall be determined in accordance with Section 9, D. or by means of tests (e.g. during the welding procedure tests).

5.4 Short bead length for tack and auxiliary welds shall be executed of at least 50 mm and require preheating whenever it has to be carried out for the other welds. Exceptions to this are tack and auxiliary welds whose heat-affected zone is reliably and completely remelted during subsequent welding, e.g. tack welds for submerged-arc welding. In the case of YP47 steel where P_{cm} is less than or equal to 0,19, 25 mm of short bead length may be adopted with approval of BKI.

5.5 Preheating shall be applied uniformly throughout the thickness of the plate or component and to a distance of 4 times the plate thickness, but not more than 100 mm, on both sides of the weld. Localized overheating is to be avoided. Preheating with gas burners should be performed with a gentle, though not sooty, flame. The preheating temperature shall be kept constant throughout the duration of the welding work.

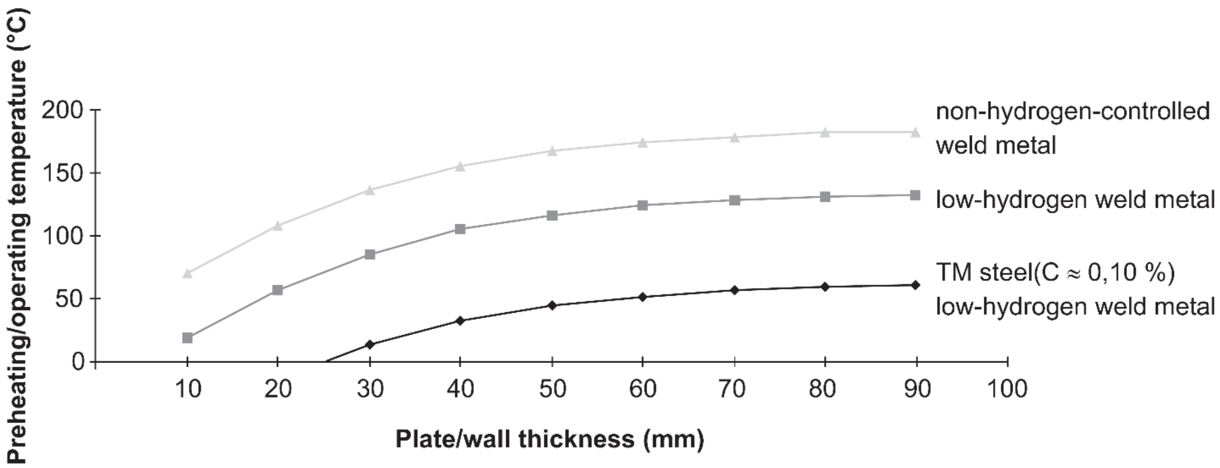


Fig. 12.40 Threshold wall thickness and preheating temperature for higher strength hull structure steels (guide values)

6. Welding positions, vertical-down welding

6.1 Welding should be performed in the optimum welding position, and positional welding (e.g. in PE or PD (overhead) position) shall be limited to the indispensable minimum.

6.2 For similar and repetitive welding operations, it is advisable to use a (rotating) fixture enabling all welds to be made as far as possible in "simple" positions, such as the flat (PA) or horizontal vertical (PB) position.

6.3 Even after a satisfactory welding procedure test and approval of the process (see F.1.), vertical-down fillet welding may not be used:

– for joining together continuous primary supporting members interrupted by transverse members (e.g. the longitudinal members of the upper and lower girder); the same applies where transverse loads predominate,
– for mainly dynamically loaded welded joints (e.g. in the area of engine baseplates, shaft brackets and rudders),
– on crane components and other lifting gear including their substructures (e.g. crane pillars),
– at intersections of main girders and in the area of the supports or stoppers of hatchway covers.

Note :

Vertical-down welding may be used for joining secondary components (e.g. stiffeners) to primary supporting members, for fillet-welding floor plates to continuous bottom longitudinal girders, for fillet-welding transverse bulkheads to the shell plating, and for between-decks, interior partitions, etc. which do not affect the longitudinal or local strength of the vessel. In case of doubt, the extent of the vertical-down welding shall be agreed with BKI.

6.4 BKI may permit exceptions to the provisions of 6.3 and increase the extent of vertical-down welding if the welding shop takes special measures to ensure a satisfactory standard of workmanship (particularly the accurate assembly of components without any significant air gaps, adequate root penetration and prevention of lack of fusion defects) even under normal conditions of fabrication. Such measures include:

- choosing a suitable welding process and appropriate welding consumables and auxiliary materials which guarantee especially good penetration (see F.1.1, note),
- special training and careful selection of welders for vertical-down welding (see also 2.2),
- conscientious monitoring of the weld preparation, the welding parameters and the welding work (e.g. electrode control) while welding is in progress,
- production tests at random (fillet weld fracture specimens) during the course of fabrication.

BKI may demand proof that special measures of this kind have been taken. In addition, BKI may require more extensive monitoring or inspections of the vertical-down welds.

7. Welding sequence

7.1 The assembly and welding sequence shall be chosen to allow shrinkage to take place as freely as possible and to minimize shrinkage stresses in the component. Butt joints in areas of plating shall invariably be fully welded, at least on one side, prior to the fastening of girders, stiffeners, etc.

7.2 Where individual plates are later welded into position in areas of plating (as in the case of erection holes in the deck or shell plating), the longitudinal seams shall be left unwelded, or shall be opened up, to a distance of approx. 300 mm beyond the transverse joints. The transverse joints shall be welded first, followed by the longitudinal seams.

7.3 The welding of patches (see G.4.2) may be performed in analogous manner, unless angular patches with rounded corners or round patches are used.

7.4 In special cases (e.g. when welding together particularly rigid components) and for similar, repetitive welding operations (e.g. for the welding of masts into ships), it is advisable to set down the assembly procedure or welding sequence in a welding sequence schedule.

7.5 Where welded and riveted joints meet (the same also applies analogously to other mechanical methods of assembly), the welds shall invariably be completed first, then the riveting adjoining the weld shall be carried out.

8. Performance of work

8.1 The areas of the components to be welded shall be clean and dry. Scale, rust, cutting slag, grease, paint and dirt shall be carefully removed prior to welding (with regard to over weldable shop primers, see 3.1).

8.2 Components shall not be subjected to any appreciable movements or vibrations during welding. Parts to be assembled while floating or suspended from cranes shall be clamped prior to the tacking of the joint in such a way that no further movement of the parts is possible. Components which have not been fully welded and are to be handled or turned shall have welded joints of adequate strength.

8.3 Cracked tack welds may not be welded over, but are to be machined out. In multi-pass welding, the slag of the previous run shall be completely removed before the next pass. Pores, visible slag inclusions and other welding defects and cracks may not be welded over, but are to be machined out and repaired.

8.4 The welding shop shall ensure that the specified welding parameters are adhered to and that the welding work is expertly performed by competent personnel (see 2.5 and 2.6).

8.5 Welds shall have sufficient penetration and shall display a clean, regular surface with "gentle" transitions to the base material. Excessive weld reinforcements and undercuts (see note to 3.3.2) together with notches affecting the edges of plates and cutouts are to be avoided.

8.6 Butt-welded joints shall display full fusion over the entire cross section, unless a deviation from this is authorized in a particular case. For this purpose, the root shall normally be grooved and capped. Following a successful welding procedure test confirmed by BKI, single-side welds, e.g. using ceramic backings, may be regarded as equivalent to butt welds executed from both sides. Other joints welded on one side only, e.g. using permanent backings, are subject to approval by BKI when scrutinizing the relevant drawings. For the evaluation of such welded joints see G.10.3.

8.7 Single- and double-bevel welds are to be made according to the design specification either with grooved roots as full-penetration welded joints or with a permitted incomplete penetration at the root or a defined, unwelded root face subject to the appropriate reduction factors (see G.10.2). The type of weld is to be specified in the drawings in each case and shall have received BKI's approval when the drawings were scrutinized.

8.8 With fillet welds, particular attention shall be given to good penetration. The penetration shall extend at least to the immediate vicinity of the theoretical root point (see G.10.3.4 to 10.3.6). The ideal fillet weld section is that of an equal-sided flat-faced weld with smooth (notch-free) transitions to the base material. At the end of web plates, at cutouts and at welding apertures, the fillet weld shall meet to form a continuous seam around the root face.

8.9 Major cases of faulty workmanship or defects in the material may only be repaired with the Surveyor's agreement. Minor surface defects shall be removed by shallow grinding. Defects which penetrate more deeply into the material (e.g cracks, or tears left by the removal of welded on erection aids) shall be cleanly machined, ground and repair-welded with an adequate heat input.

9. Welding of higher-strength hull structural steels and higher-strength (quenched and tempered) fine-grained structural steels

Preliminary remark:

The following provisions apply in analogous manner to the welding of low-alloy steels tough at sub-zero temperatures used for structural members in shipbuilding, e.g. for cargo tank supports on gas tankers. The tanks themselves are subject to the "Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX)". See also Section 14 "Welding of Pressure Vessels".

9.1 The steel marker's instructions and recommendations and any conditions arising from the welding procedure test shall be implemented when welding higher-strength hull structural steels and high-strength (quenched and tempered) fine-grained structural steels.

9.2 The welding process, welding consumables, weld build-up and thermal practice (preheating, heat input and interpass temperature) etc. shall be suited to the base material being welded and shall be maintained within the appropriate limits during welding. These parameters shall match those used during the welding procedure test. Any appreciable deviations require BKI's consent and are normally contingent on additional tests. Wherever possible, multi-pass welding shall be used (particularly for high-strength (quenched and tempered) fine-grained structural steels), the final pass being laid down as “temper bead” run some 2 mm away from the base material.

9.3 When welding high-strength fine-grained structural steels it may be necessary to verify not only the preheating but also the heat input during welding[3] and the interpass temperatures. These checks shall invariably be carried out and recorded when welding high-strength quenched and tempered fine-grained structural steels. The values shall correspond to the energy per unit length of weld established during the welding procedure tests and to be laid down in the welding schedule.

9.4 Special attention is to be paid to the generally more sensitive hardening properties and the increased notched sensitivity of higher-strength steels, and especially of high-strength fine-grained structural steels. Unnecessary arc strikes on the surface of the plate, scarring of exposed edges, etc. are to be avoided at all costs. Where necessary, such blemishes shall be cleanly ground out and inspected for incipient cracks. The same applies analogously to auxiliary welds.

9.5 Additional thermal treatments involving a high heat input (e.g. flame gouging and flame straightening) shall not impair the properties of the materials and shall, if necessary, be avoided completely. In doubtful cases, proof of the satisfactory performance of thermal treatments may be demanded.

Note:

Standard flame straightening carried out on higher-strength hull structural steels up-to and including E 36 may generally be regarded as acceptable provided that the straightening temperature does not exceed 700EC and that localized overheating or heating of the whole area over a longer period of time (e.g. using heating blocks) and abrupt cooling (e.g. with water) are avoided. The same applies in analogous manner to the flame straightening of thermo-mechanically rolled (TM) steels. Prior to flame straightening of high strength fine-grained structural steels, special agreement with the steel manufacturer is required.

10. Welding of stainless and clad steels

10.1 During the entire construction period, suitable measures shall be taken in transport, storage and fabrication to keep the surface of stainless steels free from impurities and extraneous metallic inclusions (due to abrasion from other components or auxiliary erection supports).

10.2 Welding processes and welding consumables shall be selected with due regard to strength and corrosion aspects, taking into account the recommendations of the makers of the steel and the welding consumables. Unalloyed welding consumables may not be used for welding stainless steels.

10.3 Edges are to be prepared mechanically by cutting or planning. Where a thermal cutting technique such as plasma cutting has to be employed, the edges shall subsequently be machined clean.

10.4 Clad plates shall invariably be tack-welded on the "black" side of the support material. Back-up plates are to be used sparingly and shall be made of the material to which they are to be welded.

10.5 On the side of the cladding and at the corner joints of clad plates (as in the case of drain wells), at least two layers of stainless weld metal are to be laid down over the support material (see G.10.1.6). Where necessary, different welding consumables shall be used for the intermediate and final runs depending on the base material.

10.6 Fused weld spatter is to be avoided for reasons of corrosion. Such fusion can be prevented by applying suitable media (e.g. milk of lime) to the surface of the plate on both sides of the weld. Where necessary, weld spatter is to be machined off and the area ground smooth.

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[3] Determination of heat input (energy applied per unit length of weld) “E”

$$E = \frac{U[\text{volts}] \cdot I\,[\text{amps}] \cdot \text{Welding time}[\text{min}] \cdot 6}{\text{Length of weld}\,[\text{mm}] \cdot 100} \quad \left[\frac{\text{kJ}}{\text{mm}}\right]$$

10.7 To achieve corrosion-resistant seams, post-weld treatment (pickling or passivation) shall be carried out in accordance with the instructions issued by the steelmaker or the manufacturer of the welding consumables.

11. Welding of steel castings and forgings

11.1 With steel castings and forgings of large section, difficult welding or structural conditions, heavily distorted members and low workpiece temperatures, a sufficient area surrounding the welded joint shall be uniformly preheated throughout the section.

11.2 Welding operations on steel castings and forgings shall be performed continuously and without interruption, if possible in a single heating cycle. Cooling shall take place gradually and appropriate measures shall be taken to prevent over-rapid cooling (screening, wind protection).

11.3 Repair welds (production welds) on steel castings and forgings may only be undertaken with the Surveyor's consent. Where the work concerned is relatively extensive, sketches and a description of the repair shall be submitted to BKI Head Office for approval, together with details of the welding process, welding consumables and auxiliary materials, heat treatment and composition of the base material.

11.4 BKI may stipulate stress relief heat treatment or, in special cases, normalizing heat treatment of the components after welding (e.g. for rudderstocks). The preliminary remark to Section 5, B. applies in analogous manner to the necessary proof of the properties of the welded joint in heat-treated condition.

11.5 Welds uniting hull structural steels or comparable forged or cast steels on the one hand to austenitic stainless steels on the other may not be heat-treated. The same applies in analogous manner to build-up welds made with austenitic stainless welding consumables (e.g. on rudderstocks, pintles, etc.). Any post-weld heat treatment which may be required for build-up welds made with other (e.g. heat-treatable) welding consumables shall be specified on a case-by-case basis.

12. Welding of aluminium alloys

12.1 The foregoing provisions relating to the welding of steels apply in analogous manner to the welding of aluminium alloys above and beyond the provision stipulated in the following paragraphs. Special attention is to be paid to cleanliness, thorough decreasing and the avoidance of extraneous metallic impurities. For the use of various types of steel-aluminium welding transition joints (especially the thermos sensitivity of the boundary layer between the steel and aluminium), see BKI working sheets.

12.2 As a rule, welding grooves are to be thoroughly cleaned (e.g. with solvents and/or brushes) immediately before welding. Tools and equipment shall not be used for working on other materials and shall not themselves leave behind extraneous metallic residues. Welding grooves, welding consumables and auxiliary materials shall at all costs be dry before welding begins.

12.3 Welded joints on aluminium alloy structural components used in shipbuilding shall, wherever possible, be made by inert gas welding (MIG welding, or, possibly, TIG welding for small components) performed in welding bays protected from the weather. The weld pool shall be safely shielded by an adequate supply of inert gas. Winds and draughts are to be avoided. Care shall be taken to achieve the optimum welding speed and to minimize the effect of the heat on the base material (softening).

12.4 To avoid end-crater cracking, especially when making intermittent fillet-welded joints, it is advisable (unless welding equipment with crater filling devices is used) to retract the bead somewhat prior to withdrawal of the electrode or torch so that the end crater is moved back from the end of the seam to a point on the weld and to fill the crater.

12.5 Extensive preheating of the faces to 100 – 200°C is recommended when welding thick aluminium alloy plates and sections. The welds are to be executed in a suitable sequence, smoothly and speedily and, if possible, without a break.

12.6 Cold straightening operations should be performed only by pressing, not by hammering. Hot straightening may only be carried out on alloys suitable for that purpose in accordance with the aluminium producer's instructions. Heating and straightening are to be performed speedily. Temperatures are to be carefully monitored so as to prevent fusion of the material.

13. Underwater welding

13.1 Under certain conditions, BKI may approve the welding (normally fillet welds) of components made of normal-strength hull structural steels which have water behind them. The temperature of the water or component should not be less than 5°C. The welding point shall be dry and clean. At least two passes shall be laid down, the last of which shall be run as a "temper bead" over the first pass which has been deposited on the "cooled" component such that it performs a "post-weld heat treatment" function. Welds executed in this manner shall be subjected to a crack test.

13.2 As a general principle for underwater welding, only those welding processes and/or welding consumables that guarantee a low hydrogen content in the weld metal shall be used. Welding should be performed in a dry environment (chamber pressurized to 1 bar or high-pressure chamber). The above applies in analogous manner to the temperature of the component, the welding point and the crack test. For the required welding procedure tests, see F.

13.3 Underwater arc welding in which the arc burns in the water or in a small gas vessel and where allowance has to be made for a large amount of hydrogen entering the weld metal may only be used with the explicit authorization of BKI in each individual case (even if welding procedure approval has been granted) and then only for temporary repairs (e.g. sealing welds) to components which are subjected to relatively low loads. Welds executed in this manner shall be replaced by normal welds at the next available opportunity and until such a replacement is made BKI may prescribe restrictions in the operation of the vessel (e.g. in the operating area).

I. Inspection of Welded Joints

1. General

1.1 In addition to the following provisions, the inspection of welded joints in shipbuilding is governed by the provisions of Section 10 concerning the preparation and performance of non-destructive weld tests.

1.2 As stipulated in Section 10, D., an inspection schedule shall be submitted to BKI for approval before commencing the tests. BKI reserves the right to modify this schedule even after it has been approved, and in particular to extend the scope of the tests and/or change the individual testing positions if necessitated by fabrication operations and/or test results.

2. Workshop inspections, visual examination

2.1 Workshop inspections are to be carefully performed by trained personnel (e.g. welding supervisors, see C. and H.2.) to ensure the professionally competent and satisfactory execution (appearance and dimensional accuracy) and the integrity of the welds.

2.2 After welding operations have been completed and subjected to workshop inspection, the work shall be presented to the Surveyor for checking at suitable stages of fabrication. For this purpose, welds shall be readily accessible and shall normally be uncoated. Wherever possible, the results of non-destructive tests shall be presented at this juncture.

2.3 Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory workshop inspection and any necessary repair work has been performed.

3. Non-destructive tests

3.1 The necessary weld quality as stipulated in Table 12.9 shall be attested by non-destructive tests, the scope of which shall be at least that specified in 6. Should these tests reveal defects of any considerable extent, the scope of the tests shall be increased. Unless otherwise agreed, tests shall then be performed on two further sections of weld of the same length for every weld section tested and found to be in need of repair. Where it is not certain that a defect is confined to the section of weld under test, the adjoining weld sections shall be additionally tested.

3.2 BKI may stipulate further tests, especially in the event of doubts as to the professionally competent and satisfactory execution of the welds. For the purpose of monitoring and, where necessary, giving instruction to welders, it is recommended that from time to time radiographic inspections should also be carried out on components which are not subject to regular testing.

3.3 The method of inspection to be applied in each instance shall be selected with due consideration for the test conditions (shape and dimensions of the weld, nature and location of possible defects, accessibility) so that any defects may be reliably detected. The method of inspection requires BKI's agreement. BKI may stipulate that two or more inspection techniques be used in conjunction.

3.4 Subject to the provisions of Section 10, the testing appliances and equipment used shall conform to modern technical practice and the relevant standards. The tests are to be performed by properly qualified and experienced testers. For details of the prescribed proof of qualification of ultrasonic tester see Section 10, C.1.

4. Production specimens

4.1 Production specimens, i.e. test pieces welded simultaneously at specified intervals during fabrication, may be called for where the base material, the welding process and/or the loading conditions require proof to be provided that the mechanical or other characteristics of the welded joints made under fabrication conditions are adequate.

4.2 Production specimens shall be welded and tested in a manner analogous to that prescribed in Section 4 and in F., as applicable, in connection with welding procedure tests. The scope of the tests and the requirements to be met shall be determined on a case-by-case basis. For production specimens in connection with shop primers, see Section 6, C.

5. Leakage tests

5.1 Where required, leakage tests on welded seams are normally to be carried out in accordance with the Rules for Hull (Pt.1, Vol. II), (e.g. Section 8, B.9.; Section 12, H.; Section 24, A.15., or Rules for Floating Docks (Pt.3, Vol.II) prior to the application of any paint or cement.

5.2 In special cases, and with the approval of BKI, the hydrostatic tests stipulated for the leakage tests may be replaced by other methods (e.g. testing under compressed air or vacuum, gas detection method). BKI may call for such methods as an alternative or in addition to that stipulated.

6. Weld quality grades, scope of tests, test methods, requirements

6.1 According to the nature and severity of the applied loads and their role in ensuring the soundness of the overall structure, welded joints are to be classified by reference to the influencing factors, their materials, design and service environment (e.g. operating temperature) into one of the three weld quality grades shown in Table 12.9 and shall be identified in the inspection schedule.

6.2 The individual welded joints are to be classified into quality grades according to their position in the component concerned, i.e. their position in relation to the direction of the main stress, as illustrated by the examples cited in Table 12.9. Components and welded joints not mentioned in the Table or in 6.5 shall be classified in an analogous manner.

6.3 The scope of the non-destructive tests to be applied to welded joints with quality grade 1 (radiographic and ultrasonic inspection) shall be determined by the following formula according to the type and construction of the ship. For barges and pontoons with restricted service area, the test position may be calculated by formula in Rules for Domestic Ships (Pt.8, Vol.I) Sec.5. The number "A" of test positions to be determined refers in the first place to radiographs with a (film) length of 480 mm. Where, in accordance with 6.10 or 6.11, ultrasonic tests are performed instead of radiographic inspection, 1 meter of weld is to be tested in each case in place of the 480 mm length of film.

$$A = 0{,}8 \cdot A_L \cdot c_p \left(A_B \cdot c_B + A_H \cdot c_H\right)$$

where

$A_L = \dfrac{L}{16 \cdot a_0}$

L = length of ship [m]

$a_0 = \dfrac{L}{500} + 0{,}48 \le 1{,}0$ [mm]

c_p = 1,5 with transverse frame construction

c_p = 2,0 with mixed transverse and longitudinal frame construction (in the area of the upper and lower girder)

c_p = 2,3 with longitudinal frame construction

$A_B = \dfrac{B}{2{,}5}$

B = breadth of ship [m]

c_B = 1,0 for single-hull tankers and comparable main frame cross sections

c_B = 1,3 for dry-cargo freighters and bulk carriers

c_B = 1,5 for container ships and double-hull (chemical) tankers

$A_H = \dfrac{H}{2{,}5}$

H = depth of ship [m]

c_H = 0,5 for dry-cargo freighters

c_H = 1,3 for tankers, container ships and bulk carriers

c_H = 1,5 for double-hull tankers with additional longitudinal bulkheads

6.4 The number "A" of test positions determined in accordance with 6.3 shall be distributed in such a way that roughly two-thirds of the number "A" established are positioned on the welded joints with quality grade 1 described in Table 12.10 and roughly the remaining third on those joints with quality grade 2. Appropriate consideration shall be given to the individual components specified in 6.5. Depending on the loading conditions, a different inspection density (a different distribution of the total number of test positions) for the various weld quality grades may be expedient or may be demanded by BKI.

6.5 The welded joints of the particular components listed below are to be classified and tested as follows:

- Deck stringer/sheer strake joint within 0,5 **L** of midship: weld quality grade 1, 100% ultrasonic inspection if full-penetration welding is required in accordance with G.10.2.1.
- Deck stringer/sheer strake joint outside of 0,5 **L** of midship: weld quality grade 2, 10% ultrasonic inspection if full-penetration welding is required in accordance with G.10.2.1.
- Joints between horizontal rudder coupling plate and rudder body (see Fig. 12.39): weld quality grade 1, 100% ultrasonic inspection and 100% surface crack inspection.
- Joints between rudderstock and horizontal coupling plate (see Fig 12.40): weld quality grade 1, 100% ultrasonic inspection and 100% surface crack inspection.
- Full-penetration single- and double-bevel T-joints (see Fig. 12.24): weld quality grade 1 or 2 depending on position of weld, 100% or 10% ultrasonic inspection respectively.
- Restarting points in electroslag or electrogas welds: weld quality grade 1 or 2 depending on position of weld, 100% radiography or ultrasonic inspection, the latter with the test sensitivity increased by 12 dB (see also Section 10, L.2.5).
- Welds for which proof of fatigue strength is required: weld quality grade and inspection depend on detail category (see catalogue of notch categories, Rules for Hull (Pt.1, Vol. II) Sec. 20, A.3 and Table 20.3).

6.6 In the case of ships for which no special proof of (longitudinal) strength has to be submitted (generally ships less than 65 m long; see the Rules for Hull (Pt.1, Vol. II) Sec. 5), the number "A" (of test positions) may be reduced to 70% of the figure prescribed in 6.3 and 6.4. The reduction shall be agreed with BKI in every case and is to be specially indicated in the inspection schedule.

6.7 Where the conditions of fabrication remain unchanged, i.e. where to a large extent the same welders are employed in welding the same or similar components (e.g. in repetition shipbuilding) by means of the same welding processes, welding consumables and auxiliary materials, or where the welds made by automatic welding machine, BKI Head Office may consent to a reduction of the scope of inspection specified in 6.3 and 6.4. This is conditional on proof being supplied of uniformly good results and a relatively low incidence of repairs, as attested by the results of all initial inspections performed on welded joints prior to any repairs.

6.8 Where radiographic inspections are performed randomly, they are to be carried out chiefly at the intersections of longitudinal seams and transverse joints, at sectional joints and at joints presenting difficulty or requiring to be welded in a fixed position. Joints in girders and stiffeners are to be classified similarly to those in plating and are to be included in the inspection.

6.9 Ultrasonic tests may be performed in place of a proportion (to be specified in every case) of the number of radiographs prescribed in 6.3 and 6.4. For wall and plate thicknesses of 30 mm and over, ultrasonic testing is to be preferred to radiography as a method of inspection.

6.10 In special cases, ultrasonic tests may be stipulated as an alternative, or additionally, to radiographic inspection, e.g. where certain defects, owing to their nature and location or to the configuration of the weld, cannot be sufficiently reliably detected or assessed by radiography.

6.11 Surface crack inspections shall generally be carried out following the welding of large sections, particularly those of steel castings and forgings as well as in the case of welds made under stress or at low temperatures, large-volume single- or double-bevel welds (plate thicknesses of about 30 mm and over) and thick fillet welds, e.g. on stern posts, after welding-in of masts and welds on bulkhead stools.

6.12 For the inspection of particular components and their welded joints, see 6.5. BKI may, in addition, call for further tests in conjunction with the approval of drawings.

6.13 Welded joints and components not covered by the foregoing provisions shall undergo non-destructive tests whose scope shall be specified in each individual case. Where certain components (e.g. the masts of cargo handling gear, liquefied gas tanks and the pressure hulls of underwater vehicles) are governed by special rules or code of practice, the provisions contained in these shall be implemented.

Table 12.10 Weld quality grades, scope of inspection, requirements

Weld quality grade	1	2	3
Loading, importance	Welded joints which are subjected to severe static or mainly dynamic stresses and/or which are essential to the soundness of the overall structure.	Welded joints which are subjected to medium stresses and/or whose failure entails the loss of function of individual components without endangering the structure as a whole.	Welded joints which are subjected to minor stresses and/or whose failure does not entail the loss of function of important components.
Components, position of welded joints (for individual details relating to particular components and welded joints, see 6.5)	Transverse joints in the area of the upper and lower flange plate[1)] within 0,5 **L** of midship [2)], e.g. in the outer bottom incl. bilge strake, longitudinal girders, longitudinal frames, strength deck incl. sheer strake. Longitudinal girder and beams, longitudinal bulkheads incl. longitudinal stiffeners, hatchway side coamings incl. longitudinal stiffeners. Joints in shell plating and strength deck in the immediate vicinity of fittings and fixtures (traversing the plate), e.g. rudder heels, masts including the welds uniting them to the first-named items. Joints in the flanges and webs of main girders, e.g. in hatchway covers, hatch and cantilever girders, and in cantilever masts. Joints in tank bulkheads and the bottom structures of bulk carriers including the bulkhead stools. Joints in or on components subjected mainly to dynamic loads, e.g. shaft struts, rudder heels, rudder couplings, (connecting them to the rudder body) and the main girders of engine beds.	Longitudinal bulkheads [3)] in the area of the upper and lower hull flange plate, transverse joints in the area outside 0,5 **L** of midship [2)], and joints in the rest of the shell plating and in the double bottom. Joints in watertight transverse bulkheads of dry-cargo freighters and in web frames. L-Joints in hatchway covers, end bulkheads of superstructures and deckhouses, and joints in transverse girders.	Joints in subordinate components such as decks, partitions and their stiffeners not included in the main strength structure, decks of superstructures and deckhouses, joints in bulwarks, etc.

Table 12.10 Weld quality grades, scope of inspection, requirements *(continue)*

Weld quality grade	1	2	3
Scope and method of inspection	Visual inspection and random dimensional checks. Non-destructive tests in accordance with 6. (random checks with greater intensity of inspection). Leakage and other tests, where required.	Visual inspection, random dimensional checks in cases of doubt. Non-destructive tests in accordance with 6. (random checks with lesser intensity of inspection). Leakage and other tests, where required.	Visual inspection In cases of doubt, non-destructive tests in accordance with 6. Leakage and other tests, where required.
Requirements, weld quality [4)]	Welded seams to be free from cracks, lack of fusion and root defects, slag lines, coarse pore clusters and slag inclusions, prominent undercuts, etc. inconformity with quality level B in accordance with ISO 5817 relating to steel (Annex F) and ISO 10042 relating to aluminium (Annex G), as applicable[5)].	Welded seams to be free from cracks, major lack of fusion and root defects, long slag lines, coarse slag inclusions, uninterrupted pores, coarse pore clusters, major undercuts, etc. in conformity with quality level C in accordance with ISO 5817 relating to steel (Annex F) and ISO 10042 relating to aluminium (Annex G), as applicable[5)].	Welded seams to be free from cracks, major root defects and slag inclusions, uninterrupted pores, severe undercutting, etc. in conformity with quality level D in accordance with ISO 5817 relating to steel (Annex F) and ISO 10042 relating to aluminium (Annex G), as applicable[5)].

1) In accordance with the Rules for Hull (Pt.1, Vol. II) Sec.3, B., this is the area extending to at least 0,1 **H** and 0,1 **H**' above and below respectively. The inspection shall, however, invariably cover the entire sheer strake and bilge strake area together with continuous longitudinal members (e.g. hatchway side coamings and crane rails) above the strength deck. Where partial use is made of higher-strength steel, the inspection shall embrace the whole area of this steel in terms of height, and in the case of container ships and similar vessels it shall cover the entire area of the upper box girders.

2) In ships with large deck openings, i.e. ships with large hatches (such as container ships), the transverse joints in the upper hull girder flange fore and aft of 0,5 **L** (generally the entire hatchway area) shall also be assigned to weld quality grade 1 where necessary (e.g. because of the torsional stresses imposed).

3) At weld intersections the adjoining 300 mm of longitudinal seam are to be classified identically with the relevant transverse joints.

4) See also the note to H.3.3.2. Comparable provisions contained in other standards, etc., may also be used for assessment purposes, subject to BKI’s consent.

Where components or welded joints have been dimensioned according to fatigue strength criteria on the basis of a specific detail category $\Delta\sigma_R$ (see Rules for Hull (Pt.1, Vol. II) Sec.20, Table 20.3), the quality grade shall also meet the requirements of this detail category.

5) With regard to the requirements for ultrasonic testing, see, Section 10, L.5 (Table 10.4).

Section 13 Welding of Steam Boilers

Preliminary remark:

Subject to the approval of BKI, codes of practice such as the ASME Boiler and Pressure Vessel Code, Section 1 may be adopted for the fabrication and testing of welded steam boilers (the following rules being applicable in analogous manner). See also, Section 1, B.1.4.A.

A. General

1. Scope

1.1 These Rules apply to the fabrication and testing of welded steam boilers, superheaters, feed water preheaters and similar pressurized components of the steam boiler installation.

2. Other relevant rules

2.1 The provisions of the Rules for Machinery Installations (Pt.1, Vol. III) Sec. 7.I shall also be complied with in the design and dimensioning of steam boiler components.

3. Assessment of welds

3.1 Tensionally stressed longitudinal welds may generally be assessed with a weld factor up to V = 0,8, provided that they meet the requirements specified in Sections 1 and 2 and the following paragraphs.

3.2 A higher assessment up to V = 1,0 may be applied if a production test and non-destructive testing in accordance with I.11. have been successfully performed on the finished component.

B. Approval of Welding Shops, Welding Personnel

1. All welding shops intending to perform welding work within the scope of these rules shall satisfy the requirements applicable to welding shops and personnel set out in Section 2 and shall have been approved by the Society. Applications for approval shall be submitted by the welding shops in good time before starting the welding work, enclosing the information and documentation prescribed in Section 2, A.3.

2. The welding personnel (Welders and Welding supervisors) and, where applicable, Inspectors and Inspection supervisors shall satisfy the requirements set out in Section 2, B.2., B.3. and B.4. and be recognized by the Society. For the welder's qualification tests, see Section 3.

C. Quality Inspection, Responsibility

1. The manufacturer shall submit to the Society, for inspection, drawings and other relevant documents containing at least the following information:

- The materials and welding consumables to be used,
- The welding process and the location and shape of the weld,
- The type of heat treatment, if required,
- The acceptable working pressure,
- The design temperature,
- The operating temperature,
- The test pressure,
- The weld factor "V" used as a basis for calculation,
- The nature and scope of the non-destructive tests,
- The nature and scope of the production tests.

2. If the quality or good working order of a component cannot be guaranteed or is in doubt due to inadequate or missing information in the manufacturing documents (e.g. production drawings), the Society may demand appropriate improvements.

3. The welding shops shall ensure by means of regular in-house quality inspections during fabrication and on completion of the welding work that this work has been performed competently and satisfactorily (see Section 1, F.). For the duties and responsibilities of the welding supervisor, see also ISO 14731.

4. The welding shops are responsible for ensuring that the welding work conforms to these Rules, the approved manufacturing documents, any conditions stipulated in the approval documents and the latest state of welding practice. The inspections and checks to be performed by BKI Surveyor do not relieve the welding shops of this responsibility.

5. With regard to quality inspections and the responsibilities involved in awarding subcontracts to independent branches or suppliers or to approved or non-approved outside firms working in the welding shop (subcontractors), see Section 1, F. Subcontracting of work or employment of temporary workers shall be notified to BKI.

6. The scope of the required quality inspections depends on the construction project in question. It is essential to ensure, however, that the intended materials, welding consumables and auxiliary materials are used and that the weld preparation, assembly, execution of the tack and final welds and the dimensional accuracy and completeness of the welded joints meets the requirements stated in 3. For non-destructive testing of the welded joints and production tests have to be performed, see I.

7. Following internal inspection and, if necessary, repair by the welding shop, the components shall be presented to BKI Surveyor for checking at suitable stages of fabrication. For this purpose they shall be readily accessible and shall normally be uncoated. Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory workshop inspection and any necessary repair work has been performed.

8. BKI is not responsible for guaranteeing that all the components and welded joints inspected to the prescribed extent (generally on a random basis) by its Surveyors have been fabricated in accordance with the conditions and meet the requirements in every respect. Components or welded joints which subsequently turn out to be defective may be rejected or their repair may be demanded even if acceptance testing has already been carried out.

D. Materials, Weldability

1. The materials selected shall be appropriate for the intended purpose, with allowance made for mechanical and thermal stresses. The characteristics of materials subjected to further processing shall be such that they are able to withstand the operating loads.

2. Welded structures may only be fabricated using base materials of proven weldability. The intended materials shall comply with the requirements set out in the relevant sections of Rules for Materials (Pt.1, Vol. V) Sec. 4 to 9. Other comparable materials may only be used after BKI has given its approval in each individual case.

E. Welding Consumables and Auxiliary Materials

1. The welding consumables shall enable a welded joint to be made which is appropriate to the base material, the operating temperature and the conditions of service. The suitability of the welding consumables shall also have been verified under the conditions prevailing in further processing.

2. All the welding consumables and auxiliary materials used (e.g. covered electrodes, wire-gas combinations, wire-flux combinations, etc.) shall have been approved by BKI in accordance with Section 5. They may also, however, be approved if tested at the same time as the welding procedure and restricted to the user’s works (see Section 4, B.3.2 and Section 5, A.1.4).

3. For joints between different materials, the welding consumable shall wherever possible be geared to the lower-alloyed material or the material with the lower strength.

4. Welding consumables and auxiliary materials specified in a procedure approval document with a maker’s or brand name (see F.3.5) may only be replaced by equivalent consumables approved by BKI with an appropriate quality grade if this is explicitly stated in the respective approval document. Failing this, BKI agreement shall be obtained.

5. The welding consumables and auxiliary materials may only be used in the approved welding positions. The manufacturer's recommendations and instructions for welding (e.g. type of current and polarity) shall be followed.

6. The welding consumables and auxiliary materials (especially hydrogen-controlled, basic-covered electrodes and basic welding fluxes) shall be re-dried before use in accordance with the manufacturer's instructions (observe maximum drying time) and stored in a dry place (in heated containers or the like) at the workplace.

F. Welding Procedure Tests

Preliminary remark:

In contrast to earlier issues of these Rules, procedure tests shall be performed in accordance with ISO 15614. This paragraph essentially covers requirements applicable to the welding of steam boilers over and above those set out in ISO 15614-1.

1. General

Only those welding procedures shall be employed whose satisfactory operational handling and adequate quality properties have been verified as part of a welding procedure test under production conditions at the user’s works. The general requirements set out in Section 4 shall be observed. The welding procedures shall have been approved by BKI for the particular welding shop in question.

2. Welding of test pieces, welding procedure specification (WPS)

2.1 A preliminary "manufacturer's" welding procedure specification (pWPS) setting out all the major parameters shall be produced by the welding shop for the welding of test pieces in accordance with ISO 15609, as applicable (see Annex D).

2.2 BKI expert shall select one of the welders whose names are to be supplied by the manufacturer to weld the test pieces.

2.3 The test pieces shall be made from materials whose properties are proven in accordance with the requirements specified in the Rules for Materials (Pt.1, Vol. V) Sec. 4 to 9. Their strength shall be at least 40 N/mm^2 higher than the minimum tensile strength of the material group. Pre-treatment and after-treatment of the welded joints by preheating, heat treatment and the like is only permitted if stipulated for these materials during actual fabrication.

2.4 The types of weld and welding positions employed in the fabrication process shall be qualified in the welding procedure test.

2.5 The form and dimensions of the test pieces are specified in ISO 15614-1 or, where applicable, stipulated in 2.6.

2.6 For welding of sockets, nipples, etc., the following shall be made:

– 2 socket welds in accordance with standard workshop practice or

– 2 test pieces as shown in Figs. 13.1a) and 13.1b).

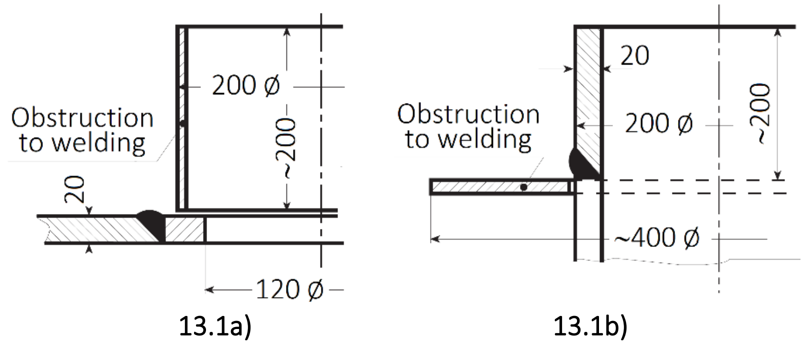

Fig. 13.1 Test pieces for welding of sockets and nipples, inserted (left) and through-type (right)

3. Test principles, delimitation of scope

The qualification of the welding procedure shall be ascertained in accordance with ISO 15607 by means of welding procedure qualification tests, for steel in accordance with ISO 15614-1.

The test is valid within the limits described in 3.1 to 3.7. The scope of the welding procedure test is specified by BKI in writing. Any exceptions require the performance of a supplementary test, the scope of which shall be decided by BKI. Production tests may be recognized as supplementary tests.

3.1 Material groups

Above and beyond the grouping system of ISO 15608, the following provisions shall be observed:

a) For materials which have to satisfy particular corrosion conditions (e.g. resistance to caustic cracking) the welding procedure tests shall be geared to these.

b) A welding procedure qualification performed on group 1 killed steel does not apply to unkilled steels unless they were welded using basic covered electrodes or wire-flux combinations with basic flux.

c) The materials 15NiCuMoNb5 and 17MnMoV6-4 shall be classified as group 2 materials.

Approval is also granted for the following further material combinations in addition to those stipulated in ISO 15614-1, Table 3 but under the following conditions (see Table 13.1).

Deviating from ISO 15614-1, Table 3, a welding procedure test available for the combination group 8 welded to group 2 does not incorporate the combination group 8 welded to group 3.

Depending on material composition and/or the type of post-weld treatment required, BKI may also limit the scope to the base material used in the welding procedure test.

3.2 Welding process

Recognition applies only to the welding process employed in the welding procedure test.

3.3 Gas welding

In gas welding a test performed on the wall thickness shall apply to the wall thickness range 0,75 t to 1,25 t.

3.4 Welding parameters

Welding procedure tests performed on multi-pass welds do not apply to single-pass welds.

3.5 Welding consumables and auxiliary material

The requirements of ISO 15614-1, para. 8.4.5. do not apply if the filler metal used is of the same type and has been approved by BKI to be under the scope of the welding procedure qualification (see E.4.)

3.6 Heat treatment

The welding procedure test applies to the heat treated condition existing at the time of the test. Heat treatment of the test piece shall be performed so that a heat treated condition is achieved which is comparable to that of the component.

Table 13.1 Range approval for dissimilar metal joints

Welding procedure qualification available for a steel group of combination joints	Suitable for the following combination joints
5 (10CrMo9-10) welded with 4	4 welded with 5 (13CrMo4-5) 4 welded with 1 4 welded with 2 (R_{eH} < 430 N/mm^2)
5	5 welded with 1 5 welded with 2
6 welded with 4	6 welded with 5 6 welded with 2 6 welded with 1

3.7 Special cases

For special cases, for example projection welds, welding of clad steels, stud welds and difficult repairs to be performed in the course of fabrication on steels which are susceptible to cracking due to hardening of the heat affected zone, welding procedure tests are necessary which are geared to these particular cases. The tests required and their scope are specified by BKI in each individual case.

4. Tests, scope of tests

Testing comprises both non-destructive and destructive tests and shall be performed in accordance with ISO 15614-1, para. 7.

Deviating from ISO 15614-1, para. 7.1 and Table 1, the following specimens shall also be taken from the test pieces:

a) One all-weld metal tensile test specimen with a diameter of 10 mm and L_0 = 50 mm shall also be taken in the case of test pieces more than 20 mm thick in materials where the effect of the weld metal caused by the welded joints may be significant.

   This applies to steels in material groups 4 and 6 and also for the steels specified in 3.1.c).

b) Notched bar impact test specimens shall be taken from the centre of the weld metal for each welding position in the case of:
   - plates: all materials with a nominal wall thickness > 5 mm
   - tubes:
   - 14MoV6-3 and X20CrMoV12-1 with a nominal wall thickness > 10 mm,
   - 16Mo3 with a nominal wall thickness > 20 mm,
   - all other grades of steel conforming to EN 10216-2 and EN 10217-2 with a nominal wall thickness > 30 mm,
   - other grades of steel above the nominal wall thicknesses as specified in the standards or in BKI approval document for the base material.

c) Micrographic specimen for alloy steels[1]. The structure shall be described and verified by means of photographs.

d) Analysis of the weld metal for alloy steels[1].

5. Test requirements

The irregularities in the test piece shall fall within the limits specified for quality level B in accordance with ISO 5817, exceptions being: excessive weld reinforcement (butt and fillet welds), excessive root reinforcement and excessive fillet weld thickness which fall into quality level C.

For the mechanical and technological tests, Table 13.2 applies.

6. Storage of specimens

The tested specimens and the remaining portions of the test pieces shall be stored until the report on the welding procedure test has been completed (see also Section 4, C.3.).

[1] For the classification of steels (unalloyed and alloyed), see EN 10020.

7. Validity, extension of welding procedure tests

The validity of a welding procedure test is generally 1 year provided that the preconditions under which it was granted have not significantly changed. It may be continued by means of regular production tests (see I.11).

In addition to production tests and tests performed on welded components (see I.) non-destructive tests may, given certain preconditions, also be recognized by BKI for continuing the validity.

The welding procedure test shall be repeated if there is a break in the fabrication of steam boilers or steam boiler components lasting longer than one year.

G. Welding Technique

1. Welds shall exhibit full penetration over their entire cross section and shall not have any cracks or lack of fusion defects. Wherever possible, the root shall be grooved and capped.

2. When welding plates whose thicknesses differ by more than 20% or more than 3 mm, the thicker plate shall be bevelled to the thickness of the thinner plate at a maximum angle of 30°.

3. In the case of shells consisting of several rings, the longitudinal seams shall be staggered.

4. Fillet welds on lapped joints are only permitted in special cases and are then to be made only as double-sided circumferential welds up to a wall thickness of 15 mm.

5. Corner welds and similar welded joints which are subjected to considerable flexural stresses under adverse conditions of fabrication or service are only allowed if BKI raises no objection to the method of execution.

Table 13.2 Requirements applicable to the mechanical and technological tests

<table>
<tr><th>Type of test</th><th colspan="3">Requirements</th></tr>
<tr><td>Tensile test transversely to weld</td><td colspan="3">As stipulated for the base material or in the test of product suitability for the welding consumable.</td></tr>
<tr><td>Hot tensile test on a specimen taken from the weld metal</td><td colspan="3">As stipulated for the base material or in the test of product suitability for the welding consumable.</td></tr>
<tr><td>Notched bar impact test [1] on specimen from centre of weld</td><td colspan="3">As stipulated for the base material in transverse direction.
For welded joints in austenitic steels, ≥ 40 J with ISO V-notch specimens.
The test shall be performed at room temperature.</td></tr>
<tr><td rowspan="7">Technological bend test</td><th>Bending angle</th><th>Strength category [2]</th><th>Mandrel diameter</th></tr>
<tr><td rowspan="2">180° [3]</td><td>Ferritic steels with a minimum tensile strength < 430 N/mm^2</td><td>2 x a</td></tr>
<tr><td>Minimum tensile strength ≥ 430 N/mm^2 to 460 N/mm^2</td><td>2,5 x a</td></tr>
<tr><td>180° [3]</td><td>High-temperature austenitic steels Ferritic steels with a minimum tensile strength ≥ 460 N/mm^2</td><td>3 x a</td></tr>
<tr><td colspan="3">If a bending angle of 180E is not attained, the following applies:</td></tr>
<tr><td>≥ 90°</td><td>Elongation (L_0 = width of weld + thickness, symmetrical to weld) ≥ minimum elongation A of base material.</td><td></td></tr>
</table>

Table 13.2 Requirements applicable to the mechanical and technological tests *(continued)*

Type of test	Requirements		
	or < 90°	Elongation over width of weld > 30% 4) and faultless appearance of fracture.	
Metallographic examination	The macrographic specimen of the welded joint shall reveal a satisfactory weld build-up and full penetration of the weld. The micrographic section is to be examined for cracks. Cracks are not acceptable. In the case of welded joints in austenitic steels, hot cracks are acceptable provided that they are few in number and widely scattered.		
Hardness testing	The hardness in the heat-affected zones shall not exceed 350 HV 10. Hardness peaks in excess of this figure in narrow transition zones shall not give rise to complaints if the outcome of the technological test meets the requirements.		

[1] For specimens less than the standard 10 mm in width, the impact energy requirements decrease in proportion to the cross section of the specimen.
[2] The tensile strength applies to the area of least thickness.
[3] The 180E requirement is deemed to have been met if the bend test was performed according to ISO 5173 and pressure was applied by the supports without cracks appearing.
[4] Different values may be agreed on for steels not welded with matching filler.

6. Holes and cut outs in or immediately adjacent to welds, especially longitudinal welds, shall be avoided wherever possible.

7. Welding of components in cold-formed areas where the outer fibers have been stretched by more than 5% ($D_m < 20 \cdot s$ for cylindrical shell rings) is only allowed if the effects of cold-forming have been eliminated by means of appropriate heat treatment.

This generally has to be accomplished by normalizing heat treatment or quenching and tempering. This requirement may be waived if proof is furnished that the properties of the material are not more than insignificantly impaired with regard to the intended use.

8. Every weld in a boiler component shall be marked in such a way that its location remains recognizable and the welder concerned can be identified at any time. Both of these may be evidenced either by stamping the weld accordingly or by making entries in drawings, welding schedules or other records.

H. Post-Weld Heat Treatment

1. Welded components shall be heat-treated after welding in accordance with the stipulations of the relevant standards or BKI approval document.

1.1 The post-weld heat treatment shall normally consist of stress relief heat treatment.

1.2 Components fabricated from steels which have undergone normalizing heat treatment shall be subjected to normalizing heat treatment if:

– the required characteristics of the welded joint can only be established by normalizing heat treatment or
– the component has undergone hot-forming after welding, unless hot-forming was completed within a temperature range equivalent to normalizing heat treatment.

1.3 Components fabricated from quenched and tempered steels shall be subjected to quenching and tempering if:

- the required characteristics of the welded joint can only be achieved by quenching and tempering or
- the component has undergone hot-forming after welding.

If, in the case of air-hardened and tempered steels, the hot- forming of the component was on the whole performed under the conditions applicable to normalizing heat treatment, tempering alone is sufficient.

1.4 For such welded joints, preheating and treatment by quenching and tempering or by tempering alone should as a rule be carried out in accordance with the instructions of the material or consumable manufacturer. A special means of heat treatment shall be specified if, for instance, the material or the weld metal is hardened to an unacceptable degree during welding.

For high-alloy steels with a ferritic or austenitic structure, the need for and method of heat treatment shall be determined on an individual basis.

2. Post-weld heat treatment may be dispensed with if the following conditions are met:

2.1 Prior to welding, the materials shall be in the heat- treated condition specified in the relevant standards or in BKI approval document. This condition is also deemed to be met if the required heat-treated condition is only attained during subsequent fabrication.

2.2 The nominal wall thickness at the joints may not exceed 30 mm.

2.3 In the chemical composition (melt analysis) of the base material and the weld metal, the following contents may not be exceeded:

- C 0,22%, Si 0,50%, Mn 1,40%,
  Cr 0,30%, Cu 0,30%, Mo 0,50%,

  Ni 0,30%, V 0,20%;

In this context, the following conditions shall also be satisfied:

- Cr + Ni ≤ 0,30% and Mn + Mo + V ≤ 1,6%.

These conditions may be relaxed in the case of steels which have been rendered resistant to brittle fracture and hardening by special metallurgical measures. Their suitability and properties shall be demonstrated to BKI after an adequate period of proving. The steels' resistance to brittle fracture, resistance to hardening and weldability shall be equivalent to those of steels falling within the above analytical limits. For the weld metal, at a C content ≤ 0,10% the Si content shall be ≤ 0,75%, the Mn content 2,0% and the sum of the Mn, Mo and V contents ≤ 2,5% if welding consumables are used which produce a weld metal with a particularly high toughness, e.g. by using welding consumables with basic characteristics.

3. Post-weld heat treatment may be dispensed with for butt welds located in the flue gas stream in tubes made of 13CrMo44 steel with no lower limit for the average wall temperature and in pipes made of 10CrMo9 10 steel above an average wall temperature of approx. 490°C, provided that the outside tube diameter does not exceed 63,5 mm and the wall thickness does not exceed 10 mm. Butt welds between the tubes and tube nipples are included under this provision, even if they are not located in the flue gas stream.

4. Components shall generally be heat-treated in their entirety. In the case of stress relief heat treatment and tempering heat treatment, an exception from sentence 1. may be made if:

- in the case of cylindrical components, a sufficiently wide cylindrical section or

– in the case of longitudinal welds in open shell rings without a circumferential weld, the weld zone over a sufficient width is heat-treated by (continuous) uniform heating, on both sides if possible, provided that BKI expert raises no objection. In both cases, thermal stresses shall not be allowed to shift to parts subject to flexural stresses (e.g. flanges or cut-outs).

5. Welding of small parts into and onto the walls of steam boilers shall generally be carried out prior to heat treatment. This especially applies if:

– the nominal wall thickness of the basic structure exceeds 30 mm (see 2.2),

– the contents specified in 2.3 are exceeded,

– cold forming takes place in conjunction with welding. When welding in individual small parts, heat treatment may be dispensed with if the properties of the materials to be joined and the welding process enable the making of a satisfactory welded joint which is appropriate to the conditions of service and the working temperature.

6. Documentary proof of the heat treatments described in 1.1 to 1.4 shall be provided by means of a works certificate to ISO 10474 or EN 10204, as applicable which shall state the method, temperature and duration of the heat treatment and the method of cooling. Any special heat treatment, e.g. temporary cooling after welding prior to tempering treatment, shall be recorded in the works certificate.

I. Inspection of Welded Components

1. Where no production tests are carried out on welded shell rings which have undergone hot bending or heat treatment, for materials with a minimum tensile strength ≥ 440 N/mm^2 [2] and alloy steels[1] a test piece taken from the plate used and stamped by BKI expert shall be subjected to the same treatment as the shell ring. A tensile test and a notched bar impact test (three test specimens) shall be performed on specimens from this test piece to establish the ultimate condition of the material of the drum or the shell ring.

2. Fully welded drums for water-tube boilers with upset or prewelded ends shall be subjected to the tests specified in 2.1 to 2.4.

2.1 The drums shall be subjected by BKI expert to a hydraulic pressure test at 1,5 times the working pressure, subject to the limitation that the resulting stress shall not exceed 0,9 times the yield strength at 20ºC, taking into account the positive diameter tolerance and the negative wall thickness tolerance. The component shall exhibit no leaks during the hydraulic pressure test and no permanent deformation afterwards. This test may be dispensed with if the complete longitudinal and circumferential welds have been subjected to non-destructive testing by appropriate means with satisfactory results.

2.2 Where dished drums are fabricated from steel with a minimum tensile strength ≥ 440N/mm^2 [2] and a minimum yield strength at room temperature ≥ 320 N/mm^2 and the nominal wall thickness is greater than 30 mm, following the final heat treatment three core samples shall be drilled out of the metal, one being taken from each end of the cylindrical part and one from the middle of the drum. The exact location of the sampling points, which shall be offset relative to each other by approx. 120° if possible, shall be indicated to the drum manufacturer by the steam boiler manufacturer in good time. The core samples shall be at least 60 mm in diameter to enable one specimen for tensile testing and one set of three specimens for notched bar impact testing to be prepared. The specimens shall be cut out transversely to the direction of rolling of the plate; if possible, the tensile test specimen should be located 1/6 of the wall thickness below the surface. Of the three notched bar impact test specimens, one shall be taken from each of the extremities and one from the middle of the core sample.

[2] The threshold may be raised to 470 N/mm^2 if proof is finished that stress relief heat treatment is not liable to result is not liable to result in an unacceptable reduction in the yield stress

2.3 Where cold-bent shell rings with a degree of deformation > 5%, hot-bent shell rings or dished half-drums are fabricated from steel with a minimum tensile strength ≥ 440 N/mm^2 [2] and a minimum yield strength at room temperature ≥ 320 N/mm^2 and the nominal wall thickness is greater than 30 mm, following heat treatment a sufficiently wide ring shall be cut off, from which one specimen for tensile testing and one set of three specimens for notched bar impact testing shall be taken transversely to the direction of rolling of the plate. Alternatively, the procedure described in 2.2 may be followed.

2.4 If, in the situations described in 2.2 and 2.3, the final heat treatment consists solely of stress relief heat treatment or if working is carried out only within the stress relief heat treatment range and is not liable to change the properties of the material substantially, the specimens prescribed in 2.2 and 2.3 may be prepared beforehand and heat-treated in the same manner. In this case, the temperature of the specimens over their length and the extent of the variation in temperature shall be measured and recorded.

3. The requirements applicable to the mechanical and technological tests stated in 1. and 2. are governed by the provisions of Rules for Materials (Pt.1, Vol. V) Sec. 4, H. and Sec. 7, A.

In testing of the base material after heat treatment, a negative tolerance of 5% applies in individual cases to the minimum yield strength and the minimum tensile strength if a load in the area of the high-temperature yield strength is applied.

The yield strength and tensile strength may be less than the minimum by more than 5%, up to 10%, if proof is furnished that

- Heat treatment has been satisfactorily carried out
- The requirements applicable to the elongation of the base material are met
- The requirements applicable to the impact energy of the base material are met
- The dimensional design based on the high-temperature yield strength established is still adequate.

Where loads in the area of the creep strength are applied, the yield strength and the tensile strength may be less than the specified minimum by max. 10%.

4. An internal and external inspection shall be carried out on the completed shell rings and drums, and especially of the welds and adjacent areas and the dished ends. For the inspection, the components shall have a smooth external and internal surface corresponding to the condition as manufactured, to ensure that significant surface defects can also be detected; the internal surface is to be descaled. At the same time, measurements shall be carried out to determine:

4.1 External circumference

The measurements shall be spaced at approx. 1 m intervals over the entire length of the component. The measurements of the external circumference shall be used to determine the average outside diameter. The outside diameter of the shell rings and drums may not vary from the stipulated outside diameter by more than ± 1,0%.

4.2 Out-of-roundness

The measurements shall be spaced at approx. 1 m intervals over the entire length of the component. The out-of-roundness

$$U = \frac{2 \times \left(D_{max} \times D_{min}\right)}{D_{max} \times D_{min}} \times 100\%$$

of the drums and shell rings following final heat treatment shall be:

- For non-heat-treated or stress relief heat-treated drums and shell rings where the wall thickness is > 1 % of the nominal diameter: 1% max.
- or normalizing heat-treated, quenched and tempered or dished drums: 2% max.

In calculating the out-of-roundness, the elastic deformations arising from the component's own weight shall be discounted. Isolated bulges and dents shall also lie within the tolerances. In addition, the bulges and dents shall have a flat profile and their depth, measured as a deviation from the normal roundness or from the shell line, as applicable, shall not exceed 1 % of the length or width of the dent or bulge.

The out-of-roundness need not be determined where the wall thickness is < 1% of the nominal diameter.

4.3 Camber or flattening

The degree of camber or flattening in the area of the longitudinal welds, measured as a deviation from the normal roundness with a template length of 500 mm, may not exceed the dimension "a".

Depending on the ratio of the average diameter d_m to the wall thicknesses "s_e" of the drum or shell ring, the following applies:

$$a \le 10 \text{ mm} \quad \text{for shell rings: } \frac{d_m}{s_e} < 40$$

$$a \le 5 \text{ mm} \quad \text{for shell rings: } \frac{d_m}{s_e} \ge 40$$

4.4 Axial non-linearity

The degree of axial non-linearity may be:

- For shell rings: up to 0,3% of the cylindrical length
- For drums: up to 0,5% of the cylindrical length

4.5 Wall thickness of welds and adjoining plate areas

The wall thickness in the plate shall lie with the tolerance permitted for the plate.

5. If special conditions of fabrication apply to the components stated in 1 and 2, i.e. where large wall thicknesses or difficult-to-weld steels are used, non- destructive testing may also be necessary for an evaluation of up to V = 0,8. Welded joints in steels which, according to the report of BKI expert, are subject to a non-standard method of heat treatment shall undergo the tests stipulated in the report, especially hardness testing and ultrasonic inspection. Proof of the outcome of these tests shall be provided by acceptance test certificate 3.1 or 3.2 to ISO 10474 or EN 10204, as applicable in accordance with BKI report.

6. An acceptance test certificate 3.1 to ISO 10474 or EN 10204, as applicable showing that the requirements stated in 3. and 4. are met shall be furnished where one of the following limits is exceeded:

- Overall length of cylindrical shell ring in excess of 2500 mm
- Specified external diameter in excess of 1200 mm
- Acceptable working pressure in excess of 16 bar
- Weld factor higher than V = 0,8.

Below these limits, an acceptance test certificate 3.2 to ISO 10474 or EN 10204, as applicable is sufficient.

7. An internal and external inspection of the completed smooth or corrugated furnaces, and especially of the welds and adjoining areas, shall be carried out. During the inspection the following shall be measured:

7.1 Deviation from specified external circumference

The measurements shall be spaced at approx. 1 m intervals over the entire length of the components. The permitted deviations from the external circumference specified in the order in a measurement cross section are:

- For corrugated furnaces:
  - non-corrugated portion ± 15 mm
  - corrugated portion:
    - pull-through type + 0 mm
- 75 mm
    - other corrugated tubes + 15 mm
- 60 mm
- For smooth furnaces:
  - at the ends of shell rings over a distance of 250 mm ± 15 mm
  - in the remainder of the cylindrical shell rings + 0 mm
- 75 mm
- For smooth furnaces with flange ends:
  - cylindrical portion + 0 mm
- 75 mm

7.2 For corrugated tubes, difference between maximum outside diameter and associated inside diameter

The measurements shall be spaced at approx. 1 m intervals over the entire length of the components. For corrugated tubes, the difference between the maximum outside diameter and the inside diameter in the corrugations shall equal the specified dimension with a maximum negative tolerance of 20 mm.

7.3 Out-of-roundness

The measurements shall be spaced at approx. 1 m intervals over the entire length of the components. The wall thickness shall invariably be measured at the ends of the shell rings and at any point where a decrease in wall thickness is significant.

The out-of-roundness

$$U = \frac{2 \times \left(D_{max} \times D_{min}\right)}{D_{max} \times D_{min}} \times 100\%$$

shall not exceed:

- For corrugated furnaces: 1,0%
- For smooth furnaces: 1,5% up to a maximum of 15 mm.

7.4 Non-linearity

The non-linearity shall be measured by placing a length of cord against the wall. It may not exceed 0,3% of the cylindrical length of the shell rings

7.5 Wall thickness of welds and adjoining plate areas

The following tolerances apply to the wall thickness of corrugated tubes: the average wall thickness shall at least equal the nominal wall thickness within the corrugation pitch. Localized deficiencies of up to 10% in the wall thickness within the corrugation pitch are permitted. The reduction in wall thickness is to be compensated for when manufacturing the corrugated tubes by means of an appropriate increase in the wall thickness of the original tube. The area A calculated from the specified corrugation depth and the specified wall thickness shall be attained. With a corrugation depth w of 75 mm, a deficiency of 5% in the area A is acceptable. In the flanged portion, a deficiency of up to 20% in the wall thickness is permitted. In the assessment, defects which in the opinion of BKI expert are clearly unimportant with regard to safety shall be disregarded. Smooth furnaces are subject to the tolerances applicable to plates.

8. Proof that the requirements stipulated in 7 are met shall be furnished by means of an acceptance test certificate 3.1 to ISO 10474 or EN 10204, as applicable). A hydraulic pressure test is not required for furnaces.

9. The cut-out areas of headers certified according to quality grade I under EN 10216-2 (see Rules for Materials (Pt.1, Vol. V) Sec. 5, C.) shall be subjected to appropriate non-destructive testing by the boiler manufacturer and the outcome of the testing shall be certified.

10. Repair welds

Exceptions to the foregoing rules may be made for repair welds in justified special cases, provided that BKI expert is informed of the nature and scope of the planned welds before work commences and he has no objections to the planned exceptions.

11. Production Tests

The production test comprises non-destructive testing of the component and quality inspection of test pieces (mechanical and technological tests).

11.1 Non-destructive testing

All longitudinal and circumferential welds shall be subjected to non-destructive testing over their entire length. They shall also be examined for surface cracks if necessary. The tests shall be performed in accordance with Section 10.

For circumferential welds where the wall thickness is < 30 mm, testing of 25% of the length of the weld is sufficient; however, all junctions with longitudinal welds shall be tested.

The tests shall not be performed until the final heat treatment of the component has been carried out.

The non-destructive test shall not reveal any major defect in the weld. Such defect include cracks, lack of side wall fusion and, in single side wall, insufficient root penetration. Other defect such as pores and slag shall be assessed in accordance with recognized code, e.g. the ASME Boiler and Pressure Vessel Code, Section I.

The results of the non-destructive test shall be documented and presented to BKI expert for assessment at the time of the structural inspection.

11.2 Quality testing of test pieces

The following test shall be carried out on a test piece welded at the same time as the component as an extension of a longitudinal seam (see 11.3.6 and 11.4):

a) Tensile test on two specimens, shape of specimen according to ISO 4136; however, test length = width of weld + at least 80 mm.

b) Technological bend test to ISO 5173 on four transverse bending test specimens (two specimens each with opposite sides of the weld in tension). On the side in tension, after machining off the weld reinforcement the original surface of the test piece shall be preserved to the greatest possible extent. Sizeable depressions such as undercuts and root notches shall not be repaired.

c) Notched bar impact test on ISO V-notch specimens to ISO 9016 on three specimens taken from the center of the weld metal with the position of the notch vertical to the surface of the test piece. The test temperature and requirements are shown in Table 13.2.

d) Structure examination of a specimen (macrographic specimen); for alloy [1)] steels, a micrographic specimen is also required.

e) A radiographic inspection to ISO 17636 shall be carried out prior to sectioning of the test piece.

Also, if the working temperature exceeds 350°C:

f) Tensile test to ISO 5178 on a specimen from the weld metal (cylindrical specimen with L_0 = 5 d to ISO 6892-1) for thicknesses ≥ 20 mm to determine the 0,2% proof stress at the working temperature.

or

g) Analysis of the weld metal with regard to the constituents which determine the mechanical properties at elevated temperature as decided by BKI expert.

For materials with a minimum tensile strength of ≥ 440 N/mm^2 and alloy[1] steels subjected to post-weld heat treatment, a tensile test and a notched bar impact test on specimens taken from the base material transversely to the direction of rolling shall also be performed on the test piece.

11.3 Number, removal and dimensions of the test pieces for quality testing

11.3.1 Procedure for the first six shell rings

If the higher evaluation is being made use of for the first time or is being extended through the inclusion of new types or grades of material, a test piece located at one end of each of the first six shell rings shall be welded together with the shell ring and tested. Unless otherwise stipulated, the specimens stated in 11.4 shall be taken from this test piece. The test pieces required for these production tests shall be taken from the plates to be used for the component. Every melt shall be covered.

11.3.2 Procedure from the seventh shell ring onwards

The preparation and number of test pieces depends on whether or not post-weld heat treatment is necessary; see H.2.

11.3.3 For components where heat treatment is unnecessary, the following applies, provided that the analytical limits stated in H.2.3. are not exceeded:

a) Preparation:

The test pieces may be taken from plates of the same type and strength category and approximately the same thickness as those used for the shell ring; a difference of ± 5 mm is acceptable. The characteristics of the plates shall be verified in accordance with Rules for Materials (Pt.1, Vol. V) Sec., 4 to 9.

b) Number of test pieces:

One test piece shall be welded as an extension of one of the longitudinal seams of each component, irrespective of the number of shell rings.

11.3.4 For components where heat treatment is necessary, the following applies:

a) Preparation:

The test pieces shall be taken from plates to be used for the component in question.

b) Number of test pieces:

One test piece shall be welded as an extension of one of the longitudinal seams of each component, irrespective of the number of shell rings. If the component consists of material from several melts, one test piece shall be welded for each melt. If the analytical values differ only slightly, BKI expert may reduce the number of test pieces accordingly, even if a component consists of material from several melts.

11.3.5 The number and locations of the test pieces are shown in Table 13.3.

After at least 50 production tests per material category, relaxations may be agreed with BKI.

11.3.6 Size of test pieces

The size of each test piece shall be such that the specimens prescribed in 11.4.2 and a sufficient number of retest specimens can be taken from it.

11.4 Welding of test pieces, number and removal of test specimens

11.4.1 Welding of test pieces

The seam of the test piece shall be welded in the course of fabrication together with the last 300 mm of weld of the shell ring. BKI expert has the right to be present while this weld is made. The test pieces shall undergo a heat treatment which is demonstrably similar to that applied to the component

11.4.2 Number of test specimens

From every welded test piece, specimens for the tests prescribed in 11.2 shall be stamped by BKI expert and removed. The specimens shall alternate with each other and lie adjacent to each other.

The remainder of the test piece is intended for retests. It shall also be stamped and marked in such a way that its affiliation can be unequivocally established.

11.5 Requirements

11.5.1 Mechanical and technological tests

The mechanical and technological tests are governed by Table 13.2 in conjunction with I.3.

11.5.2 Retest specimens

If one of the tests listed in 11.2 fails to achieve the required result, each unsuccessful test shall be repeated by testing two more specimens of the same type taken from the remainder of the test piece. The test conditions are met if the retest specimens meet the requirements.

11.6 Supplementary tests

Further tests, e.g. notched bar impact tests with the fracture section in the transition zone or radiographic inspections in various directions, shall be performed if considered necessary by the competent expert in special cases. for assessment of the weld.

Table 13.3 Number and locations of test pieces

	Heat treatment	
	Unnecessary	Necessary
1^{st} to 6^{th} shell ring	One test piece per shell ring taken form the plates to be used for the component. Every melt is to be covered (see I.11.3.1).	
From 7th shell ring and further components consisting of		
one shell ring	One test piece per shell ring (see I.11.3.2)	
two or more shell rings	One test piece per component taken form plates of the same strength category and approx. the same thickness (difference of ± 5 mm are acceptable).	One test piece per component; where different melts are used, however, one test piece for each melt from one of the plates to be used for the components.
After at least 50 production test per material category.	Relaxations by agreement with BKI.	

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Section 14 Welding of Pressure Vessels

Preliminary remark:

Subject to the approval of BKI, other codes of practice such as the ASME Boiler and Pressure Vessel Code, Section VIII may also be adopted for the fabrication and testing of welded pressure vessels (the following rules being applicable in analogous manner). See also Section 1, B.1.4.

A. General

1. Scope

1.1 These Rules apply to the fabrication and testing of the following welded steel tanks, vessels and process equipment which are designed to withstand an internal working pressure:

1.1.1 Tanks, vessels and process equipment fabricated from unalloyed and alloyed ferritic steels with nominal yield strengths up to 380 N/mm^2.

1.1.2 Tanks, vessels and process equipment fabricated from austenitic stainless steels.

1.1.3 Cargo tanks[1] and process vessels fabricated from steels tough at sub-zero temperatures for carriage of cooled liquefied gases.

1.2 Tanks, vessels and process equipment fabricated from other materials not mentioned in 1.1 may be manufactured and tested in accordance with technical codes recognized by BKI.

1.3 The design and testing of tanks, vessels and process equipment joined by other processes (e.g. brazed or bonded) shall be subject to agreement between the manufacturer and BKI Head Office in each individual case (see also Section 1, A.1.1).

2. Other relevant rules

2.1 The provisions of the Rules for Machinery Installations (Pt.1, Vol. III) Sec. 8 shall also be complied with in the design and dimensioning of pressure vessels and process equipment.

2.2 Cargo tanks designed to carry chemicals are also subject to the provisions of the Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol. X) Sec. 1.

2.3 Cargo tanks and process vessels designed to carry cooled liquefied gases are also subject to the provisions of the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX).

[1] Independent "Type C" tanks.

3. Assessment of welds

3.1 Tensionally stressed longitudinal welds in pressure vessels and process equipment, except for such welds in cargo tanks for carriage of liquefied gases, may generally be evaluated according to a weld factor up to v = 0,85, provided that they meet the requirements specified in Sections 1 and 2, and in D., E., G. and H.

A higher evaluation up to v = 1,0 may be applied if a production test and non-destructive testing in accordance with I.4. have been successfully performed on the finished component.

3.2 Cargo tanks for liquefied gases shall be so constructed that their longitudinal welds can be evaluated according to a weld factor of at least v = 0,95. A further condition is successful performance of the production tests and non-destructive tests specified in I.4.

A higher evaluation up to v = 1,0 may be applied if the characteristics of the material, the type of the welded joints, the welding process and the type of loading so permit and BKI has approved the higher evaluation.

B. Approvals of Welding Shops, Welding Personnel

1. All welding shops intending to perform welding work within the scope of these Rules shall satisfy the requirements applicable to welding shops and personnel set out in Section 2 and shall have been approved by BKI. Applications for approval shall be submitted by the welding shops in good time before starting the welding work, enclosing the information and documentation prescribed in Sections 2, A.3.

2. The welding personnel (welders and welding supervisors) and, where applicable, inspectors and inspection supervisors shall satisfy the requirements set out in Section 2, B.2., B.3. and B.4. and be recognized by BKI.

C. Quality Inspection, Responsibility

1. The manufacturer shall submit to BKI, for inspection, drawings and other relevant documents containing at least the following information:

- The materials and welding consumables to be used,
- The welding process and the location and shape of the welds,
- The type of heat treatment, if required,
- The acceptable working pressure,
- The calculated temperature or, in the case of vessels fabricated from steels tough at sub-zero temperatures, the minimum design temperature,
- The operating temperature,
- The test pressure,
- The weld factor used as a basis for calculation,
- The nature and scope of the non-destructive tests,
- The nature and scope of the production tests.

2. If the quality or good working order of a component cannot be guaranteed or is in doubt due to inadequate or missing information in the manufacturing documents (e.g. production drawings), BKI may demand appropriate improvements.

3. The welding shops shall ensure by means of regular in-house quality inspections during fabrication and on completion of the welding work that this work has been performed competently and satisfactorily (see Section 1, F.). For the duties and responsibilities of the welding supervisor, see also ISO 14731.

4. The welding shops are responsible for ensuring that the welding work conforms to these Rules, the approved manufacturing documents, any conditions stipulated in the approval documents and the latest state of welding practice. The inspections and checks to be performed by BKI Surveyor do not relieve the welding shops of this responsibility.

5. With regard to quality inspections and the responsibilities involved in awarding subcontracts to independent branches or suppliers or to approved or non-approved outside firms working in the welding shop (subcontractors), see Section 1, F. Subcontracting of work or employment of temporary workers shall be notified to BKI.

6. The scope of the required quality inspections depends on the construction project in question. It is essential to ensure, however, that the intended materials, welding consumables and auxiliary materials are used and that the weld preparation, assembly, execution of the tack and final welds and the dimensional accuracy and completeness of the welded joints meets the requirements stated in 3. For non-destructive testing of the welded joints and production tests have to be performed, see I.

7. Following internal inspection and, if necessary, repair by the welding shop, the components shall be presented to BKI Surveyor for checking at suitable stages of fabrication. For this purpose they shall be readily accessible and shall normally be uncoated. Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory workshop inspection and any necessary repair work has been performed.

8. BKI is not responsible for guaranteeing that all the components and welded joints inspected to the prescribed extent (generally on a random basis) by its surveyors have been fabricated in accordance with the conditions and meet the requirements in every respect. Components or welded joints which subsequently turn out to be defective may be rejected or their repair may be demanded even if acceptance testing has already been carried out.

D. Materials, Weldability

1. The materials selected shall be appropriate for the intended purpose, with allowance made for mechanical and thermal stresses. The characteristics of materials subjected to further processing shall be such that they are able to withstand the operating loads.

2. Welded structures may only be fabricated using base materials of proven weldability. The intended materials shall comply with the requirements set out in the relevant sections of Rules for Materials (Pt.1, Vol. V) Sec. 4 to 9. Other comparable materials may only be used after BKI has given its approval in each individual case.

3. Materials for cargo tanks and process vessels for liquefied gases shall also meet the impact energy requirements at the stipulated test temperature; see Table 14.3.

E. Welding Consumables and Auxiliary Materials

1. The welding consumables and auxiliary materials shall enable a welded joint to be made which is appropriate to the base material, the operating temperature and the conditions of service. The suitability of the welding consumables shall also have been verified under the conditions prevailing in further processing and heat treatment.

2. All the welding consumables and auxiliary materials used (e.g. covered electrodes, wire-gas combinations, wire-flux combinations, etc.) shall have been approved by BKI in accordance with Section 5. They may also, however, be approved if tested at the same time as the welding procedure and restricted to the user's works (see Section 4, B.3.2 and Section 5, A.1.4).

3. Welding consumables for steels tough at sub-zero temperatures shall also meet the impact energy requirements for the weld metal at the stipulated test temperatures; see Table 14.3.

4. If it is necessary, in special cases, to use welding consumables of dissimilar material where the strength of the resulting weld metal is lower than that of the base material, e.g. when welding 9% nickel steel with austenitic consumables, appropriate allowance shall be made in the design calculations for the vessels.

5. Welding consumables and auxiliary materials specified in a procedure approval document with a maker's or brand name (see F.3.5) may only be replaced by equivalent consumables approved by BKI with an appropriate quality grade if this is explicitly stated in the respective approval document. Failing this, BKI agreement shall be obtained.

6. The welding consumables and auxiliary materials may only be used in the approved welding positions. The manufacturer's recommendations and instructions for welding (e.g. type of current and polarity) shall be followed.

7. The welding consumables and auxiliary materials (especially hydrogen-controlled, basic-covered electrodes and basic welding fluxes) shall be re-dried before use in accordance with the manufacturer's instructions (observe maximum drying time) and stored in a dry place (in heated containers or the like) at the workplace.

F. Welding Procedure Tests

Preliminary remark:

In contrast to earlier issues of these Rules, welding procedure tests shall be performed in accordance with ISO 15614, as applicable. This paragraph essentially covers requirements applicable to the welding of pressure vessels over and above those set out in ISO 15614-1.

1. General

Only those welding procedures shall be employed whose satisfactory operational handling and adequate quality properties have been verified as part of a welding procedure test under production conditions at the user's works. The general requirements set out in Section 4 shall be observed. The welding procedures shall have been approved by BKI for the particular welding shop in question.

2. Welding of test pieces, welding procedure specification (WPS)

2.1 A preliminary "manufacturer's" welding procedure specification (pWPS) setting out all the major parameters shall be produced by the welding shop for the welding of test pieces in accordance with ISO 15609-1, as applicable (see Annex D).

2.2 BKI expert shall select one of the welders whose names are to be supplied by the manufacturer to weld the test pieces.

2.3 The test pieces shall be made from materials whose properties are proven in accordance with the requirements specified in the Rules for Materials (Pt.1, Vol. V) Sec. 4 to 9. Pre-treatment and after-treatment of the test pieces by preheating, heat treatment and the like is only permitted if required for these materials during the actual fabrication.

2.4 The types of weld and welding positions employed in the fabrication process shall be qualified in the welding procedure test.

2.5 The shape and dimensions of the test pieces are specified in ISO 15614-1, where applicable, stipulated in 2.6 and 2.7.

2.6 The plate test pieces for cargo tanks designed to carry liquefied gases shall be executed as shown in Fig. 14.1.

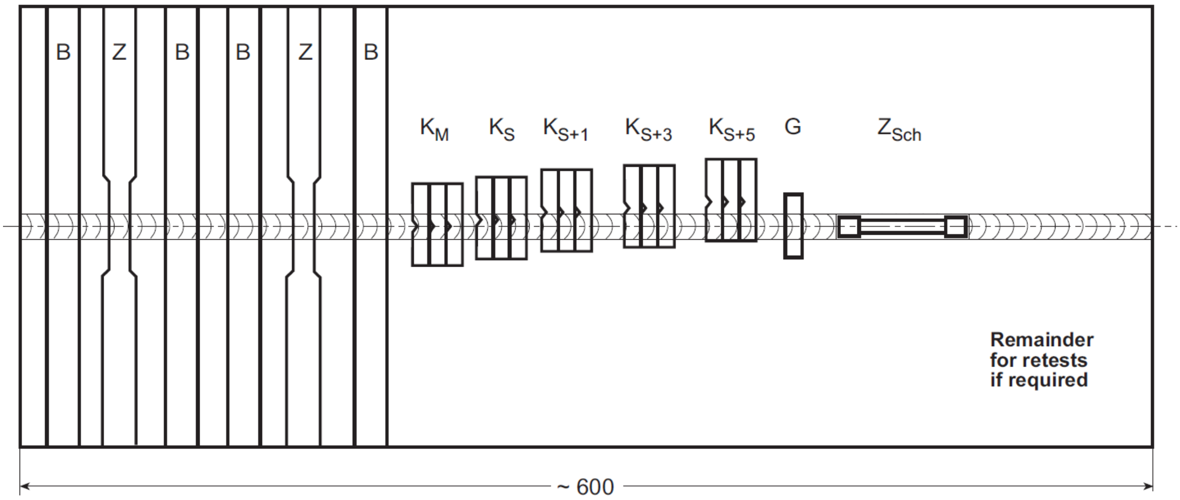

Fig. 14.1 Test piece for cargo tanks

2.7 For making fillet welds on tanks for the carriage of liquefied gases, the following shall be made:

– One fillet-welded test piece approx. 300 mm long for each welding position (see Fig. 14.2)

– One Y test piece approx. 300 mm long from the joint between the central longitudinal bulkhead and the tank walls for each welding position (see Fig. 14.3) (where applicable, e.g. for bilobe tanks).

3. Test principles, delimitation of scope

The qualification of the welding procedure shall be ascertained in accordance with ISO 15607 by means of welding procedure qualification tests, for steel in accordance with ISO 15614-1. The test is valid within the limits described in 3.1 to 3.7.

The scope of the welding procedure test is specified by BKI in writing. Any exceptions require the performance of a supplementary test, the scope of which shall be decided by BKI. Production tests may be recognized as supplementary tests.

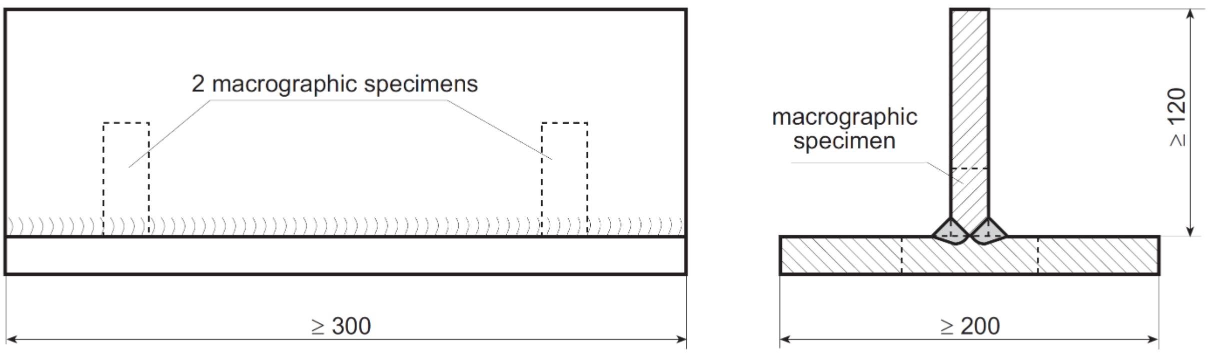

Fig. 14.2 Fillet-welded test piece

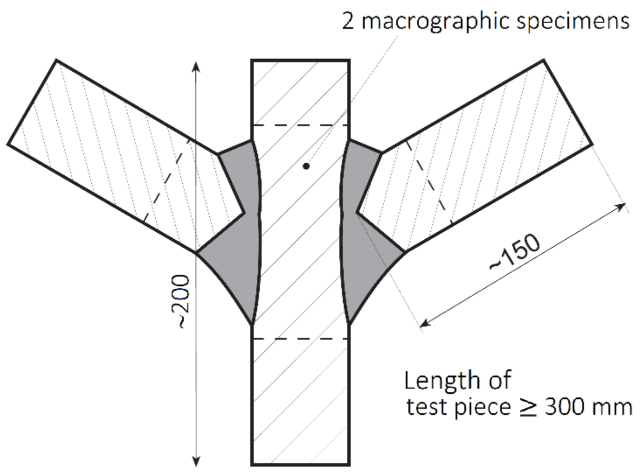

Fig. 14.3 Y test piece

3.1 Material groups

Above and beyond the grouping system of ISO 15608, Table 1, the following provisions shall be observed:

a) For materials which have to satisfy particular corrosion conditions (e.g. resistance to caustic cracking) the welding procedure tests shall be geared to these.

b) A welding procedure qualification performed on group 1killed steel does not apply to unkilled steels unless they were welded using basic covered electrodes or wire-flux combinations with basic flux.

c) Approval is also granted for the following further material combinations in addition to those stipulated in ISO 15614-1, Table 3 but under the following conditions (see Table 14.1).

d) Deviating from ISO 15614-1, Table 3, a welding procedure test available for the combination group 8 welded to group 2 does not incorporate the combination group 8 welded to group 3.

e) Depending on material composition and/or the type of post-weld treatment required, BKI may also limit the scope to the base material used in the welding procedure test.

f) For the materials used in the fabrication of cargo tanks and process vessels for liquefied gases, the test applies only to the grade of steel inspected.

3.2 Welding process

Recognition applies only to the welding process employed in the welding procedure test.

3.3 Welding parameters

Welding procedure tests performed on multi-pass welds do not apply to single-pass welds.

3.5 Welding consumables and auxiliary materials

The requirements of ISO 15614-1, para. 8.4.5. do not apply if the filler metal used is of the same type and has been approved by BKI to be under the scope of the welding procedure qualification (see E.5.).

3.6 Heat treatment

The welding procedure test applies to the heat treated condition existing at the time of the test. Heat treatment of the test piece shall be performed so that a heat treated condition is achieved which is comparable to that of the component.

3.7 Special cases

For special cases, for example projection welds, welding of clad steels, stud welds and difficult repairs to be performed in the course of fabrication on steels which are susceptible to cracking due to hardening of the heat affected zone, welding procedure tests are necessary which are geared to these particular cases. The tests required and their scopes are specified by BKI in each individual case.

Table 14.1 Range approval for dissimilar metal joints

Welding procedure qualification available for a steel group of combination joints	Suitable for the following combination joints
5 (10CrMo9-10) welded with 4	4 welded with 5 (13CrMo4-5) 4 welded with 1 4 welded with 2 (R_e < 430 N/mm^2)
5	5 welded with 1 5 welded with 2
6 welded with 4	6 welded with 5 6 welded with 2 6 welded with 1

4. Tests, scope of tests

Testing comprises both non-destructive and destructive tests and shall be performed in accordance with ISO 15614-1, para. 7.

Deviating from ISO 15614-1, para. 7.1, and Table 1, the following specimens shall also be taken from the test pieces:

a) One all-weld metal tensile test specimen with a diameter of 10 mm and L_0 = 5 d shall also be taken in the case of test pieces more than 20 mm thick in materials where the weld metal may be significantly affected by the welded joints.

   This applies to steels in material groups 2 (high temperature steels only), 4 and 6. This test shall also be performed on group 9 materials where post-weld heat treatment is stipulated.

b) Notched bar impact test specimens shall always be taken from the centre of the weld metal for each welding position in the case of wall thicknesses greater than 5 mm

c) Notched bar impact test specimens shall also be taken from the fusion line for each welding position in the case of material groups 2, 4, 5, 6, 8 and 9 (proportion of delta ferrite in the weld metal ≤ 3%) and wall thicknesses ≥ 10 mm.

d) Micrographic specimen for alloy steels[2]. The structure shall be described and verified by means of photographs.

e) Analysis of the weld metal for alloy steels[2].

f) Contrary to the provisions of b) and c), 3 notched bar impact test specimens with the notch perpendicular to the surface of the plate shall each be taken from the centre of the weld metal (KM), the fusion line (KS) and also 1, 3 and 5 mm away from the fusion line in the heat affected zone (KS+1, KS+3, KS+5) for plate test pieces for cargo tanks for the carriage of liquefied gases; see Fig. 14.1.

[2] For the classification of steels (unalloyed and alloyed), see ISO 4948-2.

5. Test requirements

The irregularities in the test piece shall fall within the limits specified for quality level B in accordance with ISO 5817, exceptions being: excessive weld reinforcement (butt and fillet welds), excessive root reinforcement and excessive throat thickness (fillet welds) which fall into quality level C.

For the mechanical and technological tests, Table 14.2 applies. The impact energy requirements for cargo tanks and process vessels designed to carry liquefied gases are given in Table 14.3.

6. Storage of specimens

The tested specimens and the remaining portions of the test pieces shall be stored until the report on the welding procedure test has been issued (see also Section 4, C.3.).

7. Validity, extension of welding procedure tests

The validity of a welding procedure test is generally 1 year provided that the preconditions under which it was granted have not significantly changed. It may be continued by means of regular production tests (see I.4.).

In addition to production tests and tests performed on welded components (see I.) non-destructive tests may, given certain preconditions, also be recognized by BKI for continuing the validity.

The welding procedure test shall be repeated if there is a break in the fabrication of pressure vessels or pressure vessel components lasting longer than one year.

Table 14.2 Test requirements applicable to welded joints in steel

<table>
<tr><th>Type of test</th><th colspan="3">Requirements</th></tr>
<tr><td>Tensile test transversely to weld</td><td colspan="3">Tensile strength as stipulated for the base material or in the assessment of suitability for the welding consumable</td></tr>
<tr><td>Tensile test on specimen of the weld metal</td><td colspan="3">Yield strength or 0,2% proof stress. tensile strength and elongation as stipulated for the base material or in the assessment of suitability for the welding consumable</td></tr>
<tr><td rowspan="2">Notched bar impact test on ISO V-notch specimen taken from the center of the weld</td><td colspan="3">Where temperature of medium [1] is –10°C or above:
As stipulated for the base material in transverse direction. Test temperature as in testing of the base material, but not lower than –10°C. When using ferritic-austenitic, austenitic and nickel-base welding consumables ≥ 40 J</td></tr>
<tr><td colspan="3">Where temperature of medium [1] is lower than –10°C:
At minimum working temperature, ≥ 27 J [2] when using ferritic welding consumables, ≥ 32 J [2] when using ferritic-austenitic, austenitic and nickel-base alloy welding consumables</td></tr>
<tr><td rowspan="2">Notched bar impact test on ISO V-notch specimen taken from the weld transition zone</td><td colspan="3">Where temperature of medium [1] is lower than –10°C or above:
≥ 27 J [2]; test temperature as in testing of the base material, but not lower than –10°C</td></tr>
<tr><td colspan="3">Where temperature of medium [1] is lower than –10°C:
≥ 16 J [2]; at minimum working temperature</td></tr>
<tr><td rowspan="6">Technological bend test</td><td>Bending angle degrees</td><td>Strength category [3]</td><td>Bending mandrel dia.</td></tr>
<tr><td>180 [4]</td><td>Ferritic steel with :
min. tensile strength < 430 N/mm^2
min. tensile strength ≥ 430 to 460 N/mm^2</td><td>
2 x a
2,5 x a</td></tr>
<tr><td>180 [4]</td><td>Austenitic stainless steel and austenitic steels tough at sub-zero temperatures
High temperature austenitic steels
Ferritic steels with a minimum tensile strength ≥ 460 N/mm^2</td><td>2 x a

3 x a
3 x a</td></tr>
<tr><td colspan="3">If a bending angle of 180 degrees is not attained, the following applies:</td></tr>
<tr><td>≥ 90</td><td colspan="2">Elongation (L_0 = width of weld + wall thickness symmetrical to weld) ≥ minimum elongation A of base materials</td></tr>
<tr><td>or < 90</td><td colspan="2">Elongation over width of weld > 30% 5) and faultless appearance of fracture</td></tr>
<tr><td>Metallographic examination</td><td colspan="3">The macrographic specimen of the welded joint shall reveal a satisfactory weld build-up and full penetration of the weld.
The micrographic section is to be examined for cracks. Only hot cracks are acceptable, and then only if they are few in number and widely scattered and agreement has been reached with the Surveyor as to their acceptability with regard to the material and the range of application.</td></tr>
<tr><td>Hardness testing</td><td colspan="3">The hardness in the heat- affected zone shall not exceed 350 HV 10. Hardness peaks in excess of this figure in narrow transition zones shall not give rise to complaints if the outcome of the technological test meets the requirements</td></tr>
<tr><td colspan="4">1) Cargo tanks and process vessels for liquefied gases are subject to the impact energy requirements at the relevant test temperatures as shown in Table 14.3.
2) Only one impact energy value may be lower than the minimum mean value, and only by max. 30%.
3) The tensile strength value applies to be the area of least thickness.
4) The 180-degree requirement is deemed to have been met if the bend test was performed according to ISO 5173 and pressure was applied by the supports without cracks appearing.
5) For steels welded with non-matching consumables. e.g. X8Ni9, different values may be agreed with BKI.</td></tr>
</table>

Table 14.3 Impact energy requirements for cargo tanks and process vessels for liquefied gases

<table>
<tr><th rowspan="2">Type of steel</th><th rowspan="2">Minimum design temperature [°C]</th><th rowspan="2">Thickness t [mm]</th><th colspan="4">Notched bar impact test on ISO V-notch specimen</th></tr>
<tr><th colspan="3">Test temperature</th><th>KV [J] min.</th></tr>
<tr><td>Carbon-manganese steels</td><td>0</td><td>t ≤ 20
20 < t ≤ 40</td><td colspan="3">0 °C
– 20 °C</td><td rowspan="4">Center of weld :

for ferritic consumables ≥ 27, for austenitic and nickel base alloy consumables ≥ 32

Weld boundary and fusion line :

≥ 27</td></tr>
<tr><td>Carbon-manganese steel incl. 0,5 % nickel steel</td><td>– 55</td><td>t ≤ 25
25 < t ≤ 30
30 < t ≤ 35
35 < t ≤ 40</td><td>5 K
10 K
15 K
20 K</td><td colspan="2">below minimum design temperature [1)]but not exceeding -20 °C</td></tr>
<tr><td>Nickel alloy steels containing:
1,5% Ni
2,25% Ni
3, 5% Ni
5,0% Ni</td><td>

– 60
– 65
– 90
– 105</td><td>

t ≤ 25
25 < t ≤ 30
30 < t ≤ 35
35 < t ≤ 40</td><td>

5 K
10 K
15 K
20 K</td><td>

Below minimum design temperature [2)]</td><td>

(– 65°C)
(– 70°C)
(– 95°C)
(–110°C)</td></tr>
<tr><td>Nickel alloy steels containing:
5,0% Ni
9,0% Ni
Austenitic steel</td><td>

– 165 [3)]
– 165
– 165</td><td>

t ≤ 25 [4)]
t ≤ 25 [4)]
t ≤ 25 [4)]</td><td colspan="3">

– 196°C
– 196°C
– 196°C</td></tr>
<tr><td colspan="7">1) For components subjected to stress relief heat treatment after welding, a test temperature of 5 K below the minimum design temperature or – 20°C, whichever is lower, may be adequate.
2) The test temperature shall not exceed the figures stated in brackets.
3) The steel type 5% Ni may only be used for design temperatures down to – 165°C after a special test of product suitability.
4) For thickness > 25 mm, the requirements shall be agreed with BKI.</td></tr>
</table>

G. Welding Technique

1. Welds shall exhibit full penetration over their entire cross section and shall not have any cracks or lack of fusion defects. Wherever possible, the root shall be grooved and capped.

If backing rings are used when making circumferential welds, they shall be removed after welding. This may be dispensed with in the case of small vessels, the inside of which is no longer accessible.

2. When welding plates of the same thickness, the edge misalignment shall not exceed the following values:

– Seams welded on both sides :

0,15 x plate thickness (mm), subject to a maximum of 3 mm

– Seams welded on one side only :

0,10 x plate thickness (mm), subject to a maximum of 2 mm.

For vessels fabricated from clad plates, a smaller edge misalignment tolerance may be necessary depending on the thickness of the cladding.

3. When welding plates whose thicknesses differ by more than 20% or more than 3 mm, the thicker plate shall be bevelled to the thickness of the thinner plate at a maximum angle of 30°.

4. In the case of shells consisting of several rings, the longitudinal seams shall be staggered. As a guide, the amount of stagger should be 4 times the plate thickness, but at least 100 mm.

5. Lapped joints with fillet welds between shell rings, bottoms and tubes are only acceptable in individual cases as circumferential welds with a wall thickness of 8 mm, provided that both sides of the lap are welded. Such joints may not be used in cargo tanks and process vessels for liquefied gases.

6. Corner welds and similar welded joints which are subjected to considerable flexural stresses under adverse conditions of fabrication or service are only acceptable if BKI raises no objection to the method of execution.

7. Holes and cut-outs in or immediately adjacent to welds, especially longitudinal welds, shall be avoided wherever possible.

8. Butt-welded joints in walls under pressure shall not be intersected by fillet welds of fitments. If intersection of fitments with vessel welds cannot be avoided, sufficiently large cut-outs shall be made in the fitments in the area of the butt welds in the vessel.

9. Weld preparation for welds between the vessel wall and domes and between the domes and the corresponding sockets shall be carried out in accordance with recognized standards. All welds on nozzles, domes and other components which penetrate the pressure vessel and all welds between flanges and vessel or nozzle shall be welded with full penetration over the entire wall thickness of the vessel or the nozzle.

As an exception, other joints without full penetration may, with BKI consent, be used for small-diameter nozzles in the dome.

10. Bearings, tank mountings and other fitments which may induce stresses in the walls of the vessel shall be joined to the vessel wall with adequately dimensioned doubling plates or transition pieces.

11. Fillet welds of sockets, tank stiffeners and fitments which may induce stresses in the walls of the vessel shall be laid down in more than one pass.

12. Doubling plates, flanges, mountings, lifting lugs and other welded fitments shall be adapted to the contour of the vessel. All parts shall be welded prior to any heat treatment and before pressure testing. An exception to this rule may be allowed in the case of parts subsequently attached to doubling plates or transition pieces.

13. Welding of components from ferritic steels in cold-formed areas where the outer fibres have been stretched by more than 5% ($D_m < 20 \cdot s$ for cylindrical shell rings) is only allowed if the effects of cold-forming have been cured by means of appropriate heat treatment.

This shall generally be accomplished by normalizing heat treatment or quenching and tempering. This requirement may be waived if proof is furnished that the properties of the material are no more than insignificantly impaired with regard to the intended use.

14. Every weld in a pressure vessel component shall be marked in such a way that its location remains recognizable and the welder concerned can be identified at any time. Both of these may be evidenced either by stamping the weld accordingly or by making entries in drawings, welding schedules or other records.

H. Post-Weld Heat Treatment

1. Welded components shall be heat-treated after welding in accordance with the stipulations of the relevant standards or BKI approval document.

1.1 The post-weld heat treatment shall normally consist of stress relief heat treatment.

1.2 Components fabricated from steels which have undergone normalizing heat treatment shall be subjected to normalizing heat treatment if:

– the required properties of the welded joint can only be established by normalizing heat treatment or

– the component has undergone hot-forming after welding, unless hot-forming was completed within a temperature range equivalent to normalizing heat treatment.

1.3 Components fabricated from quenched and tempered steels shall be subjected to quenching and tempering if:

– the required properties of the welded joint can only be established by quenching and tempering or

– the component has undergone hot-forming after welding.

If, in the case of air-hardened and tempered steels, the hot-forming of the component was on the whole performed under the conditions applicable to normalizing heat treatment, tempering alone is sufficient.

1.4 Cargo tanks for liquefied gases fabricated from carbon-manganese steels or 0,5% nickel steels and designed for service at temperatures below -10°C shall be subjected to stress relief heat treatment, unless 2.4 applies.

1.5 For high-alloy steels with a ferritic or austenitic structure and nickel alloy steels tough at sub-zero temperatures with the exception of 0,5% nickel steel, the need for and method of heat treatment shall be determined separately (see also Section 9, E.).

2. Except in the case of the tanks described in 1.4, post-weld heat treatment may be dispensed with if the following conditions are met:

2.1 Prior to welding, the materials shall be in the heat-treated condition specified in the relevant standards or in BKI approval document. This condition is also deemed to be met if the required heat-treated condition is only attained during subsequent fabrication.

2.2 The nominal wall thickness at the joints may not exceed 30 mm.

2.3 In the chemical composition (melt analysis) of the base material and the weld metal, the following contents may not be exceeded:

C 0,22%,	Si 0,50%,	Mn 1,40%,
Cr 0,30%,	Cu 0,30%,	Mo 0,50%,
Ni 0,30%,	V 0,20%;	

In this context, the following conditions shall also be satisfied:

$$Cr + Ni \leq 0{,}30\% \quad \text{and} \quad Mn + Mo + V \leq 1{,}6\%$$

These conditions may be relaxed in the case of steels which have been rendered resistant to brittle fracture and hardening by special metallurgical measures. Their suitability and properties shall be demonstrated to BKI after an adequate period of proving. The steels' resistance to brittle fracture, resistance to hardening and weldability shall be equivalent to those of steels falling within the above analytical limits. For the weld metal, at a C content ≤ 0,10%, the Si content shall be ≤ 0,75%, the Mn content ≤ 2,0% and the sum of the Mn, Mo and V contents ≤ 2.5% if welding consumables are used which produce a weld metal with a particularly high toughness, e.g. by using welding consumables with basic characteristics.

2.4 If, in the case of cargo tanks for liquefied gases fabricated from carbon-manganese steels or 0,5% nickel steels and designed for service at temperatures below - 0°C, heat treatment is on the whole not possible due to the dimensions of the tank, mechanical destressing shall be carried out after welding.

For this purpose, individual components of complex design, e.g. domes, sumps, rings and other components which penetrate the casing of the tank, shall first be welded to the adjoining shell or bottom plates and subjected with them to stress relief heat treatment before being attached to the tank structure.

3. If carbon-manganese or nickel alloy steels are welded with austenitic consumables, they shall not be heat-treated after welding.

4. Documentary proof of the heat treatments described in 1.1 to 1.4 shall be provided by means of a works certificate to ISO 10474 or EN 10204, as applicable which shall state the method, temperature and duration of the heat treatment and the method of cooling. Any special heat treatment, e.g. temporary cooling after welding prior to tempering treatment, shall be recorded in the works certificate.

I. Inspection of Welded Components

1. All tanks, vessels and process equipment shall be subjected to a hydraulic pressure test at 1,5 times the working pressure in the presence of the Surveyor, subject to the limitation that the resulting stress shall not exceed 0,9 times the yield strength at 20°C, taking into account the positive diameter tolerance and the negative wall thickness tolerance. This does not apply to cargo tanks of the type described in H.2.4. The component shall exhibit no leaks during the hydraulic pressure test and no permanent deformation afterwards.

2. An internal and external inspection shall be carried out on the completed vessels and process equipment, and especially of the welds and adjoining areas. The components shall have a smooth external and internal surface corresponding to the condition as manufactured, to enable significant surface defects to be detected. Vessels fabricated from austenitic steels shall be pickled on the inside. At the same time, measurements shall be carried out to determine.

2.1 External circumference

The measurements shall be spaced at approx. 1 - 2 m intervals over the entire length of the component, depending on the length of the vessel. The measurements of the external circumference shall be used to determine the average outside diameter. The outside diameter of the shell rings and vessels may not vary from the stipulated outside diameter by more than ± 1,5 %.

2.2 Out-of-roundness

The measurements shall be spaced at approx. 1 - 2 m intervals over the entire length of the component. The out-of-roundness:

$$U = \frac{2 \times \left(D_{max} \times D_{min}\right)}{D_{max} \times D_{min}} \times 100\%$$

shall not exceed the following values:

Table 14.4 Acceptable out-of-roundness

Ratio of wall thickness to diameter	Maximum acceptable out-of-roundness
s/d ≤ 0,01	2,0%
0,01 < s/d ≤ 0,1	1,5%
s/d > 0,1	1,0%

In calculating the out-of-roundness, the elastic deformations arising from the component's own weight shall be discounted. Isolated bulges and dents shall also lie within the tolerances. In addition, the bulges and dents shall have a flat profile and their depth, measured as a deviation from the normal roundness or from the shell line, as applicable, shall not exceed 1% of the length or width of the dent or bulge.

2.3 Axial non-linearity

The axial non-linearity shall not exceed 0,5% of the cylindrical length.

2.4 Camber or flattening;

The degree of camber or flattening in the area of the longitudinal welds, measured as a deviation from the normal roundness with a template length of 500 mm, may not exceed the dimension "a".

Depending on the ratio of the average diameter dm to the wall thickness se of the vessel or shell ring, the following applies:

$$a \leq 10 \text{ mm} \quad \text{for shell rings } \frac{d_m}{s_e} < 40,$$

$$a \leq 5 \text{ mm} \quad \text{for shell rings } \frac{d_m}{s_e} \geq 40.$$

2.5 Wall thickness of the welds and the adjoining plate areas

The wall thickness in the plate shall lie within the tolerance permitted for the plate.

3. To show that the requirements stated in 1 and 2 are met, the manufacturer shall issue an acceptance Test Certificate 3.1B according to ISO 10474 or EN 10204, as applicable and present it to the Survey or at the final acceptance testing of the vessels.

4. Production Tests

The production test comprises non-destructive testing of the component and quality testing of test pieces (mechanical and technological tests).

4.1 Non-destructive testing

The performance of the tests is subject to the provisions of Section 10.

4.1.1 Non-destructive testing of cargo tanks for the carriage of liquefied gases

.1 The following welds shall be inspected:

a) All butt welds in the pressure structure (shells, ends, domes, sumps) shall be subjected to X-ray radiographic inspection over their entire length. In addition, at least 10% of the weld length shall be tested for surface cracks.

b) Fillet welds at the joint between the central longitudinal bulkhead and the tank casing of twin tanks or similar structures shall be subjected to ultrasonic or, where this is not possible, X-ray radiographic inspection over their entire length. In addition, at least 10% of the weld length shall be tested for surface cracks.

c) 10% of the butt-welded joints of supporting rings in tanks shall be subjected to X-ray radiographic inspection. In the case of fillet welds between the web and the tank wall and between the web and the girder plate, at least 10% of the weld length shall be tested for surface cracks.

d) All butt and fillet welds of nozzles weldments, e.g. sockets, domes, sumps, rings, and of reinforcing plates around cut-outs shall be tested for surface cracks over their whole length.

e) Fillet welds of fitments welded to the tank which may induce stresses in the tank wall, e.g. lifting lugs, feet, brackets, shall be tested for surface cracks over their whole length.

f) Full root penetration nozzle connections in the pressure structure shall undergo ultrasonic or radiographic inspection if the attachment wall thickness at the pressure structure is > 15 mm and the inside diameter of the nozzle is ≥ 120 mm.

g) If cargo tanks are to be mechanically de-stressed, all points with geometry-related stress concentrations, such as the seams of socket weldments or fitments, shall afterwards be tested for cracks by the magnetic particle or dye penetrant method.

.2 If radiographic inspection is to be partly replaced by ultrasonic inspection, the method and scope shall be authorized by BKI beforehand.

.3 Notwithstanding 4.1.1.2, BKI may require radiographic inspection to be supplemented by ultrasonic testing and vice versa if considered necessary in special cases.

.4 Isotopes (Ir 192) may only be used if the use of an X-ray tube is impossible for technical reasons.

4.1.2 Non-destructive testing of pressure equipment with a weld factor v > 0,85

.1 The following welds shall be inspected:

a) Longitudinal welds shall be subjected to radiographic inspection over their entire length and circumferential welds over 25% of their length. In addition, at least 10% of the weld length shall be tested for surface cracks.

b) All butt and fillet welds of weld-in components and reinforcing plates around cutouts shall be tested for surface cracks over their entire length. The same applies to fitments if they are capable of inducing stresses in the wall of the vessel.

c) The attachment welds of nozzles with an inside diameter ≥ 120 mm and a thickness of the attachment cross section > 15 mm shall undergo radiographic or ultrasonic inspection.

.2 Where the radiographic inspection is to be replaced by ultrasonic inspection, the process and scope of the test shall be authorized by BKI beforehand. BKI may prescribe an ultrasonic inspection to supplement the radiographic inspection where there are doubts in interpretation of radiographic exposures.

4.1.3 Non-destructive testing of pressure equipment with a weld factor v ≤ 0,85

The manufacturer shall test the components at random in the course of his quality assurance procedures and shall present the results to the Surveyor at the vessel inspection. For this purpose, around 2% (10% in the case of wall thicknesses over 15 mm) of the longitudinal welds shall undergo radiographic or ultrasonic inspection, which shall include the junctions between longitudinal and circumferential welds.

4.1.4 Inspection criteria

The non-destructive testing shall not reveal any major deficiencies in the weld. These include: cracks, lack of sidewall fusion and, in the case of single-side welds, inadequate root penetration.

Other defects, e.g. pores and slag, shall be assessed in accordance with recognized codes of practice, e.g. the ASME Boiler and Pressure Vessel Code, Section VIII.

4.2 Quality inspection of test pieces

4.2.1 Quality inspection of cargo tanks for the carriage of liquefied gases

.1 On all tanks for the carriage of liquefied gases, one test piece as shown in Fig. 14.4 shall be welded on to every 50 m of butt weld (longitudinal and circumferential welds). The location of the test pieces shall be such that every welding position is covered. Wherever possible, they shall be made as extensions of the vessel seam and shall be welded together with the vessel seam in the same operation. If this is not feasible in exceptional cases, the test pieces shall be attached beside the relevant tank weld and welded immediately on completion of the associated section of the weld under the same conditions as were used for the actual weld. The test pieces shall be stamped by BKI expert before being removed from the tank. The positions and numbers of the test pieces shall be marked on the tank and indicated in the inspection schedule.

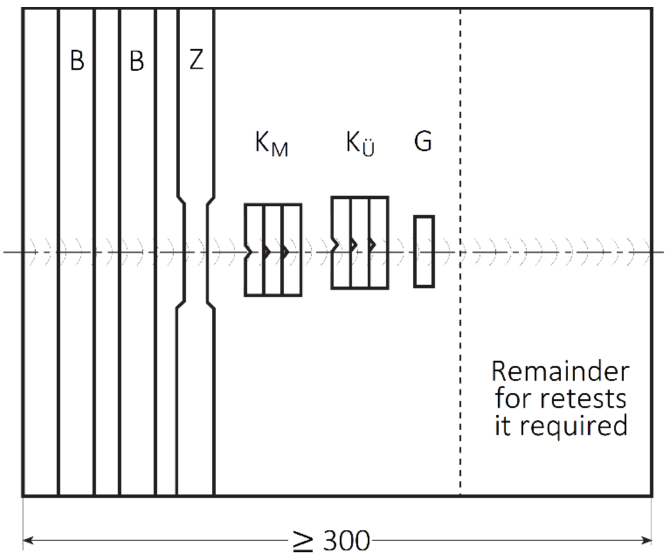

Fig. 14.4 Test piece for production tests

.2 The test pieces shall be subjected to the following tests (for shapes of specimens, see also Section 11):

a) Tensile test on one specimen (Z), shape of specimen according to ISO 4136; however, test length = width of weld + at least 80 mm.

b) Technological bend test (B) to ISO 5173 on 2 (two) specimens (one specimen each with opposite sides of the weld in tension). On the side in tension, after machining off the weld reinforcement the original surface of the test piece shall be preserved to the greatest possible extent. Sizeable depressions such as undercuts and root notches shall not be repaired.

c) Notched bar impact tests on ISO V-notch specimens in accordance with ISO 9016, taking from each test piece one set of specimens with the notch in the center of the weld metal (KM) and one set located at a point in the heat-affected zone (KÜ) at which the lowest impact energy values were measured in the welding procedure test.

d) Structure examination (G) of one specimen (macrographic specimen).

e) Hardness testing of the structure examination specimen according to d).

f) A radiographic inspection in accordance with ISO 17636 shall be performed prior to sectioning of the test pieces.

4.2.2 Quality inspection of pressure equipment with a weld factor v > 0,85

.1 In the fabrication of all vessels, a test piece as shown in Fig. 14.4 is to be welded at the same time, regardless of the number of melts used for the plates. 2 test pieces are required if there are more than five rings per pressure vessel.

.2 The test pieces shall be subjected to the scope of testing described in 4.2.1.2; however, the notched bar impact test specimens shall be prepared as follows:

a) One set of notched bar impact test specimens with the notch in the center of the weld (KM) shall be taken from each test piece.

b) In addition, one set of notched bar impact test specimens shall be taken from the transition zone (KÜ) for:

- all process pressure vessels with a design temperature below 0°C
- all alloy steels
- all unalloyed steels where the wall thickness in the area of the weld is over 30 mm.

4.2.3 Quality inspection of pressure equipment with a weld factor v ≤ 0,85

The manufacturer shall perform random quality inspections on his components as part of his quality assurance procedures in accordance with 4.2.2. These inspections shall cover 2% of the components, but shall be performed at least one test piece a year for each material group and welding process. The results of the quality inspections shall be presented to BKI expert at the acceptance testing of pressure vessels.

4.2.4 Requirements

The requirements stated in Table 14.2 and, for cargo tanks and process vessels for liquefied gases, also those stated in Table 14.3 shall be met in the quality inspection. Failing this, the associated section of weld shall be machined out and rewelded and its characteristics shall be verified by testing of a new test piece.

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Section 15 Welding of Pipelines

A. General

1. Scope

1.1 These Rules apply to the fabrication and testing of welded pipelines made of

- Unalloyed steels,
- High-temperature steels,
- Steels tough at sub-zero temperatures,
- Stainless steels.

1.2 Welded pipelines fabricated from other materials not listed in 1.1 (e.g. copper-nickel wrought alloys) may be manufactured and tested to other rules or regulations issued by the BKI for specific uses or other engineering regulations recognized by the BKI.

1.3 The design and testing of pipelines joined by other processes (e.g. brazed or bonded) are subject to agreement between the manufacturer and BKI Head Office in each individual case (see Section 1, A.1.1).

2. Other relevant standards

2.1 The provisions of the Rules for Machinery Installations (Pt.1, Vol. III) Sec. 11 shall also be complied with in the design and dimensioning of pipelines subject to pressure.

2.2 Cargo lines on ships designed for the bulk carriage of chemicals are also subject to the provisions of the Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol. X) Sec. 1.

2.3 Cargo and process lines on ships designed to carry cooled liquefied gases are also subject to the provisions of the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX).

3. Pipe classes

Depending upon the nature of the pipe and its content (medium) and also the design pressure and design temperature, pipelines are classified into three pipe classes, see Rules for Machinery Installations (Pt.1, Vol.III) Sec. 11, Table 11.1. The type of pipe connections, welding requirements, the need for postweld heat treatment and the scope of the non-destructive tests are stipulated in the following paragraphs or in other relevant rules, as applicable, in relation to the particular pipe class.

B. Approval of Welding Shops, Welding Personnel

1. All welding shops intending to perform welding work within the scope of these rules shall satisfy the requirements applicable to welding shops and personnel set out in Section 2 and shall have been approved by the BKI. Applications for approval shall be submitted by the welding shops in good time before starting the welding work, enclosing the information and documentation prescribed in Section 2, A.3.

2. The welding personnel (welders and welding supervisors) and, where applicable, inspectors and inspection supervisors shall satisfy the requirements set out in Section 2, B.2., B.3. and B.4. and be recognized by the BKI. For the welder's qualification tests, see Section 3.

3. The scope of the approval is determined by the capabilities of the welding shop and by the intended range of application (pipe class, materials, welding processes, welding positions, etc.). The intended range of application shall be specified in the application for approval; see the form "Description of Welding Shop" enclosed at Annex B. For the period of validity of the approval, see Section 2, A.4. and A.5.

C. Quality Inspection Responsibility

1. The manufacturer shall submit to the BKI, for inspection, drawings and other relevant documents containing at least the following information:

- The type of pipeline/medium,
- The pipe grades and welding consumables to be used,
- The welding process, the welding position and shape of the weld,
- The type of heat treatment, if required,
- The acceptable working pressure,
- The design temperature or, in the case of cargo and process pipelines for gas tankers, the minimum design temperature,
- The operating temperature,
- The test pressure,
- The nature and scope of non-destructive tests.

2. If the quality or good working order of a component cannot be guaranteed or is in doubt due to inadequate or missing information in the manufacturing documents (e.g. production drawings), the BKI may demand appropriate improvements.

3. Welding shops shall ensure by means of regular in-house quality inspections during fabrication and on completion of the welding work that this work has been performed competently and satisfactorily (see Section 1, F.). For the duties and responsibilities of the welding supervisor, see also ISO 14731.

4. The welding shops are responsible for ensuring that the welding work conforms to these Rules, the approved manufacturing documents, any conditions stipulated in the approval documents and the latest state of welding practice. The inspections and checks to be performed by BKI Surveyor do not relieve the welding shops of this responsibility.

5. With regard to quality inspections and the responsibilities involved in awarding subcontracts to independent branches or suppliers or to approved or non-approved outside firms working in the welding shop (subcontractors), see Section 1, F. Subcontracting of work or employment of temporary workers shall be notified to the BKI.

6. The scope of the required quality inspections depends on the construction project in question. It is essential to ensure, however, that the intended materials, welding consumables and auxiliary materials are used and that the weld preparation, assembly, execution of the tack and final welds and the dimensional accuracy and completeness of the welded joints meets the requirements stated in 3. For non-destructive testing of the welded joints, see I.

7. Following internal inspection and, if necessary, repair by the welding shop, the components shall be presented to BKI Surveyor for checking at suitable stages of fabrication. For this purpose they shall be readily accessible and shall normally be uncoated. Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory welding shop inspection and any necessary repair work has been performed.

8. The BKI is not responsible for guaranteeing that all the components and welded joints inspected to the prescribed extent (generally on a random basis) by its surveyors have been fabricated in accordance with the conditions and meet the requirements in every respect. Components or welded joints which subsequently turn out to be defective may be rejected or their repair may be demanded even if acceptance testing has already been carried out.

D. Materials, Weldability

1. The materials selected shall be appropriate for the intended purpose, with allowance made for mechanical and thermal stresses. The characteristics of materials subjected to further processing shall be such that they are able to withstand the operating loads.

2. Welded structures may only be fabricated using base materials of proven weldability. Materials for pipelines (pipes, flanges, adapting pieces, fittings) shall comply with the requirements set out in the relevant sections of Rules for Materials (Pt.1, Vol. V) Sec. 4 to 9. Other comparable materials may only be used after the BKI has given its approval in each individual case.

3. Pipeline materials for cargo and process lines for liquefied gases shall also meet the impact energy requirements at the stipulated test temperature; see Tables.15.1 to 15.3.

E. Welding Consumables and Auxiliary Materials

1. The welding consumables and auxiliary materials shall enable a welded joint to be made which is appropriate to the pipeline material, the operating temperature and the conditions of service. The suitability of the welding consumables shall also have been verified under the conditions prevailing in any potential heat treatment.

2. All the welding consumables and auxiliary materials used (e.g. covered electrodes, wire-gas combinations, wire-flux combinations, etc.) shall have been approved by the BKI in accordance with Section 5. They may also, however, be approved if tested at the same time as the welding process and restricted to the user's works (see Section 4, B.3.2 and Section 5, A.1.4).

3. Welding consumables for steels tough at sub-zero temperatures shall also meet the impact energy requirements for the weld metal at the stipulated test temperatures; see Table 15.2.

4. Welding consumables and auxiliary materials specified in a procedure approval document with a maker's or brand name (see F.3.5) may only be replaced by equivalent consumables approved by the BKI with an appropriate quality grade if this is explicitly stated in the respective approval document. Failing this, BKI agreement shall be obtained.

5. The welding consumables and auxiliary materials may only be used in the approved welding positions. The manufacturer’s recommendations and instructions for welding (e.g. type of current and polarity) shall be followed.

6. The welding consumables and auxiliary materials (especially hydrogen-controlled, basic-covered electrodes and basic welding fluxes) shall be re-dried before use in accordance with the manufacturer's instructions (observe maximum drying time!) and stored in a dry place (in heated containers or the like) at the workplace.

Table 15.1 Requirements as per para. F.5 for testing of welded joints in pipelines

<table>
<tr><th>Type of Test</th><th colspan="3">Requirements</th></tr>
<tr><td>Tensile test transversely to weld</td><td colspan="3">Tensile strength as stipulated for the base material or in the assessment of suitability for the welding consumable</td></tr>
<tr><td rowspan="2">Notched bar impact test[1] on ISO V-notch specimens taken from the centre of the weld metal</td><td>All pipelines except those indicated below</td><td colspan="2">As stipulated for the base material, at least ≥ 27 J. Test temperature as for testing of base material. When using ferriticaustenitic, austenitic and nickel base alloy welding consumables, ≥ 40 J.</td></tr>
<tr><td>Cargo and process lines of gas tankers</td><td colspan="2">Test temperature as shown in Table 15.2. When using ferritic welding consumables, ≥ 27 J [2]; when using ferritic-austenitic, austenitic and nickel-base alloy welding consumables, ≥ 34 J[2]</td></tr>
<tr><td rowspan="2">Notched bar impact test[1] on ISO V-notch specimens taken from the weld transition zone</td><td>All pipelines except those indicated below</td><td colspan="2">≥ 27 J [2] test temperature as for testing of base material.</td></tr>
<tr><td>Cargo and process lines of gas tankers</td><td colspan="2">Test temperature as shown in Table 15.2, ≥ 27 J for carbon manganese steels, ≥ 34 J for nickel alloy steels, ≥ 41 J for austenitic steel.</td></tr>
<tr><td rowspan="6">Technological bend test</td><td>Bending angle degrees</td><td>Strength category</td><td>Bending mandrel dia.</td></tr>
<tr><td>180 [3]</td><td>Ferritic steel with :
min. tensile strength < 430 N/mm^2
min. tensile strength ≥ 430 to 460 N/mm^2</td><td>
2 x a
2,5 x a</td></tr>
<tr><td>180 [3]</td><td>Austenitic stainless steels and austenitic steels tough at sub-zero temperatures
High- temperature austenitic steel
Ferritic steels with a minimum tensile strength ≥ 460 N/mm^2</td><td>2 x a
3 x a
3 x a</td></tr>
<tr><td colspan="3">If a bending angle of 180 degrees is not attained, the following applies:</td></tr>
<tr><td>≥ 90</td><td colspan="2">Elongation (L_0 = width of weld + wall thickness, symmetrically to weld) ≥ minimum elongation A of base material</td></tr>
<tr><td>or < 90</td><td colspan="2">Elongation over width of weld > 30% and faultless appearance of fracture</td></tr>
<tr><td rowspan="2">Metallographic examination</td><td colspan="3">The macrographic specimen of the welded joint shall reveal a satisfactory weld build-up and full penetration of the weld</td></tr>
<tr><td colspan="3">Micrographic specimens are to be examined for cracks. Only hot cracks are acceptable, and then only if they are few in number and widely scattered and agreement has been reached with the expert as to their acceptability with regard to the material and the range of application.</td></tr>
<tr><td>Hardness testing</td><td colspan="3">The hardness in the heat-affected zones shall not exceed 350 HV 10. Hardness peaks in excess of this figure in narrow transition zones shall not give rise to complaints if the outcome of the technological tests meets the requirements.</td></tr>
<tr><td colspan="4">1) For the requirements applicable to specimens with a depth of less than 10 mm, see Table 15.3
2) Only one impact energy value may be lower than the minimum mean value, and only by max. 30%.
3) The 180° requirement is deemed to have been met if the bend test was performed according to ISO 5173 and pressure was applied by the supports without cracks appearing.</td></tr>
</table>

Table 15.2 Test temperatures for notched bar impact testing of pipe steels tough at sub-zero temperatures

Type of steel	Standard designation	Standard	Minimum design temperature [°C]	Test Temperature [°C]
Carbon and carbon manganese steels	P215NL P255QL	ISO 10216-4	– 40 – 50	5 K below minimum design temperature, but not exceeding – 20°C
Nickel alloy steels containing: 0,5% Nickel 3,5% Nickel 5,0% Nickel 9,0% Nickel	 13MnNi6-3 12Ni14 X12Ni5 X10Ni9		 – 55 – 90 – 105 – 165	 – 60 – 95 – 110 – 196
Austenitic steels [1) 2)] (AISI 304 L) (AISI 316 L) (AISI 321) (AISI 347)	 X2CrNi19-11 X2CrNiMo18-14-3 X6CrNiTi18-10 X6CrNiNb18-10	EN 10217-7 EN 10216-5	– 165	– 196

1) The designations in brackets are comparable pipe steels to AISI standards.

2) Where austenitic pipe steel are used for design temperatures not less than – 55°C, at test temperature 5 K below the minimum design temperature but not exceeding – 20°C may be agreed upon.

Table 15.3 Impact energy requirements for specimens of reduced size

Required impact energy KV for standard specimens [1)] 10 x 10 mm [J]	Required impact energy KV for specimen sizes [1)]	
	7,5 x 10 mm [J]	5 x 10 mm [J]
27 (19)	22 (16)	18 (13)
34 (24)	28 (20)	23 (16)
41 (27)	34 (24)	27 (22)

1) Figures in brackets are for the minimum individual value.

F. Welding Procedure Tests

Preliminary remark:

In contrast to earlier issues of these Rules, welding procedure tests shall be performed in accordance with ISO 15614-1, as applicable. This paragraph essentially covers requirements applicable to the welding of pipelines over and above those set out in ISO 15614-1.

1. General

Only those welding procedures whose suitability for the application in question is evident from general experience or has been verified by means of a welding procedure test in accordance with Section 4 and the following provisions may be used. Table 4.1 in Section 4 gives a list of necessary verifications. The welding procedures shall have been approved by the BKI for the particular welding shop in question as part of the welding shop approval (see also B.).

2. Welding of test pieces, welding procedure specification (WPS)

2.1 A preliminary "manufacturer's" welding procedure specification (pWPS) setting out all the major parameters shall be produced by the welding shop for the welding of test pieces in accordance with ISO 15609-1, as applicable (see Annex D).

2.2 BKI expert shall select one of the welders whose names are to be supplied by the manufacturer to weld the test pieces.

2.3 The test pieces shall be made from materials whose properties are proven in accordance with the requirements specified in Rules for Materials (Pt.1, Vol. V) Sec. 4 to 9. Pre-treatment and after-treatment of the test pieces by preheating, heat treatment and the like is only permitted if stipulated for these materials during the actual fabrication.

2.4 The types of weld and welding positions employed in the fabrication process shall be qualified in the welding procedure test.

2.5 The shape and dimensions of the test pieces are specified in ISO 15614-1.

3. Test principles, delimitation of scope

The qualification of the welding procedure shall be ascertained in accordance with ISO 15607, Table 2 by means of welding procedure qualification tests, for steel in accordance with ISO 15614-1. The test is valid within the limits described in 3.1 to 3.7.

The scope of the welding procedure test is specified by the BKI in writing. Any exceptions require the performance of a supplementary test, the scope of which shall be decided by the BKI.

3.1 Base materials, materials groups

Above and beyond the grouping system of ISO 15608 Table 1, the following provisions shall be observed:

a) For materials which have to satisfy particular corrosion conditions (e.g. resistance to caustic cracking) the welding procedure tests shall be geared to these.

b) A welding procedure qualification performed on group 1 killed steel does not apply to unkilled steels unless they were welded using basic covered electrodes.

c) Depending on material composition and/or the type of post-weld treatment required, the BKI may also limit the scope to the base material used in the welding procedure test.

d) For cargo and process pipelines designed to carry liquefied gases, the test applies only to the grade of steel inspected.

3.2 Welding process

Recognition applies only to the welding process employed in the welding procedure test.

3.3 Gas welding

In gas welding a test performed on the wall thickness shall apply to the wall thickness range 0,75 t to 1,25 t.

3.4 Welding parameters

Welding procedure tests performed on multi-pass welds do not apply to single-pass welds.

3.5 Welding consumables and auxiliary materials

The requirements of ISO 15614-1, para. 8.4.5 do not apply if the filler metal used is of the same type and has been approved by the BKI to be under the scope of the welding procedure qualification (see E.4).

3.6 Heat treatment

The welding procedure test applies to the heat treated condition existing at the time of the test. Heat treatment of the test piece shall be performed so that a heat treated condition is achieved which is comparable to that of the component.

3.7 Special cases

For special cases, for example difficult repairs to be performed in the course of fabrication on steels which are susceptible to cracking due to hardening of the heat affected zone, welding procedure tests are necessary which are geared to these particular cases. The tests required and their scope are specified by the BKI in each individual case.

4. Tests, scope of tests

Testing comprises both non-destructive and destructive tests and shall be performed in accordance with ISO 15614-1, para. 7.

Deviating from ISO 15614-1, para. 7.1 and Table 1, the following specimens shall also be taken from the test pieces:

a) Notched bar impact test on ISO V-notch specimens to ISO 9016 taken from the center of the weld metal (KM) (one set of specimens per welding position) as follows:

   – For cargo and process lines for gas tankers where the wall thickness is ≥ 4 mm[1]

   – For other alloy steels and fine-grained structural steels where the wall thickness is ≥ 6 mm.

b) Notched bar impact test on ISO V-notch specimens as above, but with the notch in the transition zone (KÜ) where the wall thickness is ≥ 6 mm.

   For austenitic pipe steels, the test is only required for wall thicknesses ≥ 10 mm.

c) Macro- and micrographic specimens are required for alloy steels. In particular, micrographic specimens shall be examined for micro cracks. The metallographic structure is to be described or verified by means of photographs.

d) An analysis of the weld metal, except for unalloyed steels.

5. Test requirements

The irregularities in the test piece shall fall within the limits specified for quality level B in accordance with ISO 5817, exceptions being: excessive convexity and excessive throat thickness (fillet welds) which fall into quality level C.

For the mechanical and technological tests, Table 15.1 applies in conjunction with Table 15.2 which indicates the impact energy requirements for cargo and process lines for gas tankers.

6. Storage of specimens

The tested specimens and the remaining portions of the test pieces shall be stored until the report on the welding procedure test has been issued (see also Section 4, C.3).

[1] Size of specimen and requirements for wall thickness < 6 mm shall be separate agreed.

7. Validity, extension of welding procedure test

The validity of a welding procedure test is generally 1 year provided that the preconditions under which it was granted have not significantly changed. It may be continued by means of regular verifications of quality, e.g. the results of non-destructive tests or production tests.

The welding procedure test shall be repeated if there is a break in the fabrication of pipelines or pipeline components lasting longer than one year.

G. Welding Technique

1. Welds shall exhibit full penetration over their entire cross section and shall not have any cracks or lack of fusion defects. The welds shall be made in the workshop as far as possible.

2. Permanent backing rings shall be of such a shape that they can neither impede the flow nor cause corrosion. Backing rings shall be made of pipe steels of the same composition as the base metal; with unalloyed and low-alloy pipe grades, they may also, where appropriate, be made of low-carbon steels ($C \le 0{,}10\%$).

3. In the case of pipelines fabricated from austenitic steels and all other pipelines with working pressures in excess of 10 bar and design temperatures of –10°C and below, permanent backing rings may not be used on principle.

4. For butt-welded joints in lines with design temperatures below –10°C and for all stainless pipe steels, the root passes shall as a rule be laid down by tungsten inert gas welding with gas shielding on both the inside and the outside of the pipe.

5. Wherever possible, adequately dimensioned pipe fittings shall be used for branches. Where outward flanged pipeline connections are used, the inside diameter ratio shall not exceed 0,8. Outward flanges shall be made by established methods.

6. The preparation of welds shall conform to recognized standards. Wherever possible, welding edges shall be prepared by machining or with a mechanically guided cutting torch. Slag, scale, drag lines and other irregularities shall be removed. Where necessary, the same applies to the heat-affected boundary zone in the case of austenitic steels. The welding edges of steel forgings and castings shall be machined.

7. Tack welds may only be made with consumables which are also compatible with the pipe material. Where tack welds are to be left in place, they shall be of the same quality as the root welds. The rules for preheating shall also apply to tack welding.

8. Flange-pipe joints shall be chosen in accordance with the Rules for Machinery Installations (Pt.1, Vol. III) Sec. 11, in relation to the pipe class.

9. Pipeline sections to be welded shall be axially aligned. The internal misalignment of the pipe ends may not exceed the values stated in Table 15.4.

10. Weld reinforcements shall lie within the following tolerances (see Fig. 15.1):

Cover pass reinforcement:	$Ü_D \le 1 + 0{,}1\ B$ [mm]	max. 5 mm
Root pass reinforcement:	$Ü_W \le 1 + 0{,}2\ b$ [mm]	max. 3 mm

(see also ISO 5817, quality level B)

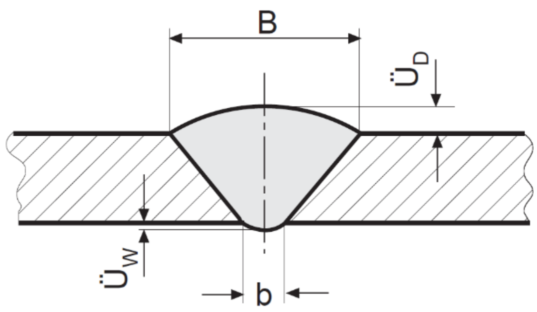


Fig. 15.1 Weld reinforcements

11. Welding of pipeline components made of ferritic steels in areas subjected to cold forming where the outer fibres have been stretched by more than 5% (e.g. where pipe bending is carried out with a radius r_m < 10 H D_a (D_a = outside diameter) is only allowed if the effects of cold forming have been eliminated by means of appropriate heat treatment. This shall generally be accomplished by normalizing heat treatment or quenching and tempering.

This requirement may be waived if proof is furnished that the properties of the material are no more than insignificantly impaired with regard to the intended use or if the conditions specified in H.1. or H.2., as applicable, are met.

H. Preheating

1. Preheating of the different types of steels will be dependent upon their thickness and chemical composition as indicated in Table 15.4.

2. In any case, dryness is to be ensured using, if necessary, suitable preheating.

3. Values in Table 15.4 are based on use of low hydrogen processes; consideration should be given to using higher preheating temperatures when low hydrogen processes are not used.

Table 15.4 Limit wall thicknesses for preheating C-CMn and low alloy carbon-molybdenum, chromium-molybdenum, chromium-molybdenum-vanadium steels pipelines

Steel	Wall thickness of the thicker element [mm]	Heat treatment temperature [°C]
Carbon and carbon-manganese steels containing : $C + \frac{Mn}{6} \leq 0{,}40$	≥ 20 [2)]	50
$C + \frac{Mn}{6} > 0{,}40$		100
0,3 Ma	≥ 13 [2)]	100
1 Cr – 0,5 Mo	≥ 13 < 13	100 150
2,25 Cr – 1 Mo and 0,5 Cr – 0,5 Mo – 0,25 V [1)]	< 13 ≥ 13	150 200

1) For these materials, preheating may be omitted for thicknesses up to 6 mm if the results of hardness tests carried out on welding procedure qualification are considered acceptable by BKI.

2) For welding in ambient temperature below 0°C, the minimum preheating temperature is required independent of the thickness unless specifically approved by BKI.

I. Heat Treatment after Cold or Hot Working and Welding

1. Ferritic steel pipes

1.1 Heat treatment after cold forming

1.1.1 Pipes or pipelines shall normally be subjected to heat treatment (normalizing heat treatment or quenching and tempering) following cold forming with a degree of deformation ≥ 5% (r_m ≤ 10 H D_a) in accordance with the material specification.

1.1.2 Post-forming heat treatment may be dispensed with in the case of unalloyed steel or fine-grained structural steel pipes with an outside diameter D_a ≤ 133 mm which are subjected to cold-bending with a bending radius r_m ≤ 1,3 H D_a.

An exception applies to pipes fabricated from steels tough at sub-zero temperatures with wall thicknesses > 2,5 mm or pipes to which stressed components are welded outside the neutral fibres.

Table 15.5 Tolerances on internal misalignment of pipe ends

Type of joint	Inside diameter D_i [mm]	Wall thickness t [mm]	Tolerances on internal misalignment
with permanent backing rings	any	any	max. 0,5 mm
without backing rings	D_i < 150 150 ≤ D_i < 300 300 ≤ D_i any	t ≤ 6 t ≤ 9,5 any t > 9,5	t/4 max. 1 mm t/4 max. 1,5 mm t/4 max. 2,0 mm t/4 max. 2,0 mm

1.2 Heat treatment after hot forming

1.2.1 Pipes and pipeline components shall be subjected to heat treatment after hot forming in accordance with the material specification.

If the hot forming operation is begun and ended within the temperature range stated in the material specification, normalizing heat treatment may be dispensed with for normalized steels. Subsequent tempering is required in the case of air-hardened and tempered steels.

1.2.2 If the pipe only undergoes localized heating in certain areas during bending, the provisions of 1.2.1 still apply; however, the entire pipe shall be in the prescribed heat- treated condition.

2. Austenitic steel pipes

2.1 Heat treatment after cold forming

Heat treatment of pipes subjected to cold bending with a bending radius ≥ 1,3 x D_a is normally not required.

2.2 Heat treatment after hot forming

Renewed heat treatment (solution heat treatment and quenching or stabilization heat treatment) in accordance with the material specification is normally required after hot forming. If the heat treatment is carried out at initial forming temperatures between 1000°C and 1150°C and if the forming operation is completed at a temperature > 750°C in the case of stabilized steels or steels with a carbon content ≤

0,03% and > 875°C in the case of other steels, follow-up heat treatment may be dispensed with. A condition of this is that the material shall be rapidly cooled down from the forming temperature.

2.3 Where more exacting corrosion resistance requirements apply, e.g. to pipelines for chemical tankers, the procedures described in 2.1 or 2.2, as applicable, may only be followed if the pipeline fabricator has proved by means of corrosion tests that the required resistance is present after forming. Failing this, renewed heat treatment after cold or hot forming is required.

3. Heat treatment of pipe fittings

The provisions of Rules for Machinery Installations (Pt.1, Vol. III) Sec. 11, C., Pipe Fittings, apply.

4. Post-weld heat treatment

4.1 Heat treatment shall be applied in accordance with Section 9. Welded joints in pipelines fabricated from ferritic steels shall be heat-treated after welding in accordance with the stipulations of the relevant standards or BKI approval document where the conditions stated in 4.1.1 and 4.1.2 apply. Unless otherwise stipulated, the post-weld heat treatment shall consist of stress relief heat treatment.

4.1.1 Electrically fusion-welded pipe joints shall undergo stress relief heat treatment if the limit wall thicknesses shown in Table 15.5 in relation to the type of pipe steel are exceeded.

4.1.2 Gas fusion-welded joints shall undergo normalizing heat treatment or quenching and tempering, depending on the type of material, if the wall thickness of the pipe exceeds 3,2 mm or the outside diameter exceeds 88,9 mm.

4.1.3 For pipes made of nickel alloy steels tough at subzero temperatures, the need for post-weld heat treatment and the limit wall thicknesses will be determined during the welding procedure test.

4.2 For pipelines fabricated from austenitic and austenitic- ferritic steels, post-weld heat treatment is generally unnecessary if the pipeline materials are in the proper heat-treated condition prior to welding.

J. Inspection of Welded Pipelines

The inspection shall consist of an internal hydraulic pressure test and non-destructive tests. The nondestructive tests shall be performed in accordance with Section 10.

1. Completed pipeline sections shall be subjected to a hydraulic pressure test at 1,5 times the working pressure in the presence of the Surveyor. The pipeline section may not exhibit any leaks during the hydraulic pressure test or any permanent deformation afterwards.

2. An external and, wherever possible, also an internal inspection of the completed pipeline sections and especially of the welds shall be performed. For the inspections, the sections shall have a smooth external and internal surface corresponding to the as-fabricated condition which enables major surface defects to be detected, and pipelines fabricated from austenitic and austenitic-ferritic steels shall be free from harmful temper colors.

3. The misalignment of pipe ends, the external weld reinforcements and - where accessible – the internal weld reinforcements shall be checked. They shall lie within the tolerances specified in G.9. and G.10.

4. The butt-welded joints of the following pipelines shall be subjected to radiographic inspection as follows:

a) All pipelines in pipe class I: 100 %.

A reduction in the scope of the test may be agreed on application for pipelines with an inside diameter ≤ 75 mm, provided that proof is furnished that the results are consistently good and that the percentage of repairs is relatively low.

b) All cargo and process lines of gas tankers with a service temperature below – 10°C: 100%.

A reduction in the scope of the test may be agreed on application for pipelines with an inside diameter ≤ 75 mm or wall thicknesses ≤ 10 mm provided that proof is furnished that the results are consistently good and that the percentage of repairs is relatively low.

c) All pipelines in pipe class II: 10%.

A reduction in the scope of the test may be agreed on application for pipelines with an inside diameter ≤ 100 mm provided that proof is furnished that the results are consistently good and that the percentage of repairs is relatively low.

d) Where the execution of welding operations gives rise to doubts as to the quality of the welded joints, BKI may also call for a random radiographic test to be carried out on the butt welds of pipe class III.

The radiographic inspection shall as a rule be performed with an X-ray tube. With BKI consent, radiographic inspection may be replaced by ultrasonic inspection for ferritic steel pipes with wall thicknesses ≥ 20 mm.

5. Fillet welds of flanges, sockets and nipples of pipelines in class I, including cargo and process lines of gas tankers, shall be 100% tested for surface cracks. For pipelines in pipe class II and III, random testing covering 10% of the welds is required.

Note:

The scope of the tests to be applied to series-manufactured pipe fittings is specified separately; see Rules for Materials (Pt.1, Vol. V) Sec. 9, B.

Table 15.6 Limit wall thicknesses for stress relief heat treatment of ferritic steel pipelines

Steel	Wall thickness of the thicker element [mm]	Heat treatment temperature [°C]
Carbon and carbon-manganese steels	≥ 15 [1), 3)]	The provision of Section 9 apply
0,3 Mo	≥ 15	
1 Cr 0,5 Mo	≥ 8	
2,25 Cr 1 Mo	all thicknesses [2)]	

1) When steels with specified Charpy V notch impact properties at low temperature are used, the thickness above which post weld heat treatment shall be applied may be increased by special agreement with BKI.

2) Stress relief heat treatment may be dispensed with where the operating temperature is at least 450°C and where the outside diameter and the wall thickness do not exceed 100 mm and 8 mm respectively.

3) For C and C-Mn steels, stress relieving heat treatment may be omitted up to 30 mm thickness by special agreement with BKI.

Section 16 Welding of Machinery Components

A. General

1. Scope

1.1 These Rules apply to all welding work performed during the fabrication and repair of machinery components such as bed plates, frames, housings for diesel engines, gear boxes, wheel bodies, steering engine housings, quadrants and similar components of a corresponding nature.

Note:

Since the machinery components listed above are mostly "steel components" which are not significantly different from hull structures in their materials, welding processes and welding works (see also Table 4.1 in Section 4), the specifications set out in Section 12 applicable to the welding of hull structures may also be applied here where no special provisions are prescribed in the following paragraphs.

1.2 They also apply to welding work performed on machinery components such as axles or shafts, pistons, propellers, hubs, machinery tanks, hydraulic cylinders, valve housings, valves etc. where BKI has approved welding work to be carried out on components of this kind either as a general approval or in an individual case. They apply to welding work performed in the course of new fabrications and also to repair welds on machinery components.

1.3 For the use of welding as a production process during the course of the manufacture of materials and/or semi-finished products, such as the "fabrication welding" of the forgings or castings used in machinery components (e.g. propellers), see also the Rules for Materials (Pt.1, Vol. V).

2. Other relevant rules and regulations

The design and dimensions of welded joints and also the welding technique are subject to the provisions of the Rules for Hull (Pt.1, Vol. II) and other rules or regulations issued by BKI for specific ranges of application. For other relevant standards, etc., see Section 1, B. of these Rules.

B. Approval of Welding Shops, Welding Personnel

1. Works and works divisions

1.1 In the following paragraphs, the term "welding shop" refers to the welding fabrication shop which may be considered an independent unit with regard to its physical and organizational situation.

1.2 Branches and subcontractors are thus generally deemed to be "independent" welding shops which have to satisfy the requirements prescribed below. In particular, every welding shop shall have a welding supervisor who is a permanent member of the welding shop staff (see Section 2).

1.3 Outside firms working in welding shops may be granted approval as independent welding shops. On this and on temporary workers, see also C.3. and Section 1, F.

2. Requirements, scope of approval

2.1 All welding shops intending to perform welding work covered by these Rules shall satisfy the requirements relating to the welding shop and its personnel set out in Section 2 and shall have been approved for this work by BKI. Applications for approval shall be submitted by the shipyards and welding shops in good time before starting the welding work, enclosing the information and documentation prescribed in Section 2, A.3.

2.2 Welding personnel (welders, operators and supervisory staff) and where applicable inspectors and test supervisors shall meet the requirements set out in Section 2, B.2., B.3. and B.4. and be recognized by BKI. For welder's qualification tests, see Section 3.

2.3 The scope of the approval is determined by the capabilities of the welding shop and by the intended range of application (components, materials, welding processes, welding positions, etc.). The intended range of application shall be specified in the application for approval; see the form "Description of Welding Shop" attached at Annex B. For the period of validity of the approvals, see Section 2, A.4. and A.5.

C. Quality Inspection, Responsibility

1. Welding shops shall ensure by means of regular in-house quality inspections during fabrication and on completion of the welding work that this work has been performed competently and satisfactorily (see Section 1, F.). For the duties and responsibilities of the welding supervisor, see also ISO 14731.

2. The welding shops are responsible for ensuring that the welding work conforms to these Rules, the approved manufacturing documents, any conditions stipulated in the approval documents, good machinery building practice and the latest state of welding practice. The inspections and checks to be performed by BKI Surveyor do not relieve the welding shops of this responsibility.

3. With regard to quality inspections and the responsibilities involved in awarding subcontracts to independent branches or suppliers or to approved or non-approved outside firms working in the welding shop (subcontractors), see Section 1, F.; the "prime contractor" shall ensure that "subcontractors" also meet the conditions specified in 1.

4. Where non-approved outside firms and temporary staff are employed in the welding shop, the welding shop is responsible for carrying out quality inspections and for compliance with the conditions stated in 1. Subcontracting of work or the employment of temporary staff shall be notified to BKI.

5. The scope of the required quality inspections depends on the construction project in question. It is essential to ensure, however, that the intended materials, welding consumables and auxiliary materials are used and that the weld preparation, assembly, execution of welding work and the dimensional accuracy and completeness of the welded joints meets the requirements stated in 2. For non-destructive testing of the welded joints, see I.

6. Following inspection and, if necessary, repair by the welding shop, the components shall be presented to BKI Surveyor for checking at suitable stages of fabrication. For this purpose they shall be readily accessible and shall normally be uncoated. Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory workshop inspection and any necessary repair work has been performed.

7. If the quality or good working order of a component cannot be guaranteed or is in doubt due to inadequate or missing information in the manufacturing documents (e.g. production drawings), BKI may demand appropriate improvements. This applies in analogous manner to supplementary or additional measures, even if these measures were not stipulated when the drawings were scrutinized or could not be stipulated due to insufficiently detailed representation in the production documents.

8. Responsibility for the proper performance of quality inspections and compliance with the conditions stated above lies with the welding shop. The inspections and checks to be performed by BKI Surveyor do not relieve the welding shops from this responsibility.

9. BKI is not responsible for guaranteeing that all the components and welded joints inspected to the prescribed extent (generally on a random basis) by its surveyors have been fabricated in accordance with the conditions and meet the requirements in every respect. Components or welded joints which subsequently turn out to be defective may be rejected or their repair may be demanded even if acceptance testing has already been carried out.

D. Materials, Weldability

1. Welded structures may only be fabricated using base materials of proven weldability. Materials shall comply with Rules for Materials (Pt.1, Vol. V). Other comparable materials (e.g. structural steels conforming to the standards) may only be used after BKI has given its approval in each individual case.

2. Any conditions relating to working and welding imposed by the approval certificate and the recommendations of the material producer shall be complied with. For the selection of materials for the ship's hull, see the Rules for Hull (Pt.1, Vol. II) and in other rules and regulations issued by BKI for specific ranges of application.

3. Steel castings and forgings shall comply with the Rules for Materials (Pt.1, Vol. V) and shall have been tested by BKI. The carbon content of components made from carbon and carbon-manganese steels or cast steels for welded structures shall not exceed 0,23% C at ladle analysis (product analysis: max. 0,25% C).

E. Welding Consumables and Auxiliary Materials

1. All the welding consumables and auxiliary materials used (e.g. covered electrodes, wire-gas combinations, wire-flux combinations, etc.) shall have been approved by BKI in accordance with Section 5. The quality grade required depends on the base materials to be welded and is shown in the relevant tables in Section 5.

2. The welding consumables shall enable a welded joint to be made which is appropriate to the base material and the type of stress to which it is subjected and also enable trouble-free further processing. For joints between dissimilar materials (with the exception of high-alloy, austenitic steels), the welding consumable should, wherever possible, be geared to the lower alloyed material or the material with the lower strength.

3. For welding very thick-walled, rigid components (approx. 30 mm and over) and welding of forgings and castings, hydrogen-controlled welding consumables and auxiliary materials shall be used wherever possible, e.g. those of quality grade ... H15 or lower or ...Y.. H10 or lower for higher-strength structural steels.

4. Hydrogen-controlled welding consumables and auxiliary materials should also be used for components which are subjected to full load immediately after welding (e.g. lifting lugs or as a result of

pressure tests) or where allowance has to be made for a high degree of residual stress due to the rigidity of the structure and, where applicable, a high yield strength or strength of a structure.

F. Welding Procedure Tests

1. General

1.1 Only welding procedures whose suitability for the application in question has been verified by means of a welding procedure test in accordance with Section 4 and the following provisions may be used. Table 4.1 in Section 4 gives a list of the requisite verifications. The welding procedure shall have been approved by BKI for the welding shop in question as part of the welding shop approval (see also B.).

1.2 Welding procedure tests supervised by BKI for verification of satisfactory operational handling and a trouble-free execution of the procedure, and also adequate quality properties for the welded joints made under production conditions at the user's works are required for all materials and welding processes.

1.4 BKI may additionally require welding procedure tests for specific (difficult) component shapes or combinations of materials, particular weld shapes, process variants or combinations, and also for particular welding consumables and auxiliary materials. The same applies in analogous manner to other joining processes or (surface) finishing operations such as thermal cutting or flame straightening.

1.5 The information in the preceding and following paragraphs, especially the information on test pieces, specimen shapes, tests and requirements, applies to the normal materials, welding processes and weld shapes in current use in ship-machine building, the behaviour of which under service conditions has been verified by experience and/or test results. In cases of doubt, BKI may call for additional and/or different test pieces, specimen shapes or tests to verify satisfactory suitability for use.

1.6 In the case of welding processes whose characteristics result in weld shapes other than those verified by experience and/or test results (e.g. those with a considerable notch effect), the influence of the weld shape on the fatigue strength behaviour of the welded joints may be investigated in addition to carrying out the prescribed tests. The same applies in analogous manner to other characteristics of the welded joints, e.g. corrosion resistance.

2. Scope of tests, test schedule, limits of application

2.1 Test schedule, test details

2.1.1 The scope of the welding procedure tests (materials, test pieces, heat treatment, specimens, tests, etc.) shall be laid down in a test schedule to be submitted for approval in good time prior to testing, in accordance with Section 4, B.1. Depending on the nature and application of a welding process, the process details stipulated in Section 4, B.1.1 shall be specified and taken into account in the tests.

2.1.2 Where no further details on the welding procedure tests are given in the following paragraphs, the provisions of Section 4 shall apply. The standards of ISO 15614 may be applied, however BKI reserve the right to set supplementary or different requirements above and beyond the provisions stated in the following paragraphs, e.g. for the scope of application (materials, weld types, welding positions, see 2.1.3).

2.1.3 For welding procedure tests for the welding of (steel) machinery components, the provisions set out in Section 12, F. relating to the welding procedure tests for (hull) structural steels shall apply in analogous manner. This shall also particularly apply with regard to weld types and welding positions. Accordingly, both butt and fillet welds (or other particular weld forms) are also covered in the welding procedure tests, as are all the welding positions encountered.

2.1.4 Welding procedure tests for the (repair) welding of propellers shall be performed in accordance with the provisions applicable to "production welds" in the Rules for Materials (Pt.1, Vol.V) issued by BKI. These shall also be complied with for the welding consumables and heat treatment recommended and also the areas where welding is not permitted.

2.1.5 For special welding processes, such as flash butt welding, friction welding, electron-beam or laser welding and also for special applications such as build-up welding on shafts, pistons or valves, the type and scope (form and dimensions of the test pieces) of the welding procedure tests and their scope in accordance with the foregoing provisions are specified separately in each individual case.

3. Test pieces, fabrication (welding), (postweld) heat treatment

3.1 For (steel) machinery components welding shall be performed on butt and fillet weld test pieces (where these are encountered in the production process) in analogous manner to Section 12, F.4 or, by agreement with BKI, in accordance with ISO 15614-1. Test pieces for other components, particular welding processes or applications shall be agreed with BKI in each individual case.

3.2 The direction of rolling of butt and fillet weld test pieces shall generally be parallel to the direction of the weld. The weld shapes shall correspond to those used in the fabrication process.

3.3 For welding, the test pieces shall be made from materials whose properties may be unequivocally proved in accordance with the requirements specified in the Rules for Materials (Pt.1, Vol. V) or approved material specifications by the submission of certificates and by marking the material (stamping). In cases of doubt, BKI may call for appropriate material examinations to be carried out. See Section 4, B.3.

3.4 The welding parameters stipulated in the preliminary welding procedure specification (pWPS) shall be complied with (see Annex D) and it is necessary to record the parameters used in the tests and specify these in the final welding procedure specification. See Section 4, B.5.

3.5 Pre-treatment and after-treatment of the test pieces by preheating, heat treatment or the like is only permitted if stipulated for these materials during actual fabrication. This treatment shall also be recorded and specified in the final welding procedure specification. See Section 4, B.6.

4. Non-destructive tests

Prior to sectioning, the test pieces shall undergo comprehensive non-destructive tests to detect welding defects or defects in the welding procedure. The test method or methods (a combination) to be applied are determined by the nature of the test piece or weld and shall be agreed with BKI and stipulated in the test schedule. See Section 4, B.7.

5. Sectioning of test pieces, type and number of specimens

5.1 The sectioning of test pieces and the preparation of specimens is subject to the provisions of Section 4, B.8.

5.2 Unless otherwise agreed in a particular case, one set of butt weld specimens shall comprise the following specimens. The specimen shapes and dimensions shall conform to the provisions of the standards or Section 11 as applicable:

– 2 transverse tensile test specimens in accordance with ISO 4136 (for larger plate thicknesses a correspondingly greater number of specimens shall be provided to cover the full cross-section),
– 1 round tensile test specimen by analogy to the provisions of Section 5, B.2.3 (Fig. 5.1 and 5.2) taken lengthwise from the weld metal if welding consumables and auxiliary materials not approved by BKI are to be used (see Section 4, B.3.2), if different materials are to be joined, if welds are

made using dissimilar welding consumables or if the characteristics of the welding process suggest that the weld metal itself is likely to be considerably affected.

– A round tensile test specimen is to be prepared in every case (except for aluminium alloys) where the mechanical properties of the weld metal are inferior to those of the base material (e.g. when welding high-strength steels). The diameter "d_0" of the specimen shall be as large as possible (but not more than 10 mm) and the gauge length "L_0" shall be 5 × d_0. The provisions of Section 5, B.2. are to be applied in analogous manner. For plate thicknesses ≤ 20 mm BKI may dispense with the round tensile specimen.

– 4 transverse bend test specimens, in accordance with ISO 5173 half to be bent with the final pass in tension (FBB) and half with the root pass in tension (RBB), or

– 4 side bend test specimens (SBB) in the case of test pieces more than 12 mm thick and welding processes liable to give rise to segregations, solidification cracking, lack of fusion or similar defects inside the weld (e.g. single-side and vertical-down welding)

Note:

In the case of pairs of materials which differ in strength, it may be advisable to use butt-welded longitudinal bend test specimens (FBB and RBB) in accordance with ISO 5173 with the weld seam in the centre of the specimen instead of butt-welded transverse bend test specimens. See also Section 11. The details of this test and the requirements (as a rule a qualitative assessment of the bending behaviour) shall be agreed on a case-by-case basis.

– 3 notched bar impact test specimens each (Charpy V-notch specimens with the notch perpendicular to the surface of the plate) in accordance with ISO 9016, from the centre of the weld (VWT 0/1), from the fusion line (VHT 0/1) and from the heat affected zone (VHT 2/1), taken from the last side welded. Where plate and castings are to be united, the notched bar impact test specimens shall be taken from the fusion boundary/transition zone and heat affected zone of both materials. With very large plate thicknesses, notched bar impact test specimens shall be taken from the surface and back of the weld and in the case of welding processes liable to cause segregation in the central zone, an additional 3 notched bar impact test specimens of each type shall be taken from the same areas in middle of the plate thickness.

  The dimension "a" (see ISO 9016) shall be such that the point of intersection of the centre line of the specimen and the middle of the notch lies in the coarse-grained area of the heat-affected zone. This dimension may be generally taken as 2 mm. Where welding procedure tests are performed on steels tough at sub-zero temperatures, test specimens with notches located at a = 1 mm, a = 3 mm and a = 5 mm shall be prepared, unless otherwise specified in an individual case.

  Depending on the base material and welding process concerned, further notched bar impact test specimens from other areas may be stipulated. Notched bar impact test specimens may be partly or wholly dispensed with where the results of these tests in connection with the use of a particular welding process are of minor significance for certain materials, e.g. austenitic stainless steels or aluminium alloys (except for low temperature applications).

– ≤ 2 macrographic specimens for evaluating the grain structure and if necessary (e.g. for alloy steels) micrographic specimens.

– Hardness tests (Vickers HV5 or HV10) in accordance with ISO 9015-1 shall be carried out where, having regard to the base material and the welding process, the possibility cannot be discounted that preheating and/or the heat flow during welding may affect the hardness values in such a way as to impair the toughness or strength characteristics of the weld. Hardness measurements shall always be performed on higher-strength structural steels and on high-strength (quenched and tempered) finegrained structural steels with minimum yield strengths of more than 355 N/mm^2.

– Weld metal analysis, if necessary and if agreed with BKI.

5.3 Two or more macrographic specimens, as applicable depending on the length of the test piece, shall be taken from the simplified (T-jointed) fillet-welded test pieces in accordance with ISO 15614 to evaluate the penetration conditions, any irregularities in the welded joints and the grain structure. If necessary, hardness measurements as described in ISO 9015-1 shall be performed (see 5.2) and (in the case of alloy steels) micrographic specimens taken. The remainder of the test pieces is to be divided into convenient portions which, after removal of one of the welds, are to be broken open on alternate sides for evaluation of the fracture (see EN 1320).

5.4 A set of double T-joint (cruciform) fillet weld test specimens according to Fig. 16.1 shall comprise the following specimens. The specimen shapes and dimensions shall conform to the provisions of Section 11:

– 3 cruciform tensile test specimens (Z) as shown in Fig. 16.2 for determining the tensile-shear strength of the weld metal
– 2 macrographic specimens (M) for evaluating the penetration conditions, any irregularities in the welded joints and the grain structure. If necessary, hardness measurements (see 5.2) shall be performed in accordance with ISO 9015-1. Where necessary (e.g. in the case of alloy steels), micrographic specimens.

The remainder of the test pieces is to be divided into convenient portions which, after removal of one of the welds, are to be broken open on alternate sides for evaluation of the fracture (see EN 1320).

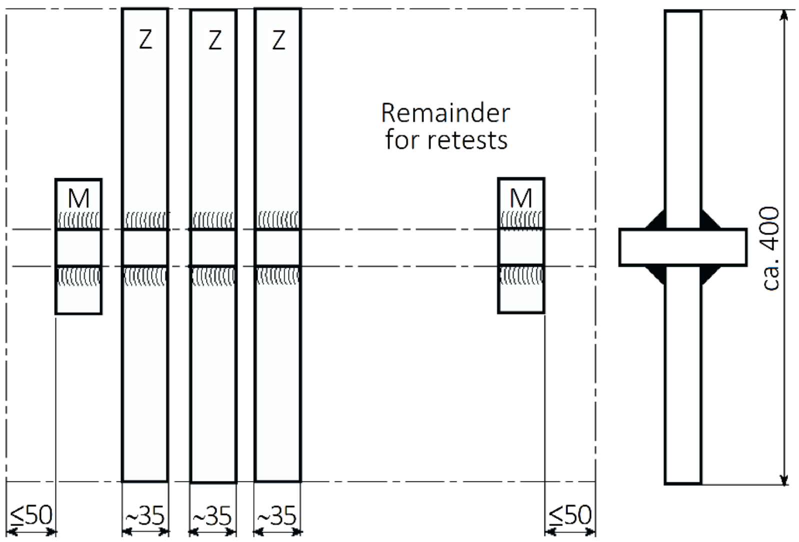
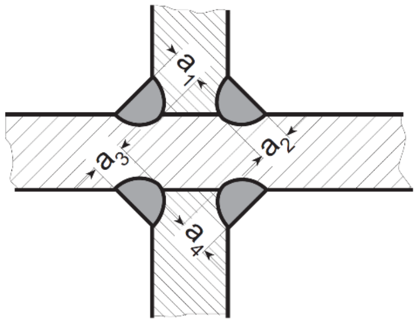


Fig. 16.1 Set of double T-joint (cruciform) specimens



$a_1 + a_2$ = fracture section $S_{1/2}$
$a_3 + a_4$ = fracture section $S_{3/4}$

$$\text{Tensile-shear strength} = \frac{\text{Breaking load F}}{S_B \text{ x width of specimen}} \qquad [\text{N/mm}^2]$$

$S_B = S_{1/2}$ or $S_{3/4}$ according to position of fracture

Fig. 16.2 Cruciform tensile test specimen, weld cross-section

5.5 The specimens and tests for particular components, materials, welding processes and/or their uses (see 2.1.5) will be specified separately in accordance with the foregoing provisions in each individual case.

6. Mechanical and technological tests, requirements

6.1 The mechanical and technological tests shall be performed according to the provisions of Section 11 or to the standards stipulated therein. For retests, see Section 4, C.2.

6.2 The results of the mechanical and technological tests shall satisfy the requirements stated in Table 16.1. BKI may stipulate different or supplementary requirements especially for the specimens and tests described in 2.1.5 and 5.5.

G. Design, Welding Technique

1. The general design principles described in Section 7 shall be observed. With regard to design and dimensioning (particularly that of (steel) machinery components in accordance with A.1.1), BKI may call for application, in analogous manner, of the provisions Section 12, G.

2. Butt welds which are critical to the strength of the component shall be executed as full-penetration welds. This category includes, for example, the butt welds joining the web and flange plates of engine bedplates and the butt welds uniting bearing brackets and connecting plates.

3. The fillet welds of load-bearing members, e.g. the neck seams of plate girders for uniting flange and web plates, shall be capable of being welded without a break. For this purpose, the stiffeners or web plates are either to be added on close to the neck seams at a later date or adequate welding apertures are to be provided.

4. Components shall be designed so as to avoid seam intersections wherever possible. Individual components of complicated shape which, if welded, would result in a clustering of weld seams, e.g. bearing brackets, should either be cast in steel or, if welded, should undergo stress relief heat treatment. See H.

5. All parts to be joined by welding have to be carefully aligned and mounted and tacked in such a way that welding can be carried out with a minimum of distortion and residual stress. Wherever possible, welding should be performed in the down hand position.

6. Wherever possible, stiffening plates and web plates which are open at the ends are to be cut off at the ends as shown in Fig. 16.3 (corresponding to the thickness of the weld) at an angle of 90° to the mounting plane and welded round at the ends.

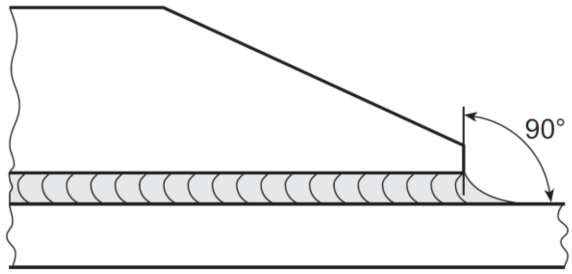


Fig. 16.3 Welding round of stiffening plates or web plates

7. Castings and forgings that are to be joined to thin-walled components shall be provided with welding flanges which have been cast or forged on. Before welding, the welding edges of castings and forgings shall be metallically clean and bright and shall have been inspected for material defects using a suitable process.

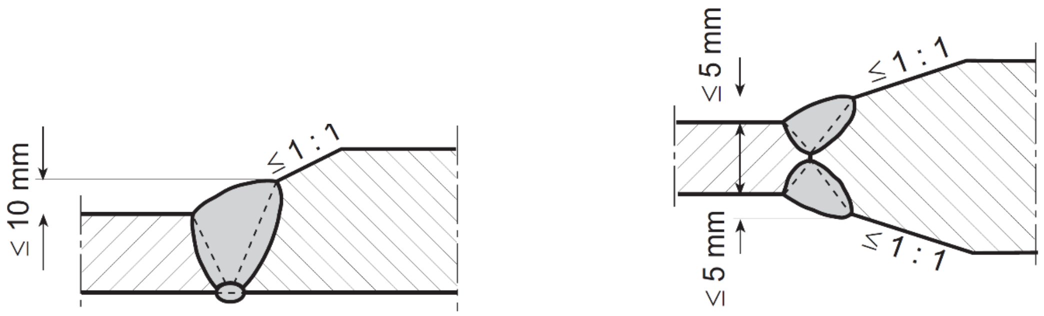
8. Tack welds which are to be left in place as part of the seam are subject to the same qualitative requirements as root passes. Defective tack welds may not be welded over. They are to be removed.

9. If the thickness of flange plates or web plates changes at butt joints, to give a better transition to the thicker section the edges which stand proud by more than 10 mm shall be bevelled off with a gradient of 1:1 or shallower as shown in Fig. 16.4. Differences in thickness less than 10 mm may be compensated for in the weld.

Where the loading transversely to the weld is predominantly dynamic, the transitions are to be made shallower and in this case the provisions of Section 12, G.3. shall be applied in analogous manner.

10. Welding may be performed in areas of components where cold forming has been carried out, including the adjoining surfaces over a width of 5 times the plate thickness t, provided that the conditions (bending radii) specified in Section 12, G.8 are met. Where components subjected to cold forming undergo normalizing heat treatment prior to welding, these conditions need not be adhered to.

11. Where approved by BKI allowing for the relevant load conditions, build-up welds on machinery components subject to dynamic loads (e.g. shafts) shall be executed in a circumferential direction using a fully-mechanized welding process. The provisions of Section 12, G.9. shall apply in analogous manner.



a) Butt joint in flange plate b) Butt joint in web plate

Fig. 16.4 Butt-welded joints in plates of different thickness

H. Post-Weld Heat Treatment

1. Thick-walled, rigid components or those of complicated design which exhibit high levels of residual stress after joining shall be heat-treated after welding in accordance with the relevant standards or BKI approval document. Examples are bedplates for diesel engines, gear boxes and welded gear wheels. See also G.4.

Note:

Post-weld heat treatment (stress-relief heat treatment) may be advisable whenever components have, subsequently, to undergo machining and where therefore there is a risk of stresses being produced during the machining process leading to distortion of the components.

2. The heat treatment generally takes the form of stress relief heat treatment. Depending on the material, however, annealing heat treatment or quenching and tempering may also be advisable or necessary. "Black to white" joints between unalloyed steels and austenitic stainless steels may not be subjected to a post-weld heat treatment. For the type and performance of the heat treatment, see Section 9.

I. Inspection of Welded Components

1. The manufacturer shall present the components for the required intermediate and final inspections, (see also Section 1, F.1. and G.) in which the following shall be demonstrated to BKI Surveyor:

- Proper weld preparation and execution of welding work,
- The satisfactory external condition of the components and especially of the welds,
- Use of the prescribed materials and dimensions by presentation of the documents relating to materials,
- The existence of relevant, valid welder's qualification and welding procedure tests covering the range of application,
- The proper performance of heat treatments by presentation of the relevant record and/or certificates,
- Compliance with the specified dimensions and tolerances by presentation of the records of dimensional data.

2. The following components shall be subjected to non-destructive testing in every case. BKI Surveyor may also demand additional tests, as follows:

– Welded wheel bodies:

  Ultrasonic and/or radiographic inspections together with surface crack inspections of the scope specified when the drawing was approved

– Engine bed plates:

  Surface crack inspection and random ultrasonic tests applied to the transverse girder welds, especially those of the bearing brackets

– Other components:

  Testing of the scope specified when the drawings were approved or when individual approval was granted.

Table 16.1 Requirements applicable to the testing of welded joints [1)]

<table>
<tr><th>Type of test</th><th colspan="3">Requirements</th></tr>
<tr><td>Tensile test transversely to weld</td><td colspan="3">Tensile strength as stipulated for the base material or in the assessment of suitability for the welding consumable</td></tr>
<tr><td>Tensile test on a specimen of the weld metal</td><td colspan="3">Yield strength or 0,2% proof stress. Tensile strength and elongation as for the base material or as specified in the assessment of suitability for the welding consumable.</td></tr>
<tr><td>Notched bar impact test on ISO V-notch specimens taken from the center of the weld</td><td colspan="3">As specified for the base material in transverse direction or as specified in the assessment of suitability for the welding consumable. ≥ 40 J [2)] when using ferritic-austenitic. austenitic and nickel base alloy welding consumable.</td></tr>
<tr><td>Notched bar impact test on ISO V-notch specimens taken from the weld transition zone</td><td colspan="3">70% of the required value for the base material in transverse direction, but at least 20 J. [2)]</td></tr>
<tr><td rowspan="6">Technological bend test</td><th>Bending angle Degrees</th><th>Strength category</th><th>Bending mandrel dia.</th></tr>
<tr><td>180 [3)]</td><td>Ferritic steels with:
min. tensile strength < 430 N/mm^2
min. tensile strength ≥ 430 to 460 N/mm^2</td><td>2 x a
2,5 x a</td></tr>
<tr><td>180 [3)]</td><td>Austenitic stainless steels and austenitic steels tough at sub-zero temperatures
Ferritic steels with a minimum tensile strength ≥ 460 N/mm^2</td><td>2 x a
3 x a</td></tr>
<tr><td colspan="3">If a bending angle of 180 degrees is not attained, the following applies:</td></tr>
<tr><td>≥ 90</td><td colspan="2">Elongation (L_0 = width of weld + wall thickness, symmetrical to weld) ≥ minimum elongation A of base material</td></tr>
<tr><td>or < 90</td><td colspan="2">Elongation over width of weld > 30% [4)] and faultless appearance of fracture</td></tr>
<tr><td rowspan="2">Metallographic examination</td><td colspan="3">The macrographic specimen of the welded joint shall reveal a satisfactory weld build-up and full penetration of the weld.</td></tr>
<tr><td colspan="3">Micrographic specimens are to be examined for cracks. Only hot cracks are acceptable, and then only if they are few in number and widely scattered and agreement has been reached with the Surveyor as to their acceptability with regard to the materials and the range of application</td></tr>
<tr><td>Hardness testing</td><td colspan="3">The hardness in the heat-affected zones shall not exceed 350 HV 10. Hardness peaks in excess of this figure in narrow transition zones shall not give rise to complaints if the outcome of the technological test meets the requirements</td></tr>
</table>

1) Where special welding processes are used as described in 2.1.5, the values shall be agreed with BKI.
2) Only one impact energy value may be lower than the minimum mean value, and only by max. 30%.
3) The 180-degree requirement is deemed to have been met if the bend test was performed according to ISO 5173 and pressure was applied by the supports without cracks appearing.
4) For steels welded with non-matching consumables, different values may be agreed with BKI.

Annex A Permohonan Persetujuan sesuai dengan Peraturan Las

Application for Approval in in Accordance with the Rules for Welding

Kami,
We,

Perusahaan : ____________________
Company

Alamat lengkap : ____________________
Full address

No. telepon : ____________ No. Fax : ____________ Alamat e-mail : ____________
Phone no. *Fax no.* *E-mail address:*

dengan ini mengajukan permohonan persetujuan kepada PT. Biro Klasifikasi Indonesia
hereby make application for approval by Biro Klasifikasi Indonesia

☐ untuk bengkel las yang namanya tercantum dalam penjelasan terlampir
for the welding shop named in the attached description

☐ untuk kawat las dan bahan tambah yang diuraikan dalam Lampiran
for the welding consumables and auxiliary materials specified in the Annexes

Kami menyetujui persyaratan berikut:
The applicant accepts the following conditions

– Peraturan Klasifikasi dan Konstruksi (khususnya, dalam hal ini, Peraturan Las (Bagian 1, Jilid VI)) yang diterbitkan oleh BKI dalam versi yang berlaku pada saat permohonan diajukan.
The Rules for Classification and Construction (particularly, in this instance, the Rules for Welding (Pt.1, Vol.VI)) issued by BKI in the version applicable at the time application is made.

– Kami menjamin bahwa semua informasi yang diperlukan untuk persetujuan dan yang ditetapkan dalam Peraturan disediakan, dan dokumen, hasil uji dll. diserahkan sesuai yang dibutuhkan dan akses ke seluruh bengkel kerja dan daerah produksi terkait diberikan setiap saat kepada Surveyor BKI untuk melaksanakan pemeriksaan.
The applicant will ensure that all the information required for the approval, and specified in the Rules is provided and documents, test results etc. are submitted as applicable and that access to all the relevant workshops and production areas is at all times allowed to the Society's Surveyor to enable him to carry out his inspection functions.

– Jika tidak ada kesepakatan tertulis, maka biaya persetujuan akan dihitung berdasarkan tarif BKI yang berlaku pada saat persetujuan diajukan. Biaya harus tetap dibayar meski persetujuan tidak dapat diberikan karena hasil uji yang tidak memenuhi syarat.
In the absence of any written arrangements to the contrary, fees will be calculated based on the Society's rate of charges at the time approval is granted. Fees are payable even if approval fails to be granted due to unsatisfactory test results.

– Setiap pembatalan permohonan persetujuan ini harus diberitahukan secara tertulis dan akan dikenakan biaya sebesar lingkup jasa yang telah diberikan pada waktu pembatalan diajukan.
Any withdrawal of this application for approval requires notice in writing and will be subject to a charge in line with the scope of services provided at the time of notification of withdrawal.

Dokumen yang diberi tanda silang pada daftar terlampir (Lampiran Permohonan Persetujuan Las) dilampirkan dengan permohonan persetujuan bengkel las; dokumen yang ditetapkan dalam Peraturan Las (Bagian 1, Jilid VI) Bab 5, A.1.8 dilampirkan bersama dengan permohonan persetujuan kawat las dan bahan tambah.
The documents marked with a cross in the attached list (Annex to the Application for Welding Approval) are enclosed with the application for approval of the welding shop; the documents stipulated in the Rules for Welding (Pt.1, Vol.VI) Section 5, A.1.8 are enclosed with the application fo approval of the welding consumables and auxiliary materials.

____
Tempat/*place* tanggal/*date*

Pemohon
Applicant

Nama & tanda tangan
Name & signature

Lampiran dari Permohonan Persetujuan Las

Annex to the Application for Welding Approval

Daftar dokumen yang harus diserahkan atau dilampirkan bersama dengan form permohonan persetujuan
List of documents to be submitted or enclosed with the application for approval

No.	Dokumen *Documents*	Lingkup persetujuan yang diinginkan *Nature of the approval sought*								
		Persetujuan Bengkel *Shop Approval*			Uji Prosedur Las *Welding Procedure Test*			Persetujuan Kawat Las *Approval Welding Consumables*		
		Baru *New* ☐	Perpanjangan *Prolongation* ☐	Revisi / Perluasan *Revision / Extension* ☐	Baru *New* ☐	Pengakuan *Recognition* ☐	Perpanjangan *Prolongation* ☐	Uji Pertama *Initial Test* ☐	Uji Ulang Tahunan *Annual Repeat Test* ☐	Revisi, Transfer, Upgrading *Revisi, Transfer, Upgrading* ☐
1	Permohonan bengkel las *Application from welding shop*	☐	☐	☐	☐	☐	☐			
2	Uraian bengkel las *Description of welding shop*	☐	☐ [1]	☐ [1]						
3	Bukti kualifikasi supersivor las dan wakilnya *Proof of qualification for welding supervisor and deputy*	☐	☐ [1]	☐ [1]						
4	Sertifikat juru las / operator las *Welders / operators certificate*	☐	☐	☐						
5	WPS & WPQR	☐	☐ [1]	☐ [1]	☐	☐	☐ [1]			
6	Rekaman uji produksi / Laporan NDT (misalnya pipa kelas I dan II, ketel uap, bejana tekan, perpanjangan tahunan kawat las di bengkel las) *Records of production tests /NDT-Reports (e.g. pipe class I and II, steam boilers, pressure vessels, annual prolongation of welding consumables in a welding shop)*	☐ [2,3]	☐ [3]	☐ [3]	☐ [3]	☐ [3]	☐ [3]			
7	Dokumentasi / informasi tentang personil NDT *Documentation / information on NDT personnel*	☐	☐ [1]	☐ [1]						
8	Bukti dokumentasi, persetujuan lain yang dimiliki misalnya ISO 9001, EN ISO 3834, DIN 2303, DIN 18800 dll. *Other available documentary proof, approvals e.g.ISO 9001,EN ISO 3834, DIN 2303, DIN 18800, etc*	☐	☐ [1]	☐ [1]						
9	Laporan pemeriksaan bengkel las *Welding Workshop Inspection Report*	☐	☐	☐						
10	Informasi kawat las dan material bantu untuk keperluan persetujuan *Welding consumables and auxiliary materials information for approval purpose*							☐		☐
11	Laporan pengelasan dan hasil uji *Welding reports and test results*							☐	☐	☐
12	Salinan label dan lembaran data teknis *Copy of label and technical data sheet*							☐		☐

[1] Hanya jika terjadi perubahan dari persetujuan yang pertama.
Only if changes have been made since the first approval.

[2] Jika ditetapkan untuk rentang persetujuan tertentu misalnya konstruksi ketel uap dan bejana tekan.
If stipulated for certain ranges of application e.g. steam boiler and pressure vessel construction.

[3] Jika pengujian yang telah dilakukan ditempat lain akan digunakan sebagai dasar persetujuan.
If tests which have already been performed elsewhere are to be used as a basis for approval

Annex B Uraian Bengkel Las

Las Description of Welding Shop

Perusahaan : ______________________________
Company

Alamat lengkap : ______________________________
Full address

No. telepon : ____________ No. Fax : ____________ Alamat e-mail : ____________
Phone no. *Fax no.* *E-mail address:*

Manajer bengkel las : ______________________________
Manager responsible for the works

Persetujuan diajukan untuk rentang aplikasi :
Approval sought for the range of application

- ☐ Pengelasan konstruksi lambung *Welding of hull structures*
- ☐ Pengelasan ketel uap *Welding of steam boiler*
- ☐ Pengelasan bejana tekan *Welding of pressure vessels*
- ☐ Pengelasan pipa *Welding of pipelines*
- ☐ Pengelasan komponen mesin *Welding of machinery components*
- ☐ Pengelasan peti kemas (termasuk perbaikan) *Welding of containers (incl. repairs)*
- ☐ Aplikasi lain *Other application* ______________________________

Uraikan kegiatan yang telah dilakukan yang terkait dengan rentang aplikasi yang diajukan (seperti : rencana las produksi; komponen, material, proses las dll. Jika mungkin, lampirkan daftar referensi pada lembar terpisah)
Past activities in the range of application for which application is made (such as : welding production schedule; components, materials, welding process etc. Where applicable attach separate reference list.)

____
____
____
____
____
____

Sertifikat, penghargaan, persetujuan dll. yang pernah diperoleh (sistem manajemen misalnya ISO 9001, ISO 14000, dll.)
Existing certificates, awards, approvals etc. (management systems e.g. ISO 9001, ISO 14000, etc.)

Persetujuan yang diperoleh *Obtained approval*	**Disertifikasi oleh** *Certified by*	**Tanggal berakhir masa berlaku** *Expiry date*	**Keterangan (ruang lingkup, dll.)** *Remarks (scope, etc.)*

1 Fasilitas Bengkel[1]

Workshop Facilities

1.1 Ruang rakit/las dan tempat merakit yang tertutup, tempat membangun dan dok, dermaga (jumlah dan ukuran)
Assembly/welding shops and covered assembly bays, building berth and docks, outfitting quays (number and size)

1.2 Fasilitas penyimpanan material dan kawat las (jelaskan, misalnya penyimpanannya terbuka/tertutup/ berpemanas)
Storage facili ties for materials and welding consumables (description, e. g. open/covered/heated storage)

1.3 Alat angkat (kapasitas angkat, ketinggian angkat)
Lifting gear (lifting capacity, lifting height)

1.4 Peralatan permesinan dan perlengkapan
Machining equipment and tools

1.5 Peralatan las dan potong, mesin-mesin dan pembangkit
Welding and cutting equipment, machines and plant

1.6 Oven pemanas dan kontainer berpemanas untuk kawat las (tipe, jumlah, temperatur maksimum)
Baking ovens and heatable containers for welding consumables (type, number, maximum temperature)

1.7 Alat bantu las (misalnya meja putar, manipulator)
Welding jigs (e. g. turntables, manipulators)

1.8 Peralatan untuk pemanasan awal, perlakuan panas pasca las dan pengukur temperatur
Equipment for preheating, post-weld heat treatment and temperature measurement

1.9 Peralatan uji yang ada dan metode uji (untuk uji merusak dan tak merusak, dll.)
Available test equipment and test methods (for destructive and non-destructive testing, etc.)

1.10 Informasi lain (misalnya fasilitas untuk penghilangan kerak dengan api/pemberian cat dasar, mesin shot blasting dll.)
Other information (e. g. flame de-scaling/priming facilities, shot blasting machines etc.)

[1] Ikhtisar, untuk informasi umum mengenai kemampuan produksi bengkel las. Publikasi alternatif atau tambahan, brosur dan sejenisnya.
Summary, for general information about the work's production capabilities. Alternative or supplementary publications, brochure and the like.

2 Lingkup Persetujuan yang diinginkan

Scope of Approval Sought

(klasifikasi material, proses las [detail sesuai dengan ISO 4063], kawat las dan material bantu dll. Jika diperlukan dilanjutkan di kertas terpisah)
(classification of materials, welding process [details in accordance with ISO 4063], welding consumables and auxiliary materials etc. If necessary, continue on separate sheet.)

Komponen: *Components*			
Material dasar: *Base material*			
Tebal pelat/dinding; diameter pipa: *Plate-/wall thicknesses; pipe diameter*			
Proses las: *Welding process*			
Posisi las: *Welding position(s)*			
Tipe las, bentuk las: *Types of weld, weld forms*			
Kawat las[2] dan material bantu (merek, pembuat): *Welding consumables and auxiliary materials (brandname, manufacturer)*			
No. WPS: *WPS no.*			
Faktor las [3]: *Weld factor*			
Perlakuan panas[4]: *Heat treatment*			
Lainnya: *Other*			

3 Personil

Personnel

Jumlah pegawai (total) : ____________________ yg sebagai juru las/operator : ____________________
Number of employees (total) *of which welders/operators*

3.1 Manajer mutu

Quality manager

Nama : ______________________________
Name

Kualifikasi[5] yg dimiliki : ______________________________
Qualifications given as
____

Tanggung jawab : ______________________________
Area of responsibility

[2] Daftar agar dilampirkan
Please attach list

[3] Jika diperlukan, misalnya untuk bejana tekan
Where applicable, e. g. for pressure vessel

[4] Jika diperlukan, misalnya anil pembebasan tegangan
Where applicable, e. g. stress-relief annealing

[5] Pelatihan kejuruan dan pengalaman kerja dicantumkan dalam bentuk table dan dilampirkan; salinan sertifikat dilampirkan.
Vocational training and employment are listed in tabular form and enclosed; copies of certificates are attached.

3.2 Supervisor las
Welding supervisor

Nama : ______________________________
Name

Kualifikasi[5] yg dimiliki : ______________________________
Qualifications given as
____

Tanggung jawab : ______________________________
Area of responsibility

3.3 Supervisor NDT[6]
NDT Supervisor

Nama : ______________________________
Name

Kualifikasi[5] yg dimiliki : ______________________________
Qualifications given as
____

Tanggung jawab : ______________________________
Area of responsibility

3.4 Juru las / operator las
Welders / operators

Proses las *Welding process*	Jumlah juru las yang bersertifikat *Number of qualified welders*
Manual metal arc welding	
Metal active gas welding	
Flux cored arc welding	
Submerged arc welding	
Electro Gas Welding	
Lainnya : *Other*	

Daftar juru las / operator las dilampirkan ☐ ya ☐ tidak
Detailed list of qualified welders/operators attached

3.5 Pelatihan internal untuk juru las: ☐ ya ☐ tidak
In house training for welders

3.6 Personil pengujian[7]
Test personnel

Metode uji *Testing method*	Jumlah orang internal *Number of internal persons*	Level 1	Level 2	Level 3
Visual testing (VT)				
Penetration testing (PT)				
Magnetic particle testing (MT)				
Radiographic testing (RT)				
Ultrasonic testing (UT)				

6 Jika NDT disubkontrakkan, bukti dokumen kualifikasi harus dilampirkan.
If NDT is subcontracted, documentary proof of qualification is to be attached.
7 Bukti dokumen kualifikasi dilampirkan.
Documentary proof of qualification attached

Jika disubkontrakkan, harap jelaskan :
If subcontracted: please specify:

____

____

____

______________________	______________________
Tempat/tanggal *place/date*	Tempat/tanggal *place/date*
Supervisor las *Welding supervisor*	Perusahaan *Company*
______________________	______________________
(Nama, tandatangan) *(Name, signature)*	(Nama, tandatangan) *(Name, signature)*

Lampiran : ____
Annex(es)

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Annex C Pelaksanaan Uji Kualifikasi Juru Las

Welder Performance Qualification Test

1. Data Sampel Las

Record of Weld Test

Nama perusahaan / *Company name*	No. WPS / *WPS no.*	Supervisor las / *Welding supervisor*
Nama juru las / *Welder name*	Kode juru las / *Welder stamp*	Tanggal pengelasan / *Date of welding*

Proses las / *Welding process*	Mode transfer logam las / *Mode of metal transfer*	Posisi las / *Welding position*

Material dasar / *Base material*	Tebal material / *Material thickness*	Diameter luar pipa / *outside diameter*
Tipe sambungan / *Joint type*	Material penahan / *Backing material*	Gouging balik / *Back gouging*

Klasifikasi kawat las (sesuai ISO atau AWS) *Filler metal class. (acc. to ISO or AWS)*	Tipe / merek kawat las / *Brand name*	Pembuat / *Manufacturer*

Tipe gas pelindung & komposisi / *Type of shielding gas & composition*	Kec. alir gas / *Gas flow rate*

Klasifikasi fluks (sesuai ISO atau AWS) *Flux class. (acc. to ISO or AWS)*	Tipe / merek fluks / *Brand name*	Pembuat / *Manufacturer*

Temperatur pemanasan awal / *Preheat temperature*	Temperatur antar pass / *Interpass temperature*

Perlakuan panas pasca las / *Postweld heat treatment*		
Temperatur / *Temperature*	Waktu tahan / *Holding time*	Kec. pemanasan dan pendinginan / *Heating and cooling rate*

Alur *Run*	Proses las *Welding process*	Diameter kawat las *Size of filler metal* [mm]	Tipe arus / polaritas *Type of current/ Polarity*	Arus las *Current* [A]	Tegangan *Voltage* [V]	Kec. Umpan kawat *Wire feed speed* [cm/min]	Kec. las *Travel speed* [cm/min]	Detail sambungan *Joint design*

2. Hasil Uji [1)]

Test Results

Pemeriksaan visual/*Visual inspection*	Uji radiografi/*Radiographic test*	Uji ultrasonik/*Ultrasonic test*	Uji lengkung/*Bending test*

Uji makro / *Macro examination*	Uji tarik dgn takik / *Notched tensile test*	Uji patah / *Fracture test*

[1)] Hasil uji dinyatakan dengan "passed"; "not passed" atau "not tested".

Welding supervisor

(Nama, tanda tangan, tanggal)

Surveyor

(Nama, tanda tangan, tanggal)

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Annex D Manufacturer's Welding Procedure Specification

☐ Preliminary WPS ☐ Final WPS

Perusahaan : ______________________________
Company

Alamat lengkap : ______________________________
Full address

No. telepon : ____________ No. Fax : ____________ Alamat e-mail : ____________
Phone no. *Fax no.* *E-mail address:*

Informasi umum *(General information)*

No. WPS : ____________ No. WPQR : ____________
WPS No. *WPQR No.*

Standard uji : ______________________________
Testing standard

Proses las : ____________ Mode transfer logam las : ____________
Welding Process *Mode of metal transfer*

Tipe sambungan : ______________________________
Joint type

Material penahan : ☐ Ya *Yes* ☐ Tidak *No* Material : ____________
Backing material *Material*

Gouging balik : ☐ Ya *Yes* ☐ Tidak *No* Metode : ____________
Back gouging *Method*

Spesifikasi material dasar : ______________________________
Base material(s) specification

Rentang tebal material : ____________ Rentang diameter luar : ____________
Material thickness range *Outside diameter range*

Posisi las : ____________ Metode persiapan dan pembersihan : ____________
Welding position *Method of preparation and cleaning*

Kawat las *(Welding consumables)*

Klasifikasi kawat las (sesuai ISO atau AWS) : ______________________________
Welding consumables classification (acc. to ISO or AWS)

Tipe / merek : ____________ Pembuat : ____________
Brand name *Manufacturer*

Dilakukan pemanasan atau pengeringan khusus : ______________________________
Any special baking or drying

Gas pelindung *(Shielding gas)*

Tipe gas / komposisi : ____________ Kec. alir gas : ____________
Type of gas / composition *Gas flow rate*

Fluks *(Flux)*

Klasifikasi fluks (sesuai ISO atau AWS) : ______________________________
Flux classification (acc. to ISO or AWS)

Tipe / merek : ____________ Pembuat : ____________
Brand name *Manufacturer*

Suhu pemanasan awal : ____________ Temperatur antar lajur : ____________
Preheating temperature *Interpass temperature*

Perlakuan panas pasca las
Post-weld heat treatment

Temperatur : ______________________ Waktu tahan : ______________________
Temperature *Holding time*

Kec. pemanasan dan pendinginan : ______________________
Heating and cooling rate

Detail persiapan kampuh (gambar)
Joint preparation details (sketch)

Desain sambungan *Joint design*	Urutan pengelasan *Welding sequences*

Detail pengelasan
Welding details

Alur *Run*	Proses las *Welding process*	Diameter kawat las *Diameter of filler metal* [mm]	Arus las *Current* [A]	Tegangan *Voltage* [V]	Tipe arus/ polaritas *Type of current/ polarity*	Kec. umpan kawat *Wire feed Speed*	Kec las *Travel speed* [cm/min]	Masukan panas *Heat input* [kJ/cm]

Informasi lain *(Other information)*

Jumlah kawat las : ______________________ Tipe & diameter elektroda tungsten : ______________________
Number of electrode *Tungsten electrode type & diameter*

Jarak ujung nosel ke benda kerja : ______________________ Diameter nosel : ______________________
Distance contact tube to work piece *Nozzle diameter*

Tipe tangkai las : ______________________ Merek & pembuat cat dasar : ______________________
Type of torch *Brand name & manufacturer of shop primer*

Supervisor las
Welding supervisor

Badan pemeriksa
Examining body

____
(Nama, tanggal, tandatangan)
(Name, date signature)

____
(Nama, tanggal, tandatangan)
(Name, date signature)

Rekaman Uji Prosedur Las
Welding Procedure Qualification Record (WPQR)

Perusahaan : ______________________________
Company

Alamat lengkap : ______________________________
Full address

No. telepon : __________ No. Fax : __________ Alamat e-mail : __________
Phone no. *Fax no.* *E-mail address:*

1. Data Sampel Las
Record of Weld Test

No. WPQR : __________ No. WPS : __________
WPQR No. *WPS No.*

Nama juru las : __________ Tanggal pengelasan : __________
Welder's name *Date of test*

Tipe sambungan dan las : __________ Material penahan : __________
Joint type and weld *Backing material*

Gouging balik : __________ Posisi las : __________
Back gouging *Welding position(s)*

Spesifikasi material dasar : ______________________________
Base material(s) specification

Proses las : __________ Mode transfer logam : __________
Welding Process *Mode of metal transfer*

Tebal material [mm] : __________ Diameter luar pipa [mm] : __________
Material thickness [mm] *Outside pipe diameter [mm]*

Metode persiapan dan pembersihan : ______________________________
Method of preparation and cleaning

Detail persiapan kampuh (gambar)
Joint preparation details (sketch)

Desain sambungan *Joint design*	Urutan pengelasan *Welding sequences*

Detail pengelasan
Welding details

Alur *Run*	Proses las *Welding process*	Diameter kawat las *Diameter of filler metal* [mm]	Arus las *Current* [A]	Tegangan *Voltage* [V]	Tipe arus/ polaritas *Type of current/polarity*	Kec. umpan kawat *Wire feed speed*	Kec las *Travel speed* [cm/min]	Masukan panas *Heat input* [kJ/cm]

Kawat las (*Welding consumables*)

Klasifikasi kawat las (sesuai ISO atau AWS) : ____________________
Welding consumables classification (acc. to ISO or AWS)

Tipe / merek : ____________________ Pembuat : ____________________
Brand name *Manufacturer*

Dilakukan pemanasan atau pengeringan khusus : ____________________
Any special baking or drying

Gas pelindung (*Shielding gas*)

Tipe gas / komposisi : ____________________ Kec. alir gas : ____________________
Type of gas / composition *Gas flow rate*

Fluks (*Flux*)

Klasifikasi fluks (sesuai ISO atau AWS) : ____________________
Flux classification (acc. to ISO or AWS)

Tipe / merek : ____________________ Pembuat : ____________________
Brand name *Manufacturer*

Suhu pemanasan awal : ____________________ Temperatur antar lajur : ____________________
Preheating temperature *Interpass temperature*

Perlakuan panas pasca las
Post-weld heat treatment

Temperatur : ____________________ Waktu tahan : ____________________
Temperature *Holding time*

Kec. pemanasan dan pendinginan : ____________________
Heating and cooling rate

Informasi lain (*Other information*)

Jumlah kawat las : ____________________ Tipe & diameter elektroda tungsten : ____________________
Number of electrode *Tungsten electrode type & diameter*

Jarak ujung nosel ke benda kerja : ____________________ Diameter nosel : ____________________
Distance contact tube to work piece *Nozzle diameter*

Tipe tangkai las : ____________________ Merek & pembuat cat dasar : ____________________
Type of torch *Brand name & manufacturer of shop primer*

Supervisor las *Welding supervisor*	Surveyor BKI *BKI Surveyor*
____________________ (Nama, tanggal, tandatangan) *(Name, date signature)*	____________________ (Nama, tanggal, tandatangan) *(Name, date signature)*

2. Hasil Uji
Test Results

No. WPQR : ______________________ No. WPS : ______________________
WPQR No *WPS No.*

Uji tak rusak *Non-destructive testing*		
Metode uji *Test method*	Hasil *Results*	No. laporan uji *Test report no.*
Pemeriksaan visual *Visual inspection*		
Uji radiografi *Radiographic test*		
Uji ultrasonik *Ultrasonic test*		
Uji partikel magnetik *Magnetic particle test*		
Uji cairan warna *Dye penetrant test*		

Uji tarik *Tensile tests*			No. laporan uji : *Test report No.*			
Bentuk/No. Spesimen *Specimen Form/No.*	Dimensi *Dimension* [mm]	Luas penampang *Cross-section* [mm^2]	Kuat luluh *Yield strength* [N/mm^2]	Kuat tarik *Tensile strength* [N/mm^2]	Elongasi *Elongation* [%]	Lokasi / Jenis patah *Location / Character of fracture*
Persyaratan *Requirements*						
T1			–		–	
T2			–		–	
WM1						–

Uji lengkung *Bend tests*			No. laporan uji : *Test report No.*		
Bentuk/No. Spesimen *Specimen Form/No.*	Dimensi *Dimension* [mm]	Diameter mandrel *Mandrel diameter* [mm]	Sudut lengkung *Bending angle* [degree]	Elongasi *Elongation* (L_0 = mm) [%]	Hasil, Ket. *Results, Remarks*
Persyaratan *Requirements*					

Metode uji *Test method*	Hasil *Results*	No. laporan uji *Test report No.*	Metode uji *Test method*	Hasil *Results*	No. laporan uji *Test report No.*
Pemeriksaan makro *Macro examination*			Uji patah *Fracture test*		
Pemeriksaan mikro *Micro examination*					

Uji impak *Impact test*								No. laporan uji : *Test report No.*
Temperatur uji [°C] : *Test temperature*								Ukuran spesimen [mm] : *Specimen sizes*
Lokasi takik *Notch location*		Nilai individu *Individual values* [J]						Nilai rata-rata *Average value*
		1	2	3	4	5	6	[J]
Persyaratan *Requirements*		Min.						Min.
Face side	Center weld metal							
	Fusion line							
	Fusion line + 2 mm							
	Fusion line + 5 mm							
	Fusion line + 10 mm							
Root side	Center weld metal							
	Fusion line							
	Fusion line + 2 mm							

Uji kekerasan HV 10 *Hardness tests HV 10*			No. laporan uji : *Test report No.*					
Sketsa *Sketch*	Points		1	2	3	4	5	6
	BM	A						
		B						
		C						
	HAZ	A						
		B						
		C						
	WM	A						
		B						
		C						

Pengujian lain *Other tests*	Hasil *Results*	No. laporan uji *Test report No.*

Sampel las dibuat dan pengujian dilakukan sesuai dengan persyaratan Peraturan Las (Bagian 1, Jilid VI) yang diterbitkan oleh BKI
The trial welds were made and the tests performed in accordance with the requirements of the Rules for Welding (Pt.1, Vol.VI) issued by BKI
dan juga Peraturan berikut :
and also the following Rules

Supervisor las
Welding supervisor

Surveyor BKI
BKI Surveyor

(Nama, tanggal, tandatangan)
(Name, date signature)

(Nama, tanggal, tandatangan)
(Name, date signature)

Annex E Welding Consumables and Auxiliary Materials

Information for approval purpose - Appendix to the application in accordance with Annex A

Elektroda/Kawat
Electrode/Wire

☐ Pembuat *Manufacturer* ☐ Penyalur *Supplier* ☐ Distributor *Distributor* ☐ Pemegang lisensi *Licensee (where applicable)*

Perusahaan *Company* : ______________________

Alamat *Address* : ______________________
____

No. Telp: *Phone no.* ______________________ No. Fax: *Fax no.* ______________________

E-mail: ______________________

Alamat untuk sertifikasi persetujuan[1]: *Address for approval certification*)* ______________________
____

Personil penghubung/ departemen: *Contact person / department* ______________________

Serbuk Fluks/ Gas Pelindung
Flux Powder/ Shielding Gas

☐ Pembuat *Manufacturer* ☐ Penyalur *Supplier* ☐ Distributor *Distributor* ☐ Pemegang lisensi *Licensee (where applicable)*

Perusahaan *Company* : ______________________

Alamat *Address* : ______________________
____

No. Telp: *Phone no.* ______________________ No. Fax: *Fax no.* ______________________

E-mail: ______________________

Alamat untuk sertifikasi persetujuan*): *Address for approval certification*)* ______________________
____

Personil penghubung/ departemen: *Contact person / department* ______________________

Informasi kawat las / bahan pendukung (sifat kawat las / bahan pendukung)
Welding consumable / auxiliary material information *(Nature of welding consumable / auxiliary material)*

☐ Kawat pengisi *Filler wire* ☐ Kombinasi kawat pejal dengan gas *Solid wire-gas combination* ☐ Kawat las *Welding rod*

☐ Kombinasi kawat berinti fluks dengan gas *Flux-cored wire-gas combination* ☐ Elektroda terbungkus *Covered electrode* ☐ Kombinasi kawat pejal dengan fluks *Solid wire-flux combination*

☐ Kawat berinti-fluks *Flux-cored wire* ☐ Kombinasi kawat berinti fluks dengan fluks *Flux-cored wire-flux combination*

Lainnya (uraikan) : *Other (describe)* ______________________

---

[1] diisi jika berbeda dengan alamat perusahaan.
to be filled if different from company address

Merek kawat las (kawat, kawat berinti fluks, elektroda, dll.):
Brand designation of welding consumable (wire, flux-cored wire, electrode, etc.)

Merek bahan pendukung (gas pelindung, fluks, dll.):
Brand designation of auxiliary material (shielding gas, flux, etc.)

Klasifikasi sesuai standard (ISO, EN, AWS dll.):
Classification to standards (ISO, EN, AWS etc.)

Lingkup persetujuan yang diinginkan / rentang aplikasi:
Intended scope of approval / range of application

Tingkatan mutu yang diajukan dalam permohonan dan simbol tambahan:
Quality grade for which application is made and added symbol

Bahan dasar yang akan disambung dengan pengelasan:
Base materials to be joined by welding

Posisi las yang diajukan untuk persetujuan sesuai dengan ISO 6947:
Welding positions for which approval is sought according to ISO 6947

Dimensi yang diajukan untuk persetujuan (diameter, panjang produk):
Dimensions for which approval is sought (diameters, lengths of products)

Arus las, polaritas:
Welding current, polarity

Kondisi perlakuan panas (pasca pengelasan):
(Post-weld) heat treatment conditions

Kondisi aplikasi khusus (misalnya temperatur kerja minimum atau maksimum):
Special application conditions (e. g. minimum or maximum application temperature)

Aturan penggunaan (misalnya, dipanaskan kembali, perlakuan panas pasca pengelasan):
Rules for application (e. g. re-baking, post-weld heat treatment)

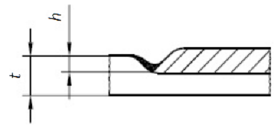
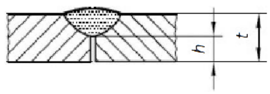
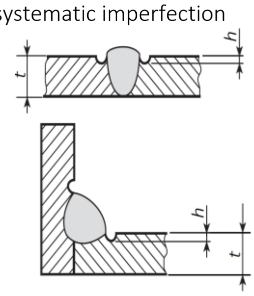
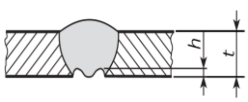
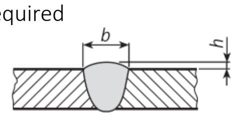
Marka, kemasan:
Marking, packing

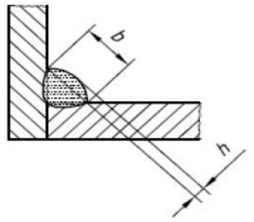
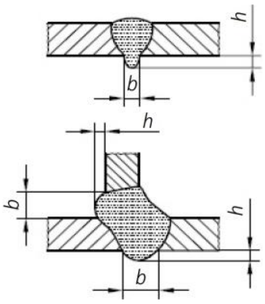
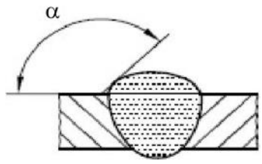
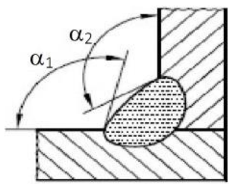
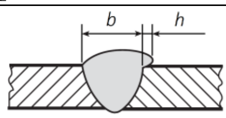
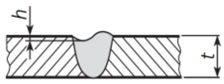
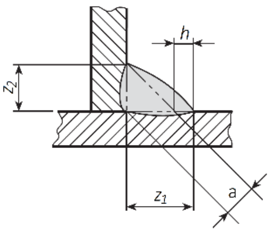
Informasi lain, dokumen yang dilampirkan
Other information, attached documents

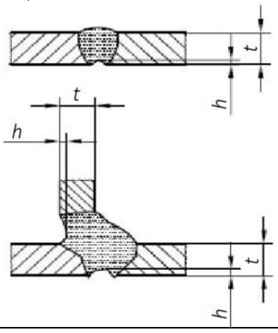
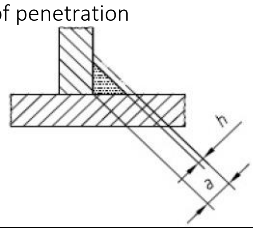
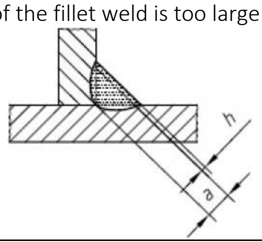
Verifikasi identitas ("pernyataan tertulis") untuk transfer persetujuan dilampirkan? *Verifications of identity ("affidavits") for transfers of approval attached?*	☐ ya/*yes*	☐ tidak/*no*
Program uji persetujuan dilampirkan? *Approval test programme attached?*	☐ ya/*yes*	☐ tidak/*no*
Rekaman uji persetujuan dilampirkan? *Approval test records attached?*	☐ Ya/*yes*	☐ tidak/*no*

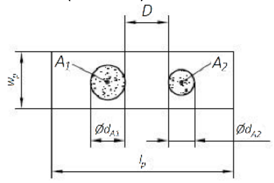
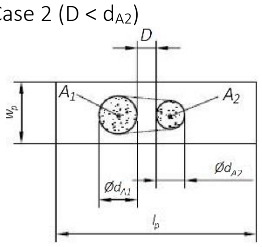
Annex F Imperfections in Welded Joints in Steel

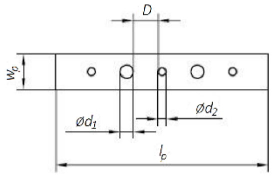
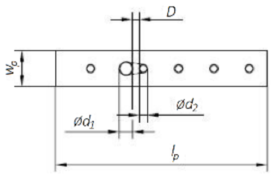
Limits for imperfections in welded joints in steel in accordance with the International Standards ISO 5817

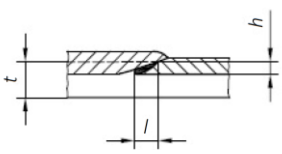
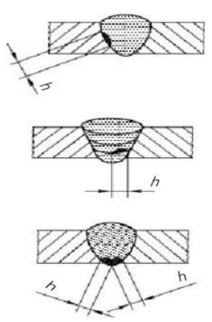
<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Imperfection designation</th><th rowspan="2">Reference to ISO 6520-1</th><th rowspan="2">Remarks</th><th rowspan="2">t
mm</th><th colspan="3">Limit for imperfections for quality levels</th></tr>
<tr><th>D (low)</th><th>C (medium)</th><th>B (high)</th></tr>
<tr><td colspan="8">1. Surface imperfection</td></tr>
<tr><td>1.1</td><td>Crack</td><td>100</td><td>--</td><td>≥ 0,5</td><td colspan="3">Not permitted</td></tr>
<tr><td>1.2</td><td>Crater crack</td><td>104</td><td>--</td><td>≥ 0,5</td><td colspan="3">Not permitted</td></tr>
<tr><td rowspan="2">1.3</td><td rowspan="2">Surface pore</td><td rowspan="2">2017</td><td>Maximum dimension of a single pore for :
– butt welds
– fillet welds</td><td>0,5 to 3</td><td>d ≤ 0,3 s
d ≤ 0,3 a</td><td colspan="2">Not permitted</td></tr>
<tr><td>Maximum dimension of a single pore for :
– butt welds
– fillet welds</td><td>> 3</td><td>d ≤ 0,3 s
but max. 3 mm
d ≤ 0,3 a
but max. 3 mm</td><td>d ≤ 0,3 s
but max. 2 mm
d ≤ 0,3 a
but max. 2 mm</td><td>Not permitted</td></tr>
<tr><td rowspan="2">1.4</td><td rowspan="2">End crater pipe</td><td rowspan="2">2025</td><td rowspan="2"></td><td>0,5 to 3</td><td>h ≤ 0,2 t</td><td colspan="2">Not permitted</td></tr>
<tr><td>> 3</td><td>h ≤ 0,2 t,
but max. 2 mm</td><td>h ≤ 0,2 t,
but max. 1 mm</td><td>Not permitted</td></tr>
<tr><td rowspan="2">1.5</td><td>Lack of fusion (incomplete fusion)</td><td rowspan="2">401</td><td>–</td><td rowspan="2">≥ 0,5</td><td colspan="3">Not permitted</td></tr>
<tr><td>Micro lack of fusion</td><td>Only detectable by micro examination</td><td colspan="2">Permitted</td><td>Not permitted</td></tr>
<tr><td>1.6</td><td>Incomplete root penetration</td><td>4021</td><td>Only for single side butt welds
</td><td>≥ 0,5</td><td>Short imperfections :
h ≤ 0,2 t,
but max. 2 mm</td><td colspan="2">Not permitted</td></tr>
<tr><td rowspan="2">1.7</td><td>Continuous undercut</td><td>5011</td><td rowspan="2">Smooth transition is required.
This is not regarded as a systematic imperfection
</td><td>0,5 to 3</td><td>Short imperfections
h ≤ 0,2 t</td><td>Short imperfections
h ≤ 0,1 t</td><td>Not permitted</td></tr>
<tr><td>Intermittent undercut</td><td>5012</td><td>> 3</td><td>h ≤ 0,2 t,
but max. 1 mm</td><td>h ≤ 0,1 t,
but max. 0,5 mm</td><td>h ≤ 0,05 t,
but max. 0,5 mm</td></tr>
<tr><td rowspan="2">1.8</td><td rowspan="2">Shrinkage groove</td><td rowspan="2">5013</td><td rowspan="2">Smooth transition is required
</td><td>0,5 to 3</td><td>h ≤ 0,2 mm + 0,1 t</td><td>Short imperfections
h ≤ 0,1 t,</td><td>Not permitted</td></tr>
<tr><td>> 3</td><td>Short imperfections:
h ≤ 0,2 t,
but max. 2 mm</td><td>Short imperfections:
h ≤ 0,1 t,
but max. 1 mm</td><td>Short imperfections:
h ≤ 0,05 t,
but max. 0,5 mm</td></tr>
<tr><td>1.9</td><td>Excess weld metal (butt weld)</td><td>502</td><td>Smooth transition is required
</td><td>≥ 0,5</td><td>h ≤ 1 mm + 0,25 b
but max. 10 mm</td><td>h ≤ 1 mm + 0,15 b
but max. 7 mm</td><td>h ≤ 1 mm + 0,1 b
but max. 5 mm</td></tr>
</table>

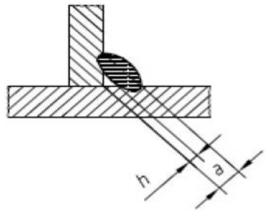
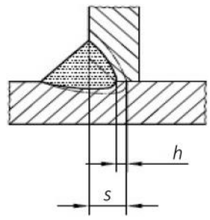
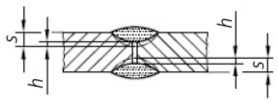
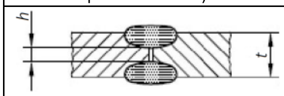
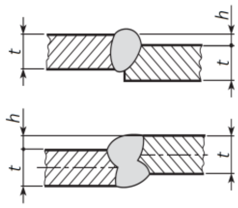
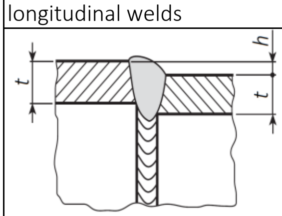
No.	Imperfection designation	Reference to ISO 6520-1	Remarks	t mm	Limit for imperfections for quality levels		
					D (low)	C (medium)	B (high)
1.10	Excessive convexity (fillet weld)	503		≥ 0,5	h ≤ 1 mm + 0,25 b but max. 5 mm	h ≤ 1 mm + 0,15 b but max. 4 mm	h ≤ 1 mm + 0,1 b but max. 3 mm
1.11	Excess penetration	504		0,5 to 3	h ≤ 1 mm + 0,6 b	h ≤ 1 mm + 0,3 b	h ≤ 1 mm + 0,1 b
				> 3	h ≤ 1 mm + 1,0 b but max. 5 mm	h ≤ 1 mm + 0,6 b but max. 4 mm	h ≤ 1 mm + 0,2 b but max. 3 mm
1.12	Incorrect weld toe	505	– butt welds 	≥ 0,5	α ≥ 90°	α ≥ 100°	α ≥ 150°
			– fillet welds  $\alpha_1 \geq \alpha$ $\alpha_2 \geq \alpha$	≥ 0,5	α ≥ 90°	α ≥ 110°	α ≥ 110°
1.13	Overlap	506		≥ 0,5	h ≤ 0,2 b	Not permitted	
1.14	Sagging incompletely filled groove	509	Smooth transition is required 	0,5 to 3	Short imperfections: h ≤ 0,25 t	Short imperfections: h ≤ 0,1 t	Not permitted
		511		> 3	Short imperfections: h ≤ 0,25 t, but max. 2 mm	Short imperfections: h ≤ 0,1 t, but max. 1 mm	Short imperfections: h ≤ 0,05 t, but max. 0,5 mm
1.15	Burn through	510	--	≥ 0,5	Not permitted		
1.16	Excessive asymmetry of filled weld (excessive unequal leg legth)	512	In cases where an asymmetric fillet weld has not been prescribed 	≥ 0,5	h ≤ 2 mm + 0,2 a	h ≤ 2 mm + 0,15 a	h ≤ 1,5 mm + 0,15 a

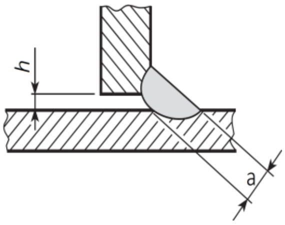
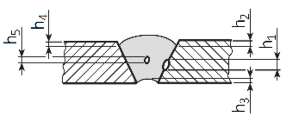
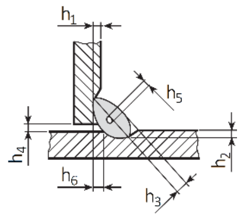
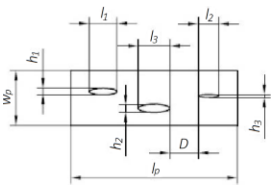
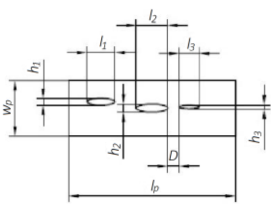
No.	Imperfection designation	Reference to ISO 6520-1	Remarks	t mm	Limit for imperfections for quality levels		
					D (low)	C (medium)	B (high)
1.17	Root concavity	515	Smooth transition is required	0,5 to 3	h ≤ 0,2 mm + 0,1 t	Short imperfections: h ≤ 0,1 t	Not permitted
				> 3	Short imperfections : h ≤ 0,2 t, but max. 2 mm	Short imperfections : h ≤ 0,1 t, but max. 1 mm	Short imperfections : h ≤ 0,05 t, but max. 0,5 mm
1.18	Root porosity	516	Spongy formation at the root of a weld due to bubbling of the weld metal at the moment of solidification (e.g. lack of gas backing)	≥ 0,5	Locally permitted	Not permitted	
1.19	Poor restart	517	--	≥ 0,5	Permitted. The limit depends on the type of imperfection occurred due to restart	Not permitted	
1.20	Insufficient throat thickness	5213	Not applicable to processes with proof of greater depth of penetration	0,5 to 3	Short imperfections: h ≤ 0,2 mm + 0,1 a	Short imperfections: h ≤ 0,2 mm	Not permitted
				> 3	Short imperfections: h ≤ 0,3 mm + 0,1 a, but max. 2 mm	Short imperfections: h ≤ 0,3 mm + 0,1 a, but max. 1 mm	Not permitted
1.21	Excessive throat thickness	5214	The actual throat thickness of the fillet weld is too large 	≥ 0,5	Unlimited	h ≤ 1 mm + 0,2 a, but max 4 mm	h ≤ 1 mm + 0,15 a, but max 3 mm
1.22	Stray arc	601	--	≥ 0,5	Permitted, if the properties of the parent metal are not affected	Not permitted	
1.23	Spatter	602	--	≥ 0,5	Acceptance depends on application, e.g. material, corrosion protection		
2. Internal imperfections							
2.1	Crack	100	All types of crack except microcracks and crater cracks	≥ 0,5	Not permitted		
2.2	Microcracks	1001	A crack usually only visible under the microscope (50 X)	≥ 0,5	Permitted	Acceptance depends on type of parent metal with particular reference to crack sensitivity	

No.	Imperfection designation	Reference to ISO 6520-1	Remarks	t mm	Limit for imperfections for quality levels		
					D (low)	C (medium)	B (high)
2.3	Gas pore Uniformly distributed porosity	2011 2012	a1) Maximum dimension of the area of the imperfections (Inclusive of systematic imperfection) related to the project area. NOTE: The porosity in the project area depends on the numbers of layers (volume of the weld)	≥ 0,5	For single layer: ≤ 2,5 % For multi-layer: ≤ 5 %:	For single layer: ≤ 1,5 % For multi-layer: ≤ 3 %:	For single layer: ≤ 1 % For multi-layer: ≤ 2 %:
			a2) Maximum dimension of the cross-sectional area of the imperfections (inclusive of systematic imperfection) related to the fracture area (only applicable to production, welder or procedure tests)	≥ 0,5	≤ 2,5 %	≤ 1,5 %	≤ 1 %
			b) Maximum dimension for a single pore for - butt welds - fillet welds	≥ 0,5	d ≤ 0,4 s, but max. 5 mm d ≤ 0,4 a, but max. 5 mm	d ≤ 0,3 s, but max. 4 mm d ≤ 0,3 a, but max. 4 mm	d ≤ 0,2 s, but max. 3 mm d ≤ 0,2 a, but max. 3 mm
2.4	Clustered (localized) porosity	2013	Case 1 ($D > d_{A2}$)  Case 2 ($D < d_{A2}$)  The sum of the different pore areas ($A_1 + A_2 + ...$) related to the evaluation area l_P x w_p (case 1). Reference length for l_P is 100 mm. If D is less than d_{A1} or d_{A2}, whichever is smaller, an envelope surrounding the porosity areas $A_1 + A_2$ shall be considered as one area of imperfection (case 2)				
			Maximum dimension of the summation of the projected area of the imperfection (inclusive of systematic imperfection)	≥ 0,5	≤ 16 %	≤ 8 %	≤ 4 %

No.	Imperfection designation	Reference to ISO 6520-1	Remarks	t mm	Limit for imperfections for quality levels		
					D (low)	C (medium)	B (high)
			Maximum dimension for a single pore for - butt welds - fillet welds	≥ 0,5	d ≤ 0,4 s but max. 4 mm d ≤ 0,4 a but max. 4 mm	d ≤ 0,3 s but max. 3 mm d ≤ 0,3 a but max 3. mm	d ≤ 0,2 s but max. 2 mm d ≤ 0,2 a but max. 2 mm
2.5	Linear porosity	2014	Case 1 ($D > d_2$)  Case 2 ($D < d_2$)  The sum of the different pore areas $\left(\frac{d_1^2 \times \pi}{4} + \frac{d_2^2 \times \pi}{4} + ...\right)$ related to the evaluation area $l_p \times w_p$ (case 1). Reference length for l_p is 100 mm. If D is smaller than the smaller diameter of one of the neighbouring pores, the full connected area of the two pores shall be applied to the sum of imperfections (case 2).				
			a1) Maximum dimension of the area of the imperfections (inclusive of systematic imperfection) related to the projected area. NOTE : The porosity in the project area depends on the numbers of layers (volume of the weld).	≥ 0,5	For single layer: ≤ 8 % For multi-layer: ≤ 16 %:	For single layer : ≤ 4 % For multi-layer: ≤ 8 %:	For single layer : ≤ 2 % For multi-layer: ≤ 4 %:
			a2) Maximum dimension of the cross-sectional area of the imperfections (inclusive of systematic imperfection) related to the fracture area (only applicable to production, welder or procedure tests)	≥ 0,5	≤ 8 %	≤ 4 %	≤ 2 %

No.	Imperfection designation	Reference to ISO 6520-1	Remarks	t mm	Limit for imperfections for quality levels		
					D (low)	C (medium)	B (high)
			b) Maximum dimension for a single pore for : – butt welds – fillet welds	≥ 0,5	d ≤ 0,4 s, but max. 4 mm d ≤ 0,4 a, but max. 4 mm	d ≤ 0,3 s, but max. 3 mm d ≤ 0,3 a, but max. 3 mm	d ≤ 0,2 s, but max. 2 mm d ≤ 0,2 a, but max. 2 mm
2.6	Elongated cavity Wormholes	2015	– butt welds	≥ 0,5	h ≤ 0,4 s but max. 4 mm *l* ≤ s but max. 75 mm	h ≤ 0,3 a but max. 3 mm *l* ≤ a but max. 50 mm	h ≤ 0,2 s but max. 2 mm *l* ≤ s but max. 25 mm
		2016	– fillet welds	≥ 0,5	h ≤ 0,4 a but max. 4 mm *l* ≤ a but max. 75 mm	h ≤ 0,3 s but max. 3 mm *l* ≤ s but max. 50 mm	h ≤ 0,2 a but max. 2 mm *l* ≤ a but max. 25 mm
2.7	Shrinkage cavity	202	--	≥ 0,5	Short imperfections permitted, but not breaking of the surfaces – butt welds : h ≤ 0,4 s but max. 4 mm – fillet welds h ≤ 0,4 a but max. 4 mm	Not permitted	
2.8	Crater pipe	2024	 The larger value of h or *l* will be measured	0,5 to 3	h or *l* ≤ 0,2 t	Not permitted	
				> 3	h or *l* ≤ 0,2 t but max. 2 mm		
2.9	Solid inclusions Slag inclusions Flux inclusions Oxides inclusions	300 301 302 303	– butt welds	≥ 0,5	h ≤ 0,4 s but max. 4 mm *l* ≤ s but max. 75 mm	h ≤ 0,3 s but max. 3 mm *l* ≤ s but max. 50 mm	h ≤ 0,2 s but max. 2 mm *l* ≤ s but max. 25 mm
			– fillet welds	≥ 0,5	h ≤ 0,4 a but max. 4 mm *l* ≤ a but max. 75 mm	h ≤ 0,3 a but max. 3 mm *l* ≤ a but max. 50 mm	h ≤ 0,2 a but max. 2 mm *l* ≤ a but max. 25 mm
2.10	Metallic inclusion other than copper	304	– butt welds	≥ 0,5	h ≤ 0,4 s but max. 4 mm	h ≤ 0,3 s but max. 3 mm	h ≤ 0,2 s max. 2 mm
			– fillet welds	≥ 0,5	h ≤ 0,4 a but max. 4 mm	h ≤ 0,3 a but max. 3 mm	h ≤ 0,2 a but max. 2 mm
2.11	Copper inclusion	3042	--	≥ 0,5	Not permitted		
2.12	Lack of fusion (incomplete fusion)	401		≥ 0,5	Short imperfections permitted : – butt welds: h ≤ 0,4 s but max. 4 mm – fillet welds: h ≤ 0,4 a but max. 4 mm	Not permitted	
	Lack of side wall fusion	4011					
	Lack of interrun fusion	4012					
	Lack of root fusion	4013					

No.	Imperfection designation	Reference to ISO 6520-1	Remarks	t mm	Limit for imperfections for quality levels		
					D (low)	C (medium)	B (high)
2.13	Lack of penetration	402	 T-joint (fillet weld)	≥ 0,5	Short imperfections : h ≤ 0,2 a, but max. 2 mm	Not permitted	
			 T-joint (partial penetration)  Butt joint (partial penetration)	≥ 0,5	Short imperfections : – butt joint : h ≤ 0,2 s but max. 2 mm – T-joint : h ≤ 0,2 a but max. 2 mm	Short imperfections : – butt joint : h ≤ 0,1 s but max. 1,5 mm – T-joint : h ≤ 0,1 a but max. 1,5 mm	Not permitted
			 Butt joint (full penetration)	≥ 0,5	Short imperfections : h ≤ 0,2 t but max. 2 mm	Not permitted	
3. Imperfections in joint geometry							
3.1	Linear misalignment	507	The limits relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centerlines coincide. t refers to the smaller thickness	0,5 to 3	h ≤ 0,2 mm + 0,25 t	h ≤ 0,2 mm + 0,15 t	h ≤ 0,2 mm + 0,1 t
			 Figure A : Plates and longitudinal welds	> 3	h ≤ 0,25 t but max. 5 mm	h ≤ 0,15 t but max. 4 mm	h ≤ 0,1 t but max. 3 mm
			 Figure B : Circumferential welds	≥ 0,5	h ≤ 0,5 t but max. 4 mm	h ≤ 0,5 t but max. 3 mm	h ≤ 0,5 t but max. 2 mm

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Imperfection designation</th><th rowspan="2">Reference to ISO 6520-1</th><th rowspan="2">Remarks</th><th rowspan="2">t
mm</th><th colspan="3">Limit for imperfections for quality levels</th></tr>
<tr><th>D (low)</th><th>C (medium)</th><th>B (high)</th></tr>
<tr><td rowspan="2">3.2</td><td rowspan="2">Incorrect root gap for fillet welds</td><td rowspan="2">617</td><td rowspan="2">Gap between the parts to be joined. Gaps exceeding the appropriate limit may, in certain cases, be compensated for by a corresponding increase in the throat.
</td><td>0,5 to 3</td><td>h ≤ 0,5 mm + 0,1 a</td><td>h ≤ 0,2 mm + 0,1 a</td><td>h ≤ 0,3 mm + 0,1 a</td></tr>
<tr><td>> 3</td><td>h ≤ 1 t mm + 0,3 a
but max. 4 mm</td><td>h ≤ 0,5 t mm + 0,2 a
but max. 3 mm</td><td>h ≤ 0,5 t mm + 0,1 a
but max. 2 mm</td></tr>
<tr><td colspan="8">4 Multiple Imperfections</td></tr>
<tr><td rowspan="2">4.1</td><td rowspan="2">Multiple imperfection in any cross section</td><td rowspan="2">None</td><td rowspan="2">
$h_1 + h_2 + h_3 + h_4 + h_5 = \Sigma h$

$h_1 + h_2 + h_3 + h_4 + h_5 = \Sigma h$</td><td>0,5 to 3</td><td colspan="3">Not permitted</td></tr>
<tr><td>> 3</td><td>Maximum total height of imperfections Σh ≤ 0,4 t or ≤ 0,25 a</td><td>Maximum total height of imperfections Σh ≤ 0,3 t or ≤ 0,2 a</td><td>Maximum total height of imperfections Σh ≤ 0,2 t or ≤ 0,15 a</td></tr>
<tr><td>4.2</td><td>Projected or cross-sectional area in longitudinal direction</td><td>None</td><td>Case 1 ($D > l_3$)

$h_1 \times l_1 + h_2 \times l_2 + h_3 \times l_3 = \Sigma h \times l$
Case 2 ($D < l_3$)

$h_1 \times l_1 + h_2 \times l_2 + \left(\frac{h_2 + h_3}{2}\right) \times D + h_3 \times l_3 = \Sigma h \times l$
The sum of the areas $\Sigma h \times l$ shall be calculated as a percentage to the evaluation area $l_p \times w_p$ (case 1)</td><td>≥ 0,5</td><td>$\Sigma h \times l \leq 16\%$</td><td>$\Sigma h \times l \leq 8\%$</td><td>$\Sigma h \times l \leq 4\%$</td></tr>
</table>

No.	Imperfection designation	Reference to ISO 6520-1	Remarks	t mm	Limit for imperfections for quality levels		
					D (low)	C (medium)	B (high)
			If D is smaller than the shorter length of one of the neighbouring imperfections, the full connection of the two imperfection shall be applied to the sum of imperfection (case 2)				

Additional information and guidelines for the application of this table.

This table, taken from the international standards ISO 5817 specifies the requirements for three classification levels of acceptance for imperfections in all types of steel for arc welding processes in accordance with the field of application and for weld thicknesses above 0,5 mm. It may also be used for other fusion welding processes or weld thicknesses, if applicable.

The table may be used in connection with the IIW catalogue ISO 5817 with realistic illustrations; they show the size of the permitted imperfections of the various classification levels by means of photos of the upper and the root sides and/or reproductions of radiograph and photos of macrographs of weld cross sections. The catalogue and the references cards may be used to assess imperfections and when opinions regarding the permitted size deviate from each other.

Symbols

The following symbols are used in the table :

- *A* area surrounding the gas pores
- *a* nominal throat thickness of the fillet weld (see also ISO 2553)
- *b* width of weld reinforcement
- *d* diameter of gas pore
- d_A diameter of area surrounding the gas pores
- *h* height or width of imperfection
- *l* length of imperfection in longitudinal direction of the weld
- *lp* length of projected or cross-sectional area
- *s* nominal butt weld thickness (see also ISO 2553)
- *t* wall or plate thickness (nominal size)
- w_p width of the weld or width or height of the cross-sectional area.
- *z* leg length of a fillet weld (see also ISO 2553)
- α angle of weld toe
- β angle of angular misalignment

Short imperfection:

One or more imperfections of total length not greater than 25 mm in any 100 mm length of the weld or a maximum of 25% of the weld length for a weld shorter than 100 mm.

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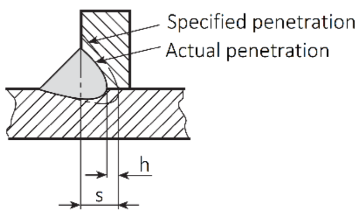
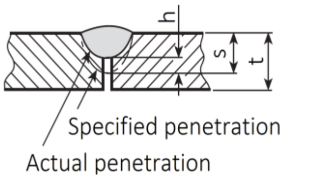
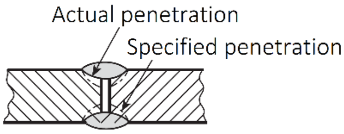
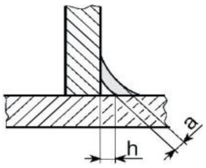
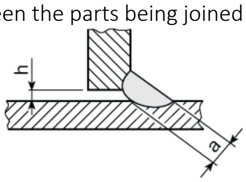
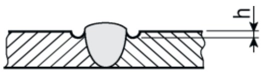
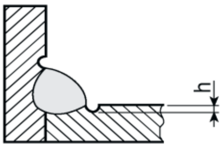
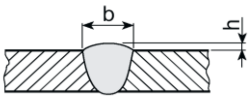
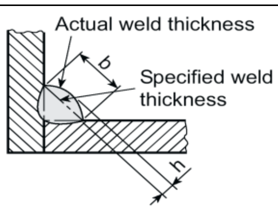
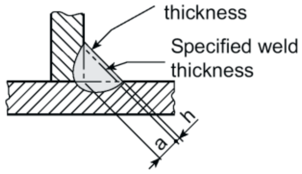
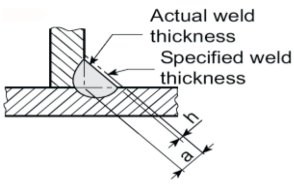
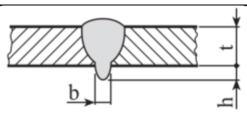
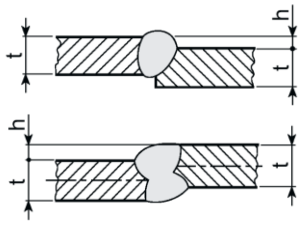
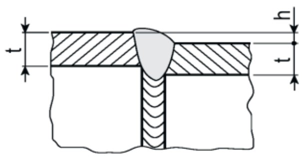
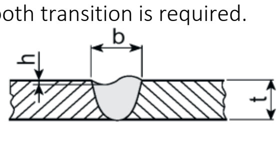
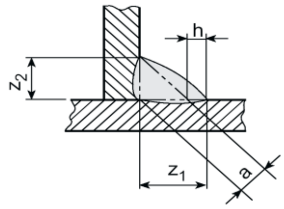
Annex G Imperfections in Welded Joints in Aluminium

Limits for Imperfections in welded joints in aluminium (alloys) in accordance with the International standards ISO 10042

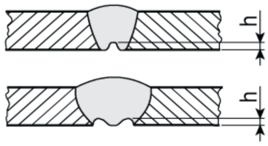
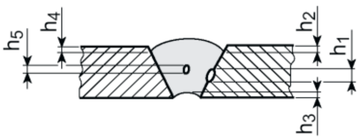
No.	Description of Imperfections	Ref. No. In acc. with ISO 6520	Remarks	Limit for imperfections for quality levels: low D	medium C	high B
1	Cracks	100	All types of cracks except micro cracks ($h \cdot l < 1\ mm^2$), crater cracks, see No. 2	not permitted		
2	End Crater crack	104		$h \le 0,2\ s$ or $0,2\ a$	Not permitted.	
3	Gas inclusion	201	The term "gas inclusion" encompasses porosity, cluster of pores and pores. The entire pore area within a cluster should be included: an envelope curve that encompasses all the pores or a circle with a diameter that matches that of the width of the weld. The permitted pore area should be localized. The possibility that other imperfections are concealed should be allowed for.	per 100 mm length: $A \le 8\ s$ or $8\ a\ mm^2$	$A \le 4\ s$ or $4\ a\ mm^2$	$A \le 2\ s$ or $2\ a\ mm^2$
4	Pore	2011		$d \le 0,5\ s$ or $0,5\ a\ mm^2$ max. 5,5 mm	$d \le 0,3\ s$ or $0,3\ a\ mm^2$ max. 4,5 mm	$d \le 0,25\ s$ or $0,25\ a\ mm^2$ max. 3,5 mm
5	Porosity	2012		$d \le 0,5\ s +$ $0,035\ s$ or $0,035\ a$ max. 2 mm	$d \le 0,5\ s +$ $0,02\ s$ or $0,02\ a$ max. 1,5 mm	$d \le 0,5\ s +$ $0,01\ s$ or $0,01\ a$ max. 1 mm
6	Cluster of pores	2013		$d \le 0,5\ s +$ $0,05\ s$ or $0,05\ a$ max. 3 mm	$d \le 0,5\ s +$ $0,035\ s$ or $0,035\ a$ max. 2 mm	$d \le 0,5\ s +$ $0,02\ s$ or $0,02\ a$ max. 1,5 mm
7	Surface pore	2017		per 100 mm length $A \le 2\ t\ mm^2$ $d \le 0,5\ mm +$ $0,035\ s$ or $0,035\ a$ max. 2 mm	$A \le 1\ t\ mm^2$ $d \le 0,5\ mm +$ $0,02\ s$ or $0,02\ a$ max. 1,5 mm	$A \le 0,5\ t\ mm^2$ $d \le 0,5\ mm +$ $0,01\ s$ or $0,01\ a$ max. 1 mm
8	Solid inclusions (other than copper and tungsten)	300	Solid inclusions include oxide inclusions. If several inclusions h_1, h_2, h_3 .... are present in a section, the sum is $\Sigma h = h_1 + h_2 + h_3$	Long imperfections: not permitted Short imperfections: $\Sigma h \le 0,1\ s$ or $0,1\ a$ max. 3 mm	max. 1,5 mm	not permitted
9	Tungsten inclusions	3041		$h \le 0,1\ s$ or $0,1\ a$ max. 3 mm	max. 1,5 mm	$h \le 0,05\ s$ or $0,05\ a$ max. 0,8 mm
10	Copper inclusions	3042		not permitted		
11	Lack of fusion	401	Where there are several instances of lack of fusion h1, h2, h3 .... the sum is Σh = h1 + h2 + h3	Long imperfections: not permitted Short imperfections: $\Sigma h \le 0,1\ s$ or $0,1\ a$ max. 3 mm	max. 1,5 mm	not permitted
12	Incomplete penetration	402	 **Fig. A**	A small number permitted, but not a regular occurance		not permitted

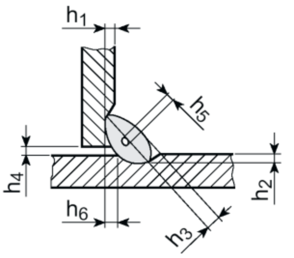
No.	Description of Imperfections	Ref. No. In acc. with ISO 6520	Remarks	Limit for imperfections for quality levels		
				low D	medium C	high B
			 **Fig. B**  **Fig. C**	h ≤ 0,4 s max. 3 mm	h ≤ 0,2 s max. 2 mm	
12.1	Incomplete penetration (fillet welds)	—		Long imperfections : not permitted Short imperfections :		
				h ≤ 0,3 a max. 2 mm	h ≤ 0,2 a max. 1,5 mm	h ≤ 0,1 a max. 1 mm
13	Poor fit-up, fillet welds	–	An excessive or insufficient gap between the parts being joined  Gaps in excess of the relevant limit may be compensated by a correspondingly larger throat thickness.	h ≤ 1 mm + 0,2 a, max. 4 mm	h ≤ 0,5 mm + 0,15 a, max. 3 mm	h ≤ 0,5 mm + 0,1 a, max. 2 mm
14	Undercut	5011 5012	Smooth transition in required.  	Long imperfections : h ≤ 0,6 mm Short imperfections : h ≤ 1,5 mm	h ≤ 0,4 mm h ≤ 1 mm	h ≤ 0,2 mm h ≤ 0,5 mm
				Long and short imperfections : Not more than 10 % of the plate thickness in the case of undercuts vertical to the main direction of load.		
15	Excessive weld reinforcement	502	Smooth transition is required. 	h ≤ 1,5 mm + 0,2 b, max. 10 mm	h ≤ 1,5 mm + 0,15 b, max. 7 mm	h ≤ 1,5 mm + 0,1 b, max. 5 mm
16	Excessive convexity	503		h ≤ 1,5 mm + 0,3 b, max. 5 mm	h ≤ 1,5 mm + 0,15 b, max. 4 mm	h ≤ 1,5 mm + 0,1 b, max. 3 mm

No.	Description of Imperfections	Ref. No. In acc. with ISO 6520	Remarks	Limit for imperfections for quality levels		
				low D	medium C	high B
17	Excessive weld thickness (fillet weld)	—	For many applications, a weld thickness in exceeds of the specified size does not represent grounds for rejection 	h ≤ 1 mm + 0,3 a, max. 7 mm	h ≤ 1 mm + 0,2 a, max. 6 mm	h ≤ 1 mm + 0,15 a, max. 5 mm
18	Reduced weld thickness (fillet weld)	—	A fillet weld with an obviously smaller weld thickness should not be regarded as a defect provided that the actual weld thickness is compensated by a deeper penetration and by so doing achieving the specified size. 	Long imperfections: not permitted		
				Short imperfections:		
				h ≤ 0,3 a, max. 2 mm	h ≤ 0,2 a, max. 1,5 mm	h ≤ 0,1 a, max. 1 mm
19	Excessive root reinforcement	504		h ≤ 5 mm	h ≤ 4 mm	h ≤ 3 mm
20	Misalignment of edges	507	The deviation limits relate to the correct position. Unless otherwise specified, the correct position is when the center lines coincide. t relates to the smaller thickness  Fig. A - Plates and longitudinal welds	h ≤ 0,5 mm + 0,25 t, max. 4 mm	h ≤ 0,5 mm + 0,15 t, max. 3 mm	h ≤ 0,5 mm + 0,1 t, max. 2,5 mm
			 Fig. B - Circumferential welds	h ≤ 0,5 t		
				max. 4 mm	max. 3 mm	max. 2,5 mm
21	Incompletely filled groove	511	Smooth transition is required. 	Long imperfections: not permitted		
				Short imperfections:		
				h ≤ 0,2 t, max. 2 mm	h ≤ 0,1 t, max. 1,5 mm	h ≤ 0,05 t, max. 1 mm

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Description of Imperfections</th><th rowspan="2">Ref. No. In acc. with ISO 6520</th><th rowspan="2">Remarks</th><th colspan="3">Limit for imperfections for quality levels</th></tr>
<tr><th>low
D</th><th>medium
C</th><th>high
B</th></tr>
<tr><td>22</td><td>Excessively unequal leg lengths of fillet weld</td><td>512</td><td>It is assumed that an asymmetrical fillet weld has not been expressly prescribed

</td><td>h ≤ 3 mm + 0,3 a</td><td>h ≤ 2 mm + 0,25 a</td><td>h ≤ 1,5 mm + 0,2 a</td></tr>
<tr><td rowspan="2">23</td><td rowspan="2">Root concavity

Root notch</td><td rowspan="2">515

5013</td><td rowspan="2">Smooth transition is required

</td><td colspan="3">Long imperfections:
not permitted</td></tr>
<tr><td>Short imperfections:
h ≤ 0,2 t
max. 2 mm</td><td>h ≤ 0,1 t
max. 1,5 mm</td><td>h ≤ 0,05 t
max. 1 mm</td></tr>
<tr><td rowspan="2">24</td><td rowspan="2">Multiple Imperfections in the section</td><td rowspan="2">—</td><td rowspan="2">For thickness s ≤ 10 mm or a ≤ 10 mm special parameters may be necessary


$h_1 + h_2 + h_3 + h_4 + h_5 \leq \Sigma h$


$h_1 + h_2 + h_3 + h_4 + h_5 + h_6 \leq \Sigma h$</td><td colspan="3">Maximum size of short imperfections Σ h</td></tr>
<tr><td>0,3 s or 0,3 a,
max. 10 mm</td><td>0,25 s or 0,25 a,
max. 10 mm</td><td>0,2 s or 0,2 a,
max. 10 mm</td></tr>
</table>

Additional information and guidelines for the application of this table.

This table, taken from the international standards EN 30042 resp. ISO 10042 specifies the requirements for three levels of acceptance for imperfections in joints of aluminium and it's weldable alloys and for thicknesses from 3 to 63 mm. It may be used, where applicable, for other fusion welding processes or weld thicknesses.

No. 24 shows multiple imperfections, a theoretically possible accumulation of individual imperfections. In this case, the total of all permitted deviations for the determined figures of the several classification levels should be reduced. However, the value for a single imperfection ≥ h, e.g. for a single pore, should not be exceeded.

The requirements given in this table should not treated as absolute limits but rather as limits that should not be exceeded with more than a defined probability. It should be noted that imperfections exceeding the size limits given are often present in a weld without impairing it's fitness-for-purpose.

The table may be used in conjunction with the IIW-Catalogue ISO 10042 which contained realistic illustrations. They show the size of the permissible imperfections for the various quality levels by means of photographs of the face and root side and/or reproductions of radiographs and of photos of macrographs of the cross sections of the welds. The catalogue and it's references cards may be used to assess the various imperfections and may be employed when opinions differ as to permissible size of imperfections.

Symbols The following symbols are used in the table : *A* area of gas cavity *a* nominal fillet weld throat thickness (fillet thickness) *b* width of weld reinforcement *d* diameter of pore *h* size (height or weight) of imperfection *l* length of imperfection *s* nominal butt weld thickness or, in the case of partial penetration, the prescribed depth of penetration *t* wall or plate thickness *z* nominal leg length of fillet welds (in case of isosceles right angle triangle section $z = a\sqrt{2}$	Short imperfection: One or more imperfections of total length not greater than 25 mm in any 100 mm length of the weld or a maximum of 25% of the weld length for a weld shorter than 100 mm. Long imperfection: One or more imperfections of total length greater than 25 mm in any 100 mm length of the weld or a minimum of 25% of the weld length for a weld shorter than 100 mm.

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Annex H Comparison of Equivalent, Internationally Recognized Film System Classes

Manufacturer / Film type	ASTM (1)	DIN (4)	EN (4)	ISO (2)	RCC-M (5)	BS (3)
AGFA (6)						
Structurix D2	special	G1	C1	G I	1	A
Structurix D3	1	G1	C2	G I	1	A
Structurix D3 s.c.	1	G1	C2	G I	2	A
Structurix D4	1	G2	C3	G I	3	A
Structurix D5	1	G2	C4	G II	3 – 4	A
Structurix D7	2	G3	C5	G III	4	B
Structurix D8	2	G4	C6	G III	5	B
Fuji (6)						
IX 25	1	G2	C3	G I	3	A
IX 50	special	G1	C1	G I	1	A
IX 80	1	G2	C3	G I	3	A
IX 100	1	G2	C4	G II	3 – 4	A
IX 150	2	G4	C6	G III	4 – 5	B
Kodak (6)						
DR	special	G1	C1	G I		
M	1	G1	C2	G I		
MX125	1	G2	C3	G I		
T200	1	G2	C4	G II		
AA400	2	G3	C5	G III		
CX	3	G4	C6	G III		
B	W-B			G III		

(1) ASTM E 94-93 / ASTM E 94-84 A
(2) ISO 5579
(3) BS 2600: Type A: high contrast – very fine-grain
Type B: high contrast – fine grain
(4) Classification in accordance with DIN EN 584-1 as compared with DIN 54117 T1 which has been replaced.
(5) French standard
(6) Provided that the appropriate proof of suitability is furnished, equivalent film types produced by other film manufacturers may also be considered.

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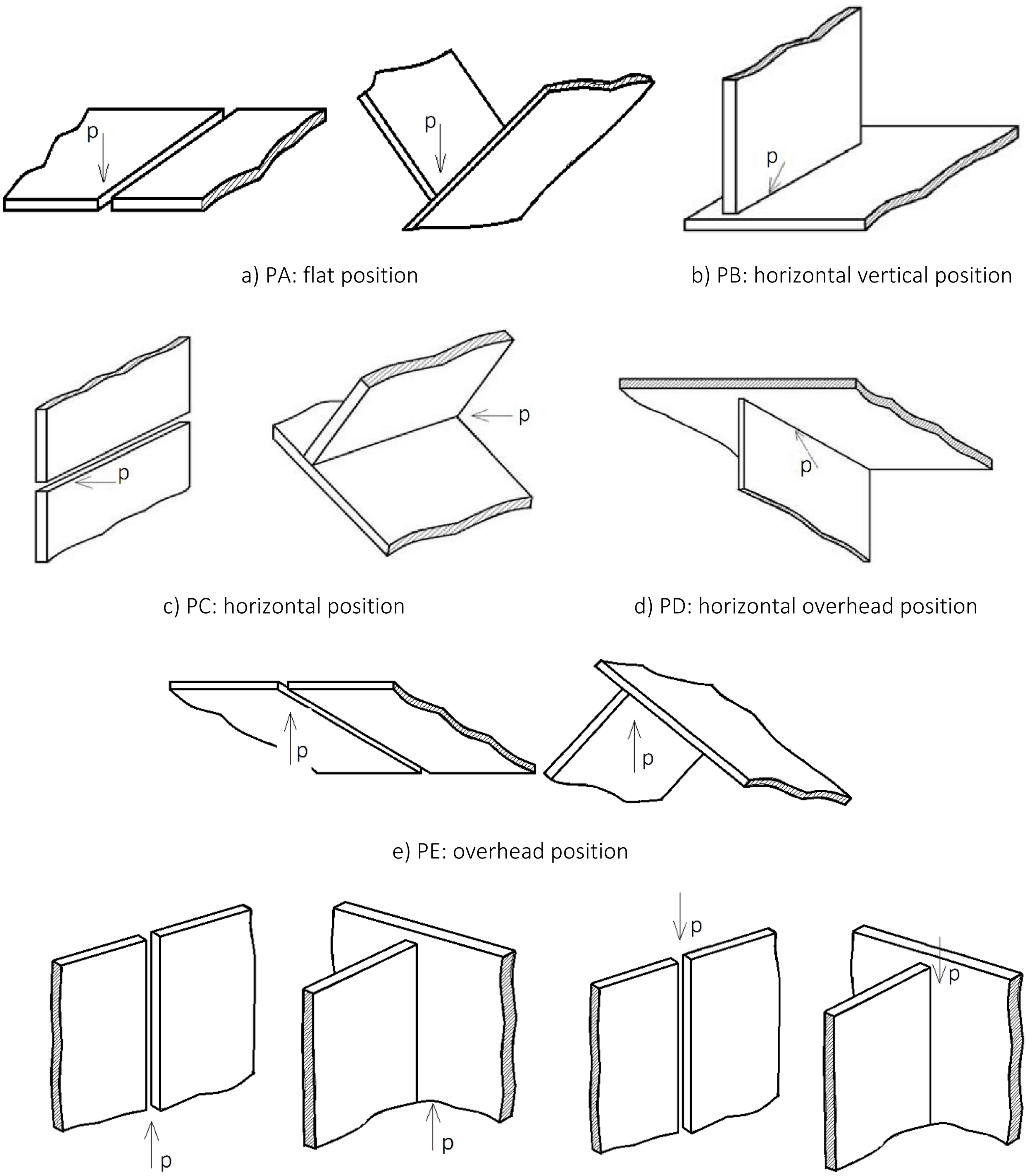
Annex I Welding Positions and Comparison

Welding Positions Symbol	Description	Comparison
PA (d)	Plate: flat L-Pipe: rotating; axis: horizontal, inclined; weld: flat	1G, 1F
PB (h)	Plate: horizontal vertical L-Pipe: rotating; axis: horizontal; weld: horizontal vertical L-Pipe: fixed; axis: horizontal; weld: horizontal vertical	2F
PC (h-v)	Plate: horizontal L-Pipe: fixed; axis: vertical; weld: horizontal	2G
PD (h-o)	Plate: horizontal overhead L-Pipe: fixed; axis: vertical; weld: horizontal overhead	4F
PE (o)	Plate: overhead	4G
PF (v-u)	Plate: vertical upward L-Pipe: fixed; axis: horizontal; weld: vertical upwards	3G, 3F 5G, 5F
PG (v-d)	Plate: vertical downward L-Pipe: fixed; axis: horizontal; weld: vertical downwards	3G (v-d), 3F (v-d) 5G (v-d), 5F (v-d)
H-L045	Pipe: fixed; axis: inclined; weld: upwards	6G
J-L045	Pipe: fixed; axis: inclined; weld: vertical downwards	6G (v-d)



a) PA: flat position

b) PB: horizontal vertical position

c) PC: horizontal position

d) PD: horizontal overhead position

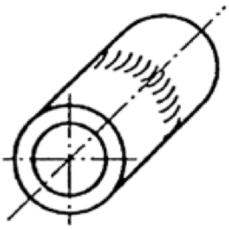
e) PE: overhead position

f) PF: vertical up position

g) PG: vertical down position

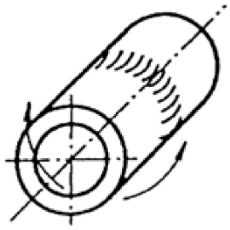
Fig. I-1 Welding positions for plates

PA (d)



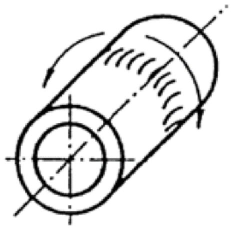
Pipe : rotating
Axis : horizontal
Weld : flat

PF (v-u)



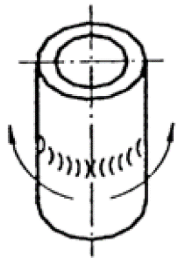
Pipe : fixed
Axis : horizontal
Weld : vertical upwards

PG (v-d)



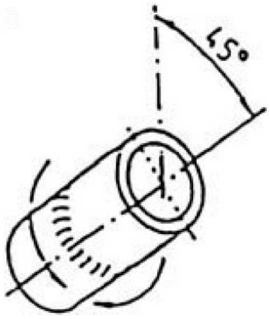
Pipe : fixed
Axis : horizontal
Weld : vertical downwards

PC (h-v)



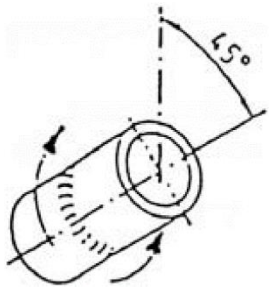
Pipe : fixed
Axis : vertical
Weld : horizontal

J-L045



Pipe : fixed
Axis : inclined
Weld : vertical downward

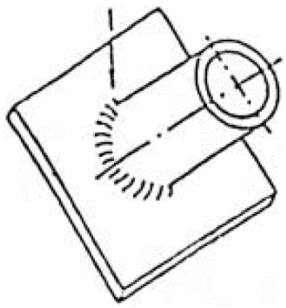
H-L045



Pipe : fixed
Axis : inclined
Weld : upward

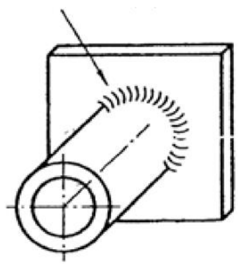
a) Butt welds

PA (d)



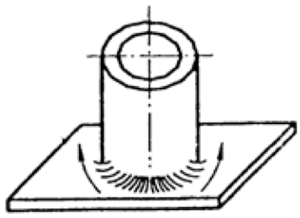
Pipe : rotating
Axis : inclined
Weld : flat

PB (h)



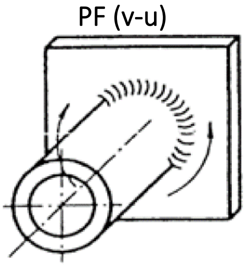
Pipe : rotating
Axis : horizontal
Weld : horizontal vertical

PB (h)



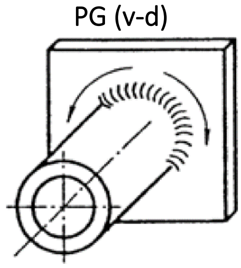
Pipe : fixed
Axis : vertical
Weld : horizontal vertical

PF (v-u)



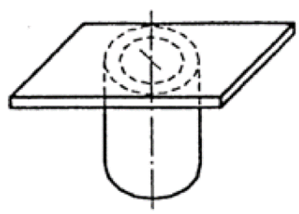
Pipe : fixed
Axis : horizontal
Weld : vertical upwards

PG (v-d)



Pipe : fixed
Axis : horizontal
Weld : vertical downwards

PD (h-o)



Pipe : fixed
Axis : vertical
Weld : horizontal overhead

b) Fillet welds

Fig. I-2 Welding positions for pipes

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