RULES
FOR THE CLASSIFICATION OF SHIPS

Part 26 - WELDING

July 2019
By decision of the General Committee of Croatian Register of Shipping,

RULES FOR THE CLASSIFICATION OF SHIPS
PART 26 – Welding

have been adopted on 17th June 2019 and shall enter into force on 1st July 2019
REVIEW OF MODIFICATIONS AND ADDITIONS IN RELATION TO 2017 EDITION

RULES FOR THE CLASSIFICATION OF SHIPS
Part 26. - Welding

All major changes in respect to 2017 edition throughout the text are shaded.

The grammatical and print errors, have been corrected throughout the subject chapter of the Rules and are not subject to above indication of changes.
The subject Rules include the requirements of the following international Organisations:

**International Association of Classification Societies (IACS)**

Unified Requirements (UR):

- W17 (rev.5, 2018)
- W23 (rev.2, 2018)
- W26 (rev.1, 2005)
- W28 (Rev.2, 2012)
- W32 (2016)

Unified Recommendations:

- No. 17 (1987)
- No. 20 (rev.1, 2007)
- No. 70 (rev.1, 2006)

**International Standard Organization (ISO):**

- European Norm (EN):
  -

**European Norm with status of Croatian Norm:**

## RULES FOR THE CLASSIFICATION OF SHIPS

### PART 26

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1 GENERAL REQUIREMENTS, PROOF OF QUALIFICATIONS, APPROVALS

1.1 GENERAL REQUIREMENTS

1.1.1 General

1.1.1.1 The present Part of the Rules (hereinafter referred to as: the Rules) applies to all welding operations performed in the course of new constructions, conversion or repair:

1. ship hull, superstructure, deck houses;
2. equipment and gear;
3. machinery and machinery installation;
4. steam boilers and pressure vessels;
5. piping;

when they are subject to the technical supervision by the CROATIAN REGISTER OF SHIPPING (hereinafter referred to as: the Register).

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. The nature and scope of the quality assurance measures required will be specified by the Register on a case-by-case basis.

1.1.1.2 The present Part of the Rules applies to all welding works on machinery, installations and equipment for which the Register has issued the Rules, guidelines or other technical directions where reference is made to this Rules.

1.1.1.3 The present Part of the Rules shall be applied analogously where other Rules, guidelines or directions issued by the Register contain no special instructions with regard to welding works.

1.1.1.4 The present Part of the Rules may be applied analogously to other welding works, other than those referred to in 1.1.1., if they are subject to the supervision of the Register. Where necessary, these cases shall be considered by the Register in each particular case.

1.1.1.5 Exceptions to the present Part of the Rules shall be agreed with the Register in each particular case.

1.1.1.6 The Register reserves the right to make amendments of the present Part of the Rules, should this prove necessary on the basis of more recent knowledge or operating experience.

Other Rules, Standards and Specifications

1.1.2 The Standards and Instructions mentioned in the following Chapters of this Part of the Rules form an integral part of it. The same applies to the working documents (e.g. drawings, welding specifications, etc.) approved by the Register.

1.1.2.2 The application of other Rules, standards, guidelines or other technical instructions shall be agreed with the Register in each particular case.

1.1.2.3 If there are differences in requirements between this Part of the Rules and the other relevant standards or specifications, the requirements of this Part of the Rules shall be applied, unless otherwise agreed.

1.1.3 Technical documentation

1.1.3.1 Technical documentation for welding which shall be submitted to the Register for approval, prior to commencement of fabrication, shall contain all necessary details for the preparation, execution and where applicable, the inspection of the welds.

This information shall, as a rule, cover the following:

a) base materials, shapes and dimensions of products;
b) welding process and welding consumables;
c) shapes and dimensions of welds;
d) preheating and heat input during welding;
e) heat treatment after welding;
f) subsequent treatment of the welds;
g) methods and scope of inspection;
h) requirements applicable to the welded joints
i) (e.g. quality, evaluation category and similar)

1.1.3.2 When during the manufacture of ships structures, materials, welding processes, welding consumables, shapes and dimensions of welds, comply with the normal shipbuilding practice the details referred to in 1.1.3.1. need not be particularly specified.

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

j) weld preparation, assembly and auxiliary (tack) welds:
   a) welding positions, welding sequence (sketches);
   b) weld build-up (build-up of joint) number of passes;
   c) heat input during welding (heat input per unit of weld length)

1.1.4 Materials, Weldability

1.1.4.1 All materials shall be chosen in accordance with the intended application and conditions of service and shall comply with the Rules, Part 25 - Metallic Materials. Their properties shall be documented to the specified extent by test certificates (e.g. in compliance with HRN EN 10204).

1.1.4.2 If according to 1.1.4.1., materials to be welded and their properties are not specified in the Rules, Part 25 - Metallic Materials, the welding shop shall prove their weldability (e.g. with respect to existing standards) or shall submit
the material specifications for approval. Where there is any doubt to the weldability of material, the welding shop shall specially demonstrate it in the welding procedure tests.

1.1.4.3 The welding shop shall ensure that only materials referred to in 1.1.4.1. and 1.1.4.2 are used and shall provide proof thereof at the Surveyors request.

1.1.5 Welding Consumables

1.1.5.1 Welding consumables shall enable a welded joint to be appropriate to the base material and service conditions. They shall be tested in compliance with the chapter 1.5 and shall be approved for the respective application. This provision applies in analogous manner to brazing materials.

1.1.5.2 Approval shall be given, as a rule, by the Register. When, in special cases, e.g. repairs, no welding consumables are approved by the Register, welding consumables approved by the other recognized testing bodies may be used in agreement with the Register.

1.1.5.3 The welding shop supervisor shall ensure that only tested welding consumables approved by the Register are used and at the Surveyors request the proof thereof shall be provided.

1.1.6 Quality Assurance, Responsibility

1.1.6.1 The welding shop is responsible for ensuring that the manufacturing conditions and quality comply to those at the time of approval as well as to the requirements of the Rules and, where applicable, that the conditions stated in approvals and supplementary Rules shall be complied with. The shop shall also ensure through regular inspections and tests that the required quality is achieved. The responsibilities of the welding supervisors are also covered in EN ISO 14731. The tests carried out by a Surveyor to the Register shall not relieve the welding shop from this responsibility.

The range and extent of the quality inspections required is determined by the structure in question.

1.1.6.2 When the delivery is carried out by subcontractors, the welding shop shall be responsible for ensuring that the conditions of the present part of the Rules are complied with by the subcontractors.

1.1.6.3 If alterations of the approved documentation or deviations from approved manufacture procedure become necessary, the welding shop shall apply for the Surveyors consent thereto. The Surveyor shall notify any alterations during fabrication.

1.1.6.4 The materials shall be marked in such a way that they can be identified and matched up with the test certificate during and after manufacture.

1.1.6.5 If the marking is likely to be erased during manufacture, the welding shop shall promptly transfer the mark to another part of the product.

1.1.6.6 In the manufacture of steam boilers and pressure vessels, each weld joint shall be marked with the welders symbol. This requirement may be dispensed with if the welding shop supervisory staff keep a record of the welders names who execute the individual weld joint.

1.1.7 Inspection, liability

1.1.7.1 The welding shop is liable to present all components of the required intermediate and final inspections to the Surveyor. All welded joint shall be easily accessible for inspection. Welded joints shall not be tested with coatings or protected so as to make it difficult or impossible to inspect the weld in concern.

1.1.7.2 All the manufacturers records and documents regarding the quality assurance shall be submitted to the Register for inspection.

These shall cover in particular:
- drawings and other working documents;
- material test certificates;
- welders and welding procedure test certificates;
- test reports and relevant documents (radiographs, ultrasonographs) of non-destructive tests;
- certificates on hot-forming and heat treatment (where applicable);
- production test results, intermediate results (if necessary).

1.1.7.3 The Register shall give no guarantees that welded structures or components tested by its surveyor fully comply with the requirements and that their manufacture has been performed correctly and in accordance with the tested procedure. Products which prove defective in service or in operation may be rejected even if an earlier inspection was satisfactory, if the defect or deficiency cannot be rectified.

1.2 REQUIREMENTS FOR APPROVAL OF WELDING SHOPS AND SHIYARDS FOR PERFORMING OF WELDING WORKS

1.2.1 Approval

1.2.1.1 Shipyards and welding shops including their branches and subcontractors (hereinafter organizations) which perform welding works on structures referred to in 1.1.1., shall be approved for these works by the Register.

The preconditions for this approval are that the organization satisfy the requirements stated in 1.2.2, that they are inspected by the Register in accordance with 1.2.3 and, where necessary, that the welding procedure tests are carried out in accordance with 1.2.4.

Any approval in accordance with 1.2.1.1 covers the most essential welding quality requirements in accordance with the standards HRN EN ISO 3834. For certification under the terms of these standards, the requirements set out in 1.2.2 and 1.2.3 must be also met. These additional requirements shall be regarded as having been met when the organization has in place a certified quality assurance system in accordance with standard HRN EN ISO 9001.

In special cases, a welding shop may be approved for performing welding works within the restricted area of activity, under the special procedure, previously approved by the Register.
1.2.1.2 The application for approval shall be submitted in writing to the Register. The application shall contain the following data relating to the approval:
   – nature and structure of components;
   – categories and dimensions of the materials used;
   – welding procedures and positions;
   – heat treatments (where necessary);
   – pressure vessel class (for boilers and pressure vessels).

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

1.2.1.4 Application for approval (the form is specified in Appendix I of the present Rules) submitted to the Register shall contain the following documentation:
   – a description of organization (the form is specified in Appendix II of the present Rules);
   – copies of the qualification documents of the welding supervisors;
   – copies of the welders certificate or the list of the qualified welders (testing standard, testing body, date of testing, test category, date of the last re-test) signed by a Surveyor;
   – copies of the welding procedure certificates.

1.2.1.5 For certification in accordance with 1.2.1.3, information and documents relating to the elements specified in Appendix I to HRN EN ISO 3834-1 for the respective grade of requirement (HRN EN ISO 3834-2 = comprehensive, -3 = standard, or -4 = elementary quality requirements) must 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 organization operates a certified quality system conforming to the standard HRN EN ISO 9001, the Quality Manual (and if specified in Appendix I to HRN EN ISO 3834-1) documentation relating to the quality assurance measures performed (quality reports) must be submitted to the Register for inspection in place (of the above information and documents).

1.2.1.6 An approval granted according to these Rules or certification in accordance with HRN EN ISO 3834 shall be valid for three (3) years. If the welding works are constantly performed under the supervision of the Register, the validity may be extended, at request of the organization, for next three years, without subsequent examination.

When welding works are being performed without the Register’s supervision for more than one year, the validity of the Approval Certificate may be extended for a period of three years, after the repeated supervision of the organization.

1.2.1.7 If the conditions under which the approval was granted, changed (e.g. the use of unqualified welding procedures, materials or welding consumables, or if the organization supervisory staff has changed), the organization shall duly notify the Register.

If the organization does not stick to the conditions under which the approval was granted to it, the approval shall cease to be valid. Also in case that serious defects are detected, the Register may carry out interim inspection and if necessary, may withdraw the approval.

1.2.2 Requirements

1.2.2.1 Organization shall have at its disposal suitable workshops, equipment and machinery to the extent necessary for proper performance of welding works. This includes, for example, suitable storage facilities and baking equipment for the welding consumables, preheating and heat treatment equipment and means for weather protection of welding work in the open air. Equipment and facilities which do not belong to the organization may be taken into account when evaluating the capabilities of the organization provided that the conditions necessary for the proper manufacture are complied with and that such equipment is available without restrictions.

1.2.2.2 Organization shall have at least one fully qualified welding supervisor who is responsible for ensuring of performing quality welding works.

Welding supervisor shall have experience appropriate to the scope of the manufacture works and shall provide necessary documentary proof to the Register.

With respect to the nature and work extent, the following persons shall be appointed as welding supervisors:
   – 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 technicians ² for fabrication of simpler or less heavily stressed components.

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

The welding supervisor shall be permanently employed with the organization. Supervisions on the welding works by outside staff is not acceptable.

1.2.2.3 Organization shall be staffed with qualified welders and for automatic welding with adequately trained operators. The required number of qualified welders shall be

¹ welding engineers (IWE, IWT, IWS) in the recommendations of the International Institute of Welding (IIW) / European Welding Federation (EWF) or engineers with an equivalent level of knowledge.

² welding technicians (IWT, IWS) as defined in the recommendations of the International Institute of Welding (IIW) / European Welding Federation (EWF) or, if necessary, other persons with suitable knowledge.
determined by the size of organization and the scope of welding works performed under supervision of the Register. However, a minimum of two qualified welders are required, for each welding process. Welders for manual and semi-automatic welding shall be tested in accordance with the Chapter 1.3.

The welding of a test piece in a successfully completed welding procedure may be taken as a proof of manual skill for testing of welder qualification.

Operators of fully mechanised or automatic welding equipment shall be trained in the use of the equipment and be capable of setting and operating the equipment in such a way that the required weld quality is achieved. The qualification of the operators must be demonstrated in accordance with HRN EN ISO 14732, on welded test pieces, e.g. in welding procedure or fabrication test.

1.2.3 Inspection

1.2.3.1 Before starting the manufacture, a Surveyor shall inspect organization in compliance with the requirements of 1.2.2.

1.2.3.2 The inspection of organization shall include all documentation necessary for evaluation of quality assurance which shall be submitted to a Surveyor. These especially include the welding supervisors qualification documents, welders certificates, reports on previous welding procedure tests as well as the results of the previous tests of welded joints.

For certification according to HRN EN ISO 3834, compliance with the additional quality requirements stated in the standards shall be demonstrated to the Surveyor.

1.2.3.3 Inspection procedure, reporting and decision of issuance Approval Certificate is to be in accordance with the Rules for the classification of Ships, Part 1, Chapter 4.

1.2.4 Welding Procedure Tests

1.2.4.1 If welding procedure tests are required they shall be carried out before the approval of organization or extension of the approval validity. Requirements for the performance of these tests and requirements applicable to test results are given in Chapter 1.4. Welding procedure tests shall be performed in such a way that the conditions of manufacture are covered with regard to materials, welding procedures, welding consumables, wall thickness, shapes of welds and heat treatment. The properties of base material for test piece shall be documented by test certificate.

1.2.4.2 In general, a welding procedure test is valid only within the tolerances specified in the Approval Certificate and shall not be transferable from the organization where it has been performed to another organization. The Register may permit the exemption in case of a branch organization which is under the constant supervision of the main organization where the manufacture conditions are the same as well as the welding processes used. Welding procedure tests performed in the workshop are not valid at the same time for welding in the field. In such cases the welding procedure test shall be repeated in a whole or partly under field conditions as determined by the Register. The Register may desist from the repeated tests if the properties of the field welds are documented by the production tests.

1.2.4.3 Welding procedure tests performed under the supervision of other testing bodies may be accepted by the Register in a whole or partly at the organization request if they are acceptable on the basis of test results. In such cases, the complete test reports as well as the Approval Certificate issued by other testing body shall be submitted to the Register for evaluation.

1.2.5 Certificate on Approval; Certificate according to HRN EN ISO 3834

The Register shall issue Certificate on Approval for the organization to carry out welding works, provided the relevant requirements are satisfied in the tests. The Certificates on Approval shall be valid within the limits specified in the Certificates. Where proof has been furnished that the additional requirements listed in 1.2.1.5 according to HRN EN ISO 3834 have been met, the Register issued a certificate based on this in accordance with this standard.

If the previously issued Certificate on Approval has been replaced or amended, the data specified in the more recent Certificate shall be taken as valid. This applies specially to the range of application, e.g. for a specific welding processes.

1.3 QUALIFICATION TESTING AND CERTIFICATION OF WELDERS

1.3.1 General

1.3.1.1 Welders intended to be engaged in welding of hull structural steels shall be qualified in accordance with 1.3.2.

Welders intended to be engaged in welding on structures other than referred to in 1.1.1 shall be certified to a standard recognised by the Register, e.g. HRN EN ISO 9606 series, ASME Section IX, ANSI/AWS D1.1.

1.3.1.2 Qualification tests shall be carried out under supervision of the Register and in compliance with the requirements of this Chapter.

1.3.2 Qualification scheme for welders of hull structural steels

1.3.2.1 Scope

1.3.2.1.1 This section gives requirements for a qualification scheme for welders intended to be engaged in the fusion welding of steels as specified in Rules, Part 25 - Metallic Materials, Sections 3.2, 3.11, 3.12 and 3.4.2 for hull structures.

1.3.2.1.2 This qualification scheme does not cover welders engaged in oxy-acetylene welding.

1.3.2.1.3 This qualification scheme does not cover welding of pipes.
1.3.2.2 General

1.3.2.2.1 Those welders intended to be engaged in welding of hull structures in shipyards and manufacturers shall be tested and qualified in accordance with this scheme and issued with a qualification certificate endorsed by the Register.

1.3.2.2.2 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., must 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 the Register with reference to HRN EN ISO 14732.

1.3.2.2.3 These requirements are applicable to welding of hull structures both during new construction and the repair of ships.

1.3.2.2.4 The training of welders, control of their qualification and maintenance of their skills are the responsibility of shipyards and manufacturers. The Surveyor is to verify and be satisfied that the welders are appropriately qualified.

1.3.2.2.5 Welders or welding operators qualified in accordance with national or international welder qualification standards may also be engaged in welding of hull structures at the discretion of the Register provided that the qualification testing, range of approval and revalidation requirements are considered equivalent to these requirements.

1.3.2.3 Range of qualification of welders

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

- a) base metal
- b) welding consumables type
- c) welding process
- d) type of welded joint
- e) plate thickness
- f) welding position

1.3.2.3.2 Base metals for qualification of welders or welding operators are combined into one group with a specified minimum yield strength $R_{yH} \leq 460$ N/mm$^2$.

The welding of any one metal in this group covers qualification of the welder or welding operator for the welding of all other metals within this group.

1.3.2.3.3 For manual metal arc welding, qualification tests are required using basic, acid or rutile covered electrodes. The type of covered electrodes (basic, acid or rutile) included in the range of approval is left at the discretion of the Register.

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

1.3.2.3.4 The welding processes for welder's qualification are to be classified in Table 1.3.2.3.1 as,

- M - Manual welding
- S - Semi-automatic welding / Partly mechanized welding
- T - TIG welding

Each testing normally qualifies only for one welding process. A change of welding process requires a new qualification test.

1.3.2.3.5 The types of welded joint for welder's qualification are to be classified as shown in Table 1.3.2.3.2 in accordance with the qualification test.

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.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Welding process in actual welding works</th>
<th>HRN EN ISO 4063</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>Manual welding</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Partly mechanized welding</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>TIG welding</td>
<td></td>
</tr>
</tbody>
</table>

| | Metal arc welding (metal arc welding with covered electrode) | 111 |
| | Metal inert gas (MIG) welding | 131 |
| | Metal active gas (MAG) welding | 135, 138<sup>(1)</sup>, 136<sup>(2)</sup> |
| | Flux cored arc (FCA) welding | |
| | Tungsten inert gas (TIG) welding | 141 |

Note:
The Register may require separate qualification for solid wires, metal-cored wires and flux cored wires as follows:
(1) A change from MAG welding with solid wires (135) to that with metal cored wires (138), or vice versa is permitted.
(2) A change from a solid or metal cored wire (135/138) to a flux cored wire (136) or vice versa requires a new welder qualification test.
Table 1.3.2.3.2
Types of welded joint for welder’s qualification

<table>
<thead>
<tr>
<th>Type of welded joint used in the test assembly for the qualification test</th>
<th>Type of welded joint qualified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt weld</td>
<td></td>
</tr>
<tr>
<td>Single sided weld</td>
<td>With backing</td>
</tr>
<tr>
<td></td>
<td>Without backing</td>
</tr>
<tr>
<td>Double sided weld</td>
<td>With gouging</td>
</tr>
<tr>
<td></td>
<td>Without gouging</td>
</tr>
<tr>
<td>Fillet weld</td>
<td>-</td>
</tr>
</tbody>
</table>

1.3.2.3.6 For fillet welding, welders who passed the qualification tests for multi-layer technique welding can be deemed as qualified for single layer technique, but not vice versa.

1.3.2.3.7 The qualified plate thickness range arising from the welder qualification test plate thickness is shown in Table 1.3.2.3.3. The types of welded joint for welder’s qualification.

Table 1.3.2.3.3
Plate thicknesses for welder’s qualification

<table>
<thead>
<tr>
<th>Thickness of test assembly T (mm)</th>
<th>Qualified plate thickness range t (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T ≤ 3</td>
<td>T ≤ t ≤ 2T</td>
</tr>
<tr>
<td>3 ≤ T &lt; 12</td>
<td>3 ≤ t ≤ 2T</td>
</tr>
<tr>
<td>12 ≤ T</td>
<td>3 ≤ t</td>
</tr>
</tbody>
</table>

1.3.2.3.8 The welding positions qualified as a result of the actual welding position used in a satisfactory welder’s qualification test, are shown in Table 1.3.2.3.4 and Table 1.3.2.3.5. Diagrams showing the definitions of weld position used in Table 1.3.2.3.4 and Table 1.3.2.3.5 are shown in Figure 1.3.2.3.1.

The Register may require a qualification test with fillet welding for welders who are employed to perform fillet welding only. Welders engaged in welding of T joints with partial or full penetration are to be qualified for butt welding.

1.3.2.3.9 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 Figure 1.3.2.4.4 or Figure 1.3.2.4.5.

Table 1.3.2.3.4
Qualified welding positions when testing with butt welding

<table>
<thead>
<tr>
<th>Qualification test position with butt weld</th>
<th>Qualified welding positions in actual welding works</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt welds</td>
<td>Fillet welds</td>
</tr>
<tr>
<td>PA</td>
<td>PA</td>
</tr>
<tr>
<td>PC</td>
<td>PA, PC</td>
</tr>
<tr>
<td>PE</td>
<td>PA, PC, PE</td>
</tr>
<tr>
<td>PF</td>
<td>PA, PF</td>
</tr>
<tr>
<td>PG</td>
<td>PG</td>
</tr>
</tbody>
</table>

Table 1.3.2.3.5
Qualified welding positions when testing with fillet welding

<table>
<thead>
<tr>
<th>Qualification test position with fillet weld</th>
<th>Qualified welding positions in actual welding works</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillet welds</td>
<td></td>
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</table>
1.3.2.4 Qualification test

1.3.2.4.1 General

Welding of the test assemblies and testing of test specimens shall be witnessed by the Surveyor.

1.3.2.4.2 Test assemblies

1.3.2.4.2.1 Test assemblies for butt welds and for fillet welds are to be prepared as shown in Figure 1.3.2.4.1, Figure 1.3.2.4.2 and Figure 1.3.2.4.3 in each qualification test.

1.3.2.4.2.2 Test assemblies for butt tack welds and for fillet tack welds are to be prepared as shown in Figure 1.3.2.4.4 and Figure 1.3.2.4.5.
1.3.2.4.2.3 Testing materials and welding consumables shall conform to one of the following requirements or to be of equivalent grade approved by the Register.
   a) Testing materials
      - Hull structural steels specified in Rules, Part 25-Metallic materials, Section 3.2 Normal and higher strength structural steels,
      - Hull structural forged steels specified in Rules, Part 25-Metallic materials, Section 3.11 Hull and machinery steel forgings,
      - Hull structural cast steels specified in Rules, Part 25-Metallic materials, Section 3.12 Hull and machinery steel castings,
      - Hull structural steels with specified minimum yield point 460 N/mm² specified in Rules, Part 25-Metallic materials, Section 3.4.2 Application of YP47 steel plates,
   b) Welding consumables
      - Consumables for hull structural steels specified in Chapter 1.5.1.
      - Consumables for YP47 steels specified in Rules, Part 25-Metallic materials, paragraph 3.4.2.6.4.

1.3.2.4.2.4 The welder qualification test assembly is to be welded according to a welding procedure specification (WPS or pWPS) simulating the conditions in production, as far as practicable.

1.3.2.4.2.5 Root run and capping run need each to have a minimum of one stop and restart. The welders are allowed to remove minor imperfections only in the stop by grinding before restart welding.

Figure 1.3.2.4.1
Dimensions and types of test assembly for butt welds (T < 12 mm)
Figure 1.3.2.4.2
Dimensions and types of test assembly for butt welds (T ≥ 12 mm)

Figure 1.3.2.4.3
Dimensions and types of test assembly for fillet welds
1.3.2.4.3 Examination and test

1.3.2.4.3.1 The test assemblies specified in 1.3.2.4.2 shall be examined and tested as follows:

a) For butt welds
   - Visual examination
   - Bend test

b) For fillet welds
   - Visual examination
   - Fracture test

Note:
Radiographic test or fracture test may be carried out in lieu of bend test except the gasshielded welding processes with solid wire or metal cored wire.

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 the Register.

1.3.2.4.3.2 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, except for the following imperfection types for which level C applies;
   - Excess weld metal
   - Excess penetration
   - Excessive convexity
   - Excessive throat thickness

1.3.2.4.3.3 Bend test

Transverse bend test specimens are to be in accordance with the Rules, Part 25-Metallic materials, Chapter 2 Test specimens and mechanical testing procedures for material.

The mandrel diameter to thickness ratio (i.e. D/T) is to be that specified for welding consumable (Chapter 1.5.1 and the Rules, Part 25-Metallic materials, paragraph 3.4.2.6.4) approvals +1.

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 12mm 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.

The test specimens are to be bent through 180 degrees. After the test, the test specimens shall not reveal any open defects in any direction greater than 3mm. Defects appearing at the corners of a test specimen during testing should be investigated case by case.

1.3.2.4.3.4 Radiographic test

When radiographic testing is used for butt welds, imperfections detected shall be assessed in accordance with ISO 5817, level B.

1.3.2.4.3.5 Fracture test (Butt welds)

When fracture test is used for butt welds, full test specimen in length is to be tested in accordance with ISO 9017. Imperfections detected shall be assessed in accordance with ISO 5817, level B.

1.3.2.4.3.6 Fracture test (Fillet welds)

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 ISO 5817, level B.

1.3.2.4.3.7 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 at least 10mm 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.

1.3.2.4.4 Retest

1.3.2.4.4.1 When a welder fails a qualification test, the following shall apply:
   a) 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 assembly 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.
   b) In cases where the welder fails to meet the requirements in all parts of the required tests or in the retest prescribed in 4.4.1 a), the welder shall undertake further training and practice.
   c) 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 4.2 and 4.3.

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

1.3.2.5 Certification

1.3.2.5.1 Qualification certificates are normally issued when the welder has passed the qualification test by the Register. Each Shipyard and Manufacturer shall be responsible for the control of the validity of the certificate and the range of the approval.

1.3.2.5.2 The following items shall be specified in the certificate:
   a) Range of qualification for base metal, 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.
1.3.2.5.3 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 according to the rules of the Register.

1.3.2.5.4 The status of approvals of each individual qualification is to be demonstrated to the Register when requested.

1.3.2.6 Period of Validity

1.3.2.6.1 Initial approval

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

The certificate is to be signed at six-month intervals by the shipyards/manufacturer 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.

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

The validity of the certificate may be maintained in agreement with the Register as specified in 1.3.2.6.2. The maintenance scheme of qualification is in accordance with 1.3.2.6.2.1 a) or b).

1.3.2.6.2 Maintenance of the approval

1.3.2.6.2.1 Revalidation shall be carried out by the Register. The skill of the welder shall be periodically verified by one of the following:

a) The welder shall be engaged every 3 years.

b) Every 2 years, two welds made during the last 6 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 the thickness. These tests revalidate the welder's qualifications for an additional 2 years.

1.3.2.6.2.2 The Register has to verify compliance with the above conditions and sign the maintenance of the welder's qualification certificate.

1.4 WELDING PROCEDURE TESTS

1.4.1 Scope

1.4.1.1 This Chapter gives requirements for qualification tests of welding procedures intended for the use of weldable steels and aluminum alloys as specified in Rules, Part 25 – Metallic materials, Sections 3.2, 3.4, 3.11, 3.12, 5.1 and 5.2. The welding procedure tests of other metallic materials shall be considered by the Register in each particular case.

Welding procedures applied for manufacture and build in of structures referred to in 1.1.1 shall be tested and approved by the Register in compliance with the requirements of this Chapter.

This Chapter specifies the scope and methods of the welding procedure testing for the arc welding processes of steels and aluminum alloys referred to in 1.3.1.2. Other processes shall be specially approved.

1.4.1.2 Welding procedure qualification tests made in accordance with EN, ISO, JIS, AWS or ASME may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.4.2 General

1.4.2.1 Welding procedure qualification tests are intended to verify that a manufacturer is adequately qualified to perform welding operations using a particular procedure.

1.4.2.2 In general welding procedure tests are to reflect fabrication conditions in respect to welding equipment, inside or outside fabrication, weld preparation, preheating and any postweld heat treatment. It is to be the manufacturer's responsibility to establish and document whether a procedure is suitable for the particular application.

1.4.2.3 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.

1.4.2.4 Welding procedures qualified at a manufacturer are valid for welding in workshops under the same technical and quality management.

1.4.3 Preliminary welding procedure specification and welding procedure specification

1.4.3.1 A welding procedure specification (WPS) is to be prepared by the shipyard or manufacturer which intends to perform the welding procedure qualification test. This document is also referred to as a preliminary welding procedure specification (pWPS). The pWPS can be modified and amended during procedure tests as deemed necessary however it is to define all relevant variables as mentioned in the WPS (refer to HRN EN ISO 15614 or other recognized standards).

1.4.3.2 The shipyard or manufacturer is to submit to the Register a pWPS for review prior to the tests. In case that the test pieces welded according to the pWPS show unac-
ceptable results the pWPS is to be adjusted by the shipyard or manufacturer. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.

1.4.3.3 The WPS is to be used as a basis for the production welds, and upon satisfactory completion of the tests based on the pWPS, the Register may approve it as a WPS. In case that a WPS is approved by the Register the approval range is to be in compliance with Section 1.4.4.6 (steels) and 1.4.5.5 (aluminium alloys).

1.4.3.4 A welding procedure specification shall, as a minimum, containing the following data as relevant for the welding operation:
- parent material (grade, standard, conditions of heat treatment) and thickness range,
- dimensions of base material (thickness, diameter),
- type of welding process and equipment as appropriate,
- joint/grove design, preparation and backing material, if any,
- welding position/s and direction of welding,
- welding consumables (grade, trade name, electrode or wire diameter, shielding/backing gas, flux),
- welding sequence, number and order of passes (layers),
- welding parameters (current, voltage, travel speeds, etc.),
- preheat and interpass temperature,
- post-weld heat treatment if applicable,
- other information relevant to the welding procedure as applicable.

1.4.4 Qualification of welding procedures for steels

1.4.4.1 General

1.4.4.1.1 Preparation and welding of test pieces are to be carried out in accordance with the pWPS and under the general condition of production welding which it represents.

1.4.4.1.2 Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

1.4.4.1.3 If tack welds and/or start and stop points are a condition of the weld process they are to be fused into the joint and are to be included in the test assemblies.

1.4.4.2 Butt weld

1.4.4.2.1 Assembly of test pieces in plate

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig. 1.4.4.2-1 with the minimum dimensions:

a) manual or semi-automatic welding:
   width = 2a, a = 3 x t, min 150 mm
   length b = 6 x t, min 350 mm

b) automatic welding:

   width = 2a, a = 4 x t, min 200 mm
   length b = 1000 mm

   For hull structural steel plates impact tested in the longitudinal direction (CVN-L) in Rules, Part 25 – Metallic materials, Section 3.2, 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) in Rules, Part 25 – Metallic materials, Section 3.4, the butt weld of the test piece is parallel to the rolling direction of the two plates.

![Figure 1.4.4.2-1](image)

Test assembly for a butt weld in plate

1.4.4.2.2 Assembly of test pieces in pipe

The test assembly is to be in accordance with Figure 1.4.4.2-2. When small pipe diameters are used, several test pieces may appear necessary.

![Figure 1.4.4.2-2](image)

a = minimum value 150 mm
D = outside diameter

Figure 1.4.4.2-2
Test assembly for a butt weld in pipe
1.4.4.2.3 Assembly of test pieces for a branch connection

The test assembly is to be in accordance with Figure 1.4.4.2.3. The angle $\alpha$ is the minimum to be used in production. In this case a branch connection is considered as a fully penetrated joint.

1.4.4.2.4 Examination and testing

Test assemblies are to be examined non-destructively and destructively in accordance with the Table 1.4.4.2.4, Figure 1.4.4.2.4-1 (butt weld in plate), Figure 1.4.4.2.4-2 (butt weld in pipe), Figure 1.4.4.2.4-3 (branch connection) and Figure 1.4.4.2.4-4 (T-joint).

$a_1 = \text{minimum value } 150 \text{ mm}$  
$D_1 = \text{outside diameter of the main pipe}$  
$t_1 = \text{main pipe material thickness}$  
$D_2 = \text{outside diameter of the branch pipe}$  
$t_2 = \text{branch pipe material thickness}$  
$\alpha = \text{angle between main and branch pipe}$

**Figure 1.4.4.2-3**  
Test assembly for a butt weld in pipe

<table>
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<tr>
<th>Test piece</th>
<th>Type of test</th>
<th>Extent of testing</th>
<th>Note</th>
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<tr>
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<td>Radiographic or Ultrasonic testing</td>
<td>100%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Transverse tensile test</td>
<td>2 specimens</td>
<td>as per 1.4.4.2.4.2</td>
</tr>
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<td></td>
<td>Longitudinal tensile test</td>
<td>required</td>
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<tr>
<td></td>
<td>Transverse bend test</td>
<td>4 specimens</td>
<td>as per 1.4.4.2.4.4</td>
</tr>
<tr>
<td></td>
<td>Impact test</td>
<td>required</td>
<td>as per 1.4.4.2.4.5</td>
</tr>
<tr>
<td></td>
<td>Macro examination</td>
<td>1 specimen</td>
<td>as per 1.4.4.2.4.6</td>
</tr>
<tr>
<td></td>
<td>Hardness test</td>
<td>required</td>
<td>as per 1.4.4.2.4.7</td>
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<td>Butt weld on pipe with full penetration Figure 1.4.4.2.4-2</td>
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<td>-</td>
</tr>
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<td>Radiographic or Ultrasonic testing</td>
<td>100%</td>
<td>2</td>
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<tr>
<td></td>
<td>Transverse tensile test</td>
<td>2 specimens</td>
<td>as per 1.4.4.2.4.2</td>
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<td></td>
<td>Transverse bend test</td>
<td>4 specimens</td>
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<td>required</td>
<td>as per 1.4.4.2.4.5</td>
</tr>
<tr>
<td></td>
<td>Macro examination</td>
<td>1 specimen</td>
<td>as per 1.4.4.2.4.6</td>
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<tr>
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<td>Hardness test</td>
<td>required</td>
<td>as per 1.4.4.2.4.7</td>
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<tr>
<td>Branch connection with full penetration Figure 1.4.4.2.4-3</td>
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<td>100%</td>
<td>-</td>
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<tr>
<td></td>
<td>Surface crack detection</td>
<td>100%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Macro examination</td>
<td>2 specimens</td>
<td>as per 1.4.4.2.4.6</td>
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<td></td>
<td>Hardness test</td>
<td>required</td>
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<td>T-joint with full penetration Figure 1.4.4.2.4-4</td>
<td>Visual</td>
<td>-</td>
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</tbody>
</table>
Figure 1.4.2.4-1
Location of test specimens for a butt weld in plate

Figure 1.4.2.4-2
Location of test specimens for a butt weld in pipe

1) Macro and hardness test specimen to be taken in position A
2) Macro test specimen in position B

Figure 1.4.2.4-3
Location of test specimens for a branch connection
1.4.4.2.4 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified, non-destructive testing is to be performed after heat treatment. For steels according to Rules, Part 25 – Metallic materials, Section 3.4 with specified minimum yield strength of 420 N/mm² and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with the Register.

Imperfections detected by visual or non-destructive testing are to be assessed in accordance with HRN EN ISO 5817, class B, except for excess weld metal and excess of penetration for which the level C applies.

1.4.4.2.4.2 Transverse tensile test

The testing is to be carried out in accordance with Rules, Part 25 – Metallic materials, Section 2.4. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal.

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.

1.4.4.2.4.3 Longitudinal tensile test

Longitudinal tensile test of deposited weld metal taken lengthways from the weld is required for cases where the welding consumable is not approved by the Register.

The testing is to be carried out in accordance with Rules, Part 25 – Metallic materials, Section 2.4. The tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the appropriate grade of consumable.

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.

1.4.4.2.4.4 Bend test

Transverse bend tests for butt joints are to be in accordance with Rules, Part 25 – Metallic materials, Section 2.6.

The mandrel diameter to thickness ratio (i.e. D/t) is to be that specified for the welding consumable (Section 1.5) approvals + 1.

The bending angle is to be 180°. After testing, the test specimens are not to reveal any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.

Two root and two face bend specimens are to be tested. For thickness 12 mm and over, four side bend specimens may alternatively be 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.

1.4.4.2.4.5 Impact test

a) Normal and higher strength hull structural steels according to Rules, Part 25 – Metallic materials, Section 3.2.

The positions of specimens are to be in accordance with these requirements. Dimensions and testing are to be in accordance with the requirements of Rules, Part 25 – Metallic materials, Section 2.7.

Test specimen with Charpy-V-notch are to be used and sampled from 1 to 2 mm below the surface of the base metal, transverse to the weld and on the side containing the last weld run.

V-notch specimens are located in the butt-welded joint as indicated in Figure 1.4.4.2.4.5-1 and Figure 1.4.4.2.4.5-2 and the V-notch is to be cut perpendicular to the surface of the weld.

Test temperature and absorbed energy are to be in accordance with Table 1.4.4.2.4.5.

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.

Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be taken from the respective areas where each was employed. This is not to apply to the process or consumables used solely to make the first weld run or root deposit.

The testing of sub - size specimen is to be in accordance with Rules, Part 25 – Metallic materials, Section 2.7.2.
### Table 1.4.4.2.4.5

Impact test requirements for butt joints ($t \leq 50$ mm)

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>Testing temperature $(\circ C)$</th>
<th>Value of minimum average absorbed energy (J) $^{1,2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>For manually or semi-automatically welded joints</td>
</tr>
<tr>
<td></td>
<td>Downhand, Horizontal, Overhead</td>
<td>Vertical upward, Vertical downward</td>
</tr>
<tr>
<td>A$^3$</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td>B$^3$, D</td>
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</tr>
<tr>
<td>E</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>A32, A36</td>
<td>20</td>
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<tr>
<td>D32, D36</td>
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</tr>
<tr>
<td>F40</td>
<td>-40</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1) For thickness above 50 mm impact test requirements are to be agreed by the Register.
2) These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3) For Grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be minimum 27 J.

b) High strength quenched and tempered steels according to Part 25 – Metallic materials, Section 3.4.

Impact test is to be performed as described in the above a).

V-notch specimens are located in the butt welded joint as indicated in Figure 1.4.4.2.4.5-1 and Figure 1.4.4.2.4.5-2 and the V-notch is to be cut perpendicular to the surface of the weld.

Test temperature and absorbed energy are to be in accordance with the requirements of base metal as specified in Part 25 – Metallic materials, Section 3.4.

c) Weldable C and C-Mn hull steel castings and forgings according to Part 25 – Metallic materials, Sections 3.11 and 3.12.

For base metal with specified impact values test temperature and absorbed energy are to be in accordance with the requirements of the base metal to be welded.
a) $t \leq 50 \text{ mm}$\(^1\)

Note:
1) For one side single run welding over 20 mm notch location $\text{a}$ is to be added on root side.

b) $t > 50 \text{ mm}$

Notch locations:
- $a$ – center of weld $\text{WM}$
- $b$ – on fusion line $\text{FL}$
- $c$ – in HAZ, 2 mm from fusion line

**Figure 1.4.4.5-1**
Location of V-notch for butt weld of normal heat input (heat input $\leq 50 \text{ kJ/cm}$)

a) $t \leq 50 \text{ mm}$\(^1\)

Note:
1) For one side welding with thickness over 20 mm notch location $\text{a}$, $\text{b}$, and $\text{c}$ is to be added on root side.

b) $t > 50 \text{ mm}$

Notch locations:
- $a$ – center of weld $\text{WM}$
- $b$ – on fusion line $\text{FL}$
- $c$ – in HAZ, 2 mm from fusion line
- $d$ – in HAZ, 5 mm from fusion line
- $e$ – in HAZ, 10 mm from fusion line in a case of heat input $> 200 \text{ kJ/cm}$

**Figure 1.4.4.5-2**
Location of V-notch for butt weld of high heat input (heat input $> 50 \text{ kJ/cm}$)
1.4.4.2.4.6 Macro examination

The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, the fusion line and the heat affected zone.

Macro examination is to include about 10 mm unaffected base metal.

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

1.4.4.2.4.7 Hardness test

Hardness test is required for steels with specified minimum yield strength of $R_{eH} \geq 355$ N/mm$^2$. The Vickers method HV 10 is normally to be used. The indentations are to be made in the weld metal, the heat affected zone and the base metal measuring and recording the hardness values.

At least two rows of indentations are to be carried out in accordance with Fig. 1.4.4.2.4.7-1 and 1.4.4.2.4.7-2, and for T-joint in accordance with Fig. 1.4.4.3.3.3-1 and 1.4.4.3.3.3-3.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides).

The results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength $R_{eH} \leq 420$ N/mm$^2$: 350 HV10
- Steel with a specified minimum yield strength $420$ N/mm$^2 < R_{eH} \leq 690$ N/mm$^2$: 420 HV10

Figure 1.4.4.2.4.7-1
Examples of hardness test with rows of indentations (R) in butt welds

Table 1.4.4.2.4.7
Recommended distances l between indentations for hardness test in the heat affected zone

<table>
<thead>
<tr>
<th>Vickers hardness Symbol</th>
<th>Distance between indentations l (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV 10</td>
<td>1</td>
</tr>
</tbody>
</table>

The distance of any indentation from the previous indentation is not to be less than the value allowed for the previous indentation by HRN EN ISO 6507-1.
1.4.4.3 Fillet weld

1.4.4.3.1 Assembly of test pieces

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig. 1.4.4.3-1 with the minimum dimensions:

- **a)** manual or semi-automatic welding:
  - width \( a = 3 \times t \), min 150 mm
  - length \( b = 6 \times t \), min 350 mm

- **b)** automatic welding:
  - width \( a = 3 \times t \), min 150 mm
  - length \( b = 1000 \) mm

1.4.4.3.2 Welding of test pieces

The test assembly is welded on one side only. For single run manual and semi-automatic welding, a stop/restart is to be included in the test length and its position is to be clearly marked for subsequent examination.

1.4.4.3.3 Examination and testing

Test assemblies are to be examined non-destructively and destructively in accordance with the Table 1.4.4.3.3.
Table 1.4.4.3.3
Examinations and tests for fillet welds

<table>
<thead>
<tr>
<th>Test piece</th>
<th>Type of test</th>
<th>Extent of testing</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillet weld</td>
<td>Visual</td>
<td>100%</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Surface crack detection</td>
<td>100%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Macro examination</td>
<td>2 specimens</td>
<td>as per 1.4.4.3.3.2</td>
</tr>
<tr>
<td></td>
<td>Hardness test</td>
<td>required</td>
<td>as per 1.4.4.3.3.3</td>
</tr>
<tr>
<td></td>
<td>Fracture test</td>
<td>required</td>
<td>as per 1.4.4.3.3.4</td>
</tr>
</tbody>
</table>

Notes:
1) Penetrant testing or magnetic particle testing. For non-magnetic materials, penetrant testing.

1.4.4.3.3.1 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified, non-destructive testing is to be performed after heat treatment. For steels according to Rules, Part 25 – Metallic materials, Section 3.4 with specified minimum yield strength of 420 N/mm2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with the Register.

Imperfections detected by visual or non-destructive testing are to be assessed in accordance with HRN EN ISO 5817, class B, except for excess convexity and excess throat thickness for which the level C applies.

1.4.4.3.3.2 Macro examination

The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone.

Macro examination is to include about 10 mm 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.

1.4.4.3.3.3 Hardness test

Hardness test is required for steels with specified minimum yield strength of $R_{eH} \geq 355$ N/mm$^2$. The Vickers method HV 10 is normally to be used. The indentations are to be made in the weld metal, the heat affected zone and the base metal measuring and recording the hardness values. At least two rows of indentations are to be carried out in accordance with Fig. 1.4.4.3.3.3-1, 1.4.4.3.3.3-2 and 1.4.4.3.3.3-3.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides).

The results from the hardness test are not to exceed the following:
- Steel with a specified minimum yield strength $R_{eH} \leq 420$ N/mm$^2$: 350 HV10
- Steel with a specified minimum yield strength $420$ N/mm$^2 < R_{eH} \leq 690$ N/mm$^2$: 420 HV10

1.4.4.3.3.4 Fracture test

The fracture test is to be performed by folding the upright plate onto the through plate. Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfections that are detected is to be assessed in accordance with HRN EN ISO 5817, class B.

Figure 1.4.4.3.3.3-1
Examples of hardness test with rows of indentations (R) in fillet welds and in T-joint welds
1.4.4.4 Re-testing

1.4.4.1 If the test piece 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 is to be regarded as not capable of complying with the requirements without modification.

1.4.4.2 If any test specimens fail to comply with the relevant requirements for destructive testing due to weld imperfections only, two further test specimens are to be obtained for each one that failed. These specimens can be taken from the same test piece if there is sufficient material available or from a new test piece, and are to be subjected to the same test. If either of these additional test specimens does not comply with the relevant requirements, the pWPS is to be re-
garded as not capable of complying with the requirements without modification.

1.4.4.4.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with Rules, Part 25 – Metallic materials, Section 2.9.2.

1.4.4.4.4 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.

1.4.4.4.5 The re-testing of Charpy impact specimens are to be carried out in accordance with Rules, Part 25 – Metallic materials, Section 2.9.3.

1.4.4.4.6 Where there is insufficient welded assembly remaining to provide additional test specimens, a further assembly is to be welded using the same procedure to provide the additional specimens.

1.4.4.5 Test record

1.4.4.5.1 Welding conditions for test assemblies and test results are to be recorded in welding procedure test record. Forms of welding procedure test records can be taken from the Register rules or from relevant standards.

1.4.4.5.2 A statement of the results of assessing each test piece, including repeat tests, is to be made for each welding procedure test. The relevant items listed for the WPS of these requirements are to be included.

1.4.4.5.3 A statement that the test piece was made according to the particular welding procedure is to be signed by the Surveyor witnessing the test and is to include the Register identification.

1.4.4.6 Range of approval

1.4.4.6.1 General

1.4.4.6.1.1 All the conditions of validity stated below are to be met independently of each other.

1.4.4.6.1.2 Changes outside of the ranges specified are to require a new welding procedure test.

1.4.4.6.1.3 Shop primers may have an influence on the quality of fillet welds and is to be considered. Welding procedure qualification with shop primer will qualify those without but not vice versa.

1.4.4.6.2 Base metal

1.4.4.6.2.1 Normal and higher strength hull structural steels according to Rules, Part 25 – Metallic materials, Section 3.2

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested.
b) For each toughness grade, welding procedures are considered applicable to the same and two lower strength levels as that tested.
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 sub 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

Where steels used for construction are supplied from different delivery conditions from those tested the Register may require additional tests.

1.4.4.6.2.2 High strength quenched and tempered steels according to Rules, Part 25 – Metallic materials, Section 3.4

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested.
b) For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested.
c) The approval of quenched and tempered steels does not quality thermo-mechanically rolled steels (TMCP steels) and vice versa.

1.4.4.6.2.3 Weldable C and C-Mn hull steel forgings according to Rules, Part 25 – Metallic materials, Section 3.11

a) Welding procedures are considered applicable to the same and lower strength level as that tested.
b) The approval of quenched and tempered hull steel forgings does not quality other delivery conditions and vice versa.

1.4.4.6.2.4 Weldable C and C-Mn hull steel castings according to Rules, Part 25 – Metallic materials, Section 3.12

a) Welding procedures are considered applicable to the same and lower strength level as that tested.
b) The approval of quenched and tempered hull steel castings does not quality other delivery conditions and vice versa.

1.4.4.6.3 Material thickness and pipe diameter

1.4.4.6.3.1 The qualification of a WPS carried out on a test assembly of thickness \( t \) is valid for the thickness range given in Table 1.4.4.6.3.1.

1.4.4.6.3.2 In addition to the requirements of Table 1.4.4.6.3.1, the range of approval of throat thickness \( h_{\text{t}} \) for fillet welds is to be as follows:

- Single run: \( f_{\text{t}} \leq 0.75 \times a +t \) to \( f_{\text{t}} \leq 0.5 \times a +t \)
- Multi-run: as for butt welds with multi-run (i.e. \( a=t \)
Table 1.4.4.6.3.1
Approval range of thickness for butt weld and T-joint welds and fillet welds

<table>
<thead>
<tr>
<th>Thickness of test piece ( t^{(1)} ) (mm)</th>
<th>Range of approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillet weld Figure 1.4.4.3-1</td>
<td>Butt and T-joint welds with single run or single run from both sides</td>
</tr>
<tr>
<td>( 3 \times t \leq 12 )</td>
<td>0,7t to 1,1t</td>
</tr>
<tr>
<td>( 12 &lt; t \leq 100 )</td>
<td>0,7t to 1,1t(^3))</td>
</tr>
<tr>
<td></td>
<td>0,5t to 2t ((\text{max.} 150))</td>
</tr>
</tbody>
</table>

Notes:
1) For multi process procedures, the recorded thickness contribution of each process is to be used as 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.
3) For high heat input processes over 50 kJ/cm, the upper limit of range of approval is to be 1.0 x \( t \).

1.4.4.6.3.3 For the vertical-down welding, the test piece thickness \( t \) is always taken as the upper limit of the range of application.

1.4.4.6.3.4 For unequal plate thickness of butt welds the lesser thickness is ruling dimension.

1.4.4.6.3.5 Notwithstanding the above, the approval of maximum thickness of base metal for any technique is 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 1.4.4.2.4.7 and 1.4.4.3.3.3.

1.4.4.6.3.6 The qualification of a welding procedure test on diameter \( D \) shall include qualification for diameters in the following ranges given in Table 1.4.4.6.3.6.

<table>
<thead>
<tr>
<th>Diameter of the test piece ( D ) (mm)</th>
<th>Range of approval (^{11})</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D \leq 25 )</td>
<td>0,5D to 2D</td>
</tr>
<tr>
<td>( D &gt; 25 )</td>
<td>( \text{Ø}0,5D (25 \text{ mm min.}) )</td>
</tr>
</tbody>
</table>

Notes:
1) Approval given for plates also covers pipes when the outside diameter is > 500 mm or when the diameter is > 150 mm welded in the PA or PC rotated position, within the limitations of the Table 1.4.4.6.10.

1.4.4.6.3.7 A welding procedure test carried out on a branch connection with angle \( \hat{U} \) shall approve all branch angles \( \hat{U} \) in the range of \( \text{Ø}0 \text{Ø}90^\circ \).

1.4.4.6.4 Welding position

Approval for a test made in any position is restricted to that position (See Pictures 1.4.4.6.4-1, 1.4.4.6.4-2, 1.4.4.6.4-3 and 1.4.4.6.4-4). To qualify a range of positions, test assemblies are to be welded for highest heat input position and lowest heat input position and all applicable tests are to be made on those assemblies.

For example, butt welds in plate the highest heat input position is normally PF and the lowest PC. For fixed pipe welds the hardness tests shall be taken from the overhead welding position.

1.4.4.6.5 Welding process

1.4.4.6.5.1 The approval is only valid for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run to a single run.

1.4.4.6.5.2 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.

1.4.4.6.6 Welding consumable

Except high heat input processes over 50kJ/cm, welding consumables cover other approved welding consumables having the same grade mark including all suffixes specified in Section 1.5 with the welding consumable tested.

1.4.4.6.7 Heat input

1.4.4.6.7.1 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.

1.4.4.6.7.2 The lower limit of heat input approved is 25% lower than that used in welding the test piece.

1.4.4.6.8 Preheating and interpass temperature

1.4.4.6.8.1 The minimum preheating temperature is not to be less than that used in the qualification test.

1.4.4.6.8.2 The maximum interpass temperature is not to be higher than that used in the qualification test.
1.4.4.6.9  Post-weld heat treatment

The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

1.4.4.6.10  Type of joint

1.4.4.6.10.1  Range of approval depending on type of welded joints for test assembly is to be specified in Table 1.4.4.6.10.

1.4.4.6.10.2  A qualification test performed on a butt weld will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 1.4.5.3 above.

<table>
<thead>
<tr>
<th>Type of welded joint for test assembly</th>
<th>Range of approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>One side With backing</td>
<td>A, C</td>
</tr>
<tr>
<td>One side Without backing</td>
<td>B</td>
</tr>
<tr>
<td>Both side With gouging</td>
<td>C</td>
</tr>
<tr>
<td>Both side Without gouging</td>
<td>D</td>
</tr>
</tbody>
</table>

Notes:
- T joints butt welded only qualify T joints butt welded and fillet welds.
- Fillet welding qualifies fillet welding only.

1.4.4.6.11  Other variables

The range of approval relating to other variables may be taken as specified in HRN EN ISO 15614-1.

1.4.5. Qualification of welding procedures for aluminium alloys

1.4.5.1  General

1.4.5.1.1  Basic requirements are given in 1.4.1, 1.4.2 and 1.4.3.

1.4.5.1.2  These requirements specifically excludes the welding procedure intended for LNG containment.

1.4.5.1.3  The welding processes below indicated, together with their relevant numbering according to ISO 4063, are in general used for welding aluminium alloys:
- 131 - metal-arc inert gas welding (MIG welding)
- 141 - tungsten inert gas arc welding (TIG welding)
- 15 - plasma arc welding

1.4.5.1.4  The welding consumables shall be approved in accordance with the requirements specified in Section 1.5.4.

Where non approved welding consumables are used at the discretion of the Register, the requirements for the qualification of the welding procedures shall be established on a case by case basis. In general additional tests on deposited weld metal are required in accordance with Section 1.5.4.

1.4.5.2  Butt weld

1.4.5.2.1  Assembly of test pieces and welding

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution during welding and according to 1.4.4.2.1.

The edge preparation and fit up is to 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 cleaning of the parts to be welded shall be carried out in accordance with the welding procedure.

The welding is to be carried out in accordance with the pWPS and under the general conditions of production welding which it represents.

1.4.5.2.2  Examination and testing

Test assemblies are to be examined non-destructively and destructively in accordance with the Table 1.4.5.2.2. Test specimens are to be taken in accordance with Figure 1.4.5.2.

<table>
<thead>
<tr>
<th>Test piece</th>
<th>Type of test</th>
<th>Extent of testing</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt weld on plate with full penetration</td>
<td>Visual</td>
<td>100%</td>
<td>as per 1.4.5.2.3</td>
</tr>
<tr>
<td></td>
<td>Dye penetrant test</td>
<td>100%</td>
<td>as per 1.4.5.2.3</td>
</tr>
<tr>
<td></td>
<td>Radiographic or Ultrasonic examination</td>
<td>100%</td>
<td>as per 1.4.5.2.3</td>
</tr>
<tr>
<td></td>
<td>Transverse tensile test</td>
<td>2 specimens</td>
<td>as per 1.4.5.2.4</td>
</tr>
<tr>
<td></td>
<td>Transverse bend test</td>
<td>2 root and 2 face specimens</td>
<td>as per 1.4.5.2.5</td>
</tr>
<tr>
<td></td>
<td>Macroscopic examination</td>
<td>1 specimen</td>
<td>as per 1.4.5.2.6</td>
</tr>
<tr>
<td></td>
<td>Microscopic examination</td>
<td>1 specimen</td>
<td>as per 1.4.5.2.6</td>
</tr>
</tbody>
</table>

Notes:
1) Ultrasonic testing shall not be used for t ≤ 10 mm.
2) 2 root and 2 face bend test specimens can be substituted by 4 side bend test specimens for t ≥ 12 mm.
3) Only for 6xxx-alloys (material group 23) and all casting alloys.
1.4.5.2.3 Non-destructive examination

Non destructive examinations are to be carried out after any required post weld heat treatment, natural or artificial ageing, and prior to the cutting of the test specimens.

Welds are to be free from cracks. Imperfections detected by visual or non-destructive testing are to be assessed in accordance with HRN EN ISO 10042, level B, except for excess weld metal or convexity, excess throat thickness and excess of penetration for which the level C applies.

1.4.5.2.4 Transverse tensile test

The specimens for transverse tensile test is to be carried out in accordance with Rules, Part 25 – Metallic materials, Section 2.4. The tensile strength shall meet requirements stated in Table 1.4.5.2.4.

<table>
<thead>
<tr>
<th>Grade (alloy designation)</th>
<th>Minimum tensile strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5754</td>
<td>190</td>
</tr>
<tr>
<td>5086</td>
<td>240</td>
</tr>
<tr>
<td>5083</td>
<td>275</td>
</tr>
<tr>
<td>5383</td>
<td>290</td>
</tr>
<tr>
<td>5059</td>
<td>330</td>
</tr>
<tr>
<td>5456</td>
<td>290</td>
</tr>
<tr>
<td>6005A</td>
<td>170</td>
</tr>
<tr>
<td>6061</td>
<td>170</td>
</tr>
<tr>
<td>6082</td>
<td>170</td>
</tr>
</tbody>
</table>

1.4.5.2.5 Bend test

The specimens for bend tests are to be machined to the dimensions given in Rules, Part 25 – Metallic materials, Section 2.4. For dissimilar or heterogeneous butt joints longitudinal bend tests may be required instead of transverse bend tests.

The bend test specimens are to be bent on a mandrel with maximum diameter as given in the formula below. The bending angle shall be 180°.

\[
d = \frac{100 \cdot t_s}{A} - t_s
\]

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 should be used).

After testing the test specimens should 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.

Wrap around method bend tests are recommended for the above mandrel diameter for each alloy.

1.4.5.2.6 Macroscopic / Microscopic examination

The test specimen shall be prepared and examined in accordance with ISO 17639 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 macroscopic 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 macroscopic examination shall include unaffected parent material.

The acceptance levels specified in 1.4.5.2.3 apply.
Care should be taken when etching certain alloys to avoid producing crack-like indications.

1.4.5.3 Fillet weld

1.4.5.3.1 Assembly of test pieces and welding

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution during welding and according to 1.4.4.3.1.

The two plates should be positioned and tack welded edgewise so as to constitute a T assembly without clearance.

Welding on one or both sides and fit up should be as detailed in the pWPS.

<table>
<thead>
<tr>
<th>Test piece</th>
<th>Type of test</th>
<th>Extent of testing</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillet weld on plate</td>
<td>Visual</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dye penetrant test</td>
<td>100%</td>
<td>as per 1.4.5.3.3</td>
</tr>
<tr>
<td></td>
<td>Macroscopic examination 1)</td>
<td>2 specimens</td>
<td>as per 1.4.5.3.4</td>
</tr>
<tr>
<td></td>
<td>Microscopic examination 2)</td>
<td>1 specimen</td>
<td>as per 1.4.5.3.4</td>
</tr>
<tr>
<td></td>
<td>Fracture test</td>
<td>1 specimen</td>
<td>as per 1.4.5.3.4</td>
</tr>
</tbody>
</table>

Notes:
1) One of the macro sections shall be taken at the position of the stop/restart (see 1.4.5.3.1).
2) Only for 6xxx-alloys (material group 23) and all casting alloys.

1.4.5.3.3 Visual examination and surface crack detection

The requirements specified in 1.4.5.2.3 are to be complied with.

In general for manual and semiautomatic welding a stop/restart position should be included in the test length and should be clearly marked for subsequent examination.

The cleaning of the parts to be welded should be carried out in accordance with the welding procedure.

1.4.5.3.2 Examination and testing

Test assemblies are to be examined non-destructively and destructively in accordance with the Table 1.4.5.2.2. Test specimens is to be taken in accordance with Figure 1.4.5.3.

1.4.5.3.4 Macroscopic / microscopic examination and fracture test

The fracture test as well as the macro examination shall, in general, satisfy the acceptance level specified in 1.4.5.2.3.

Dimension of leg size, throat and penetration should in general be reported.

1.4.5.4 Re-testing

If the test assembly fails to comply with any of the requirements for visual examination or NDE, one further test assembly is to be welded and subjected to the same examination.

If any test specimen fails to comply with the relevant requirements, two additional test specimens are to be obtained for each one that failed. These specimens can be taken from the same assembly, if there is sufficient material, or from a new test assembly. For the acceptance both tests shall give satisfactory results.

Where failed in the above re-testing, the pWPS is to be modified before further consideration by the Surveyor is given to a new test assembly for re-qualification.

1.4.5.5 Range of approval

1.4.5.5.1 General

The approval of the WPS obtained by a shipyard or a manufacturer is valid for welding in all its workshops under the same technical and quality control.
All the conditions of validity stated below should be met independently of each other. Changes outside of the ranges specified may require a new welding procedure test.

1.4.5.5.2 Parent metal

The aluminium alloys are grouped into three groups:

- Group A: aluminium-magnesium alloys with Mg content \( \leq 3.5\% \) (alloy 5754)
- Group B: aluminium-magnesium alloys with \( 4\% \leq \text{Mg} \leq 5.6\% \) (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 procedure also for the other alloys of the same Group with equal or lower specified tensile strength after welding.

The qualification made on Group B alloy qualifies the procedure also for Group A alloys.

1.4.5.5.3 Thickness

The qualification of a WPS carried out on a test assembly of thickness \( t \) is valid for the thickness range given in Table 1.4.5.5.3-1.

In case of butt-joints between dissimilar thickness, \( t \) is the thickness of the thinner material.

In case of fillet joints between dissimilar thickness, \( t \) is the thickness of the thicker material.

In addition to the requirements of Table 1.4.5.5.3-1, the range of qualification of the throat thickness \( a \) is given in Table 1.4.5.5.3-2.

Where a fillet weld is qualified by means of a butt weld test, the throat thickness range qualified should be based on the thickness of the deposited weld metal.

Where the majority of production work is fillet welding, an additional fillet weld test may be required.

<table>
<thead>
<tr>
<th>Thickness of the test piece, ( t ) (mm)</th>
<th>Range of qualifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t \leq 3 )</td>
<td>0.5 to 2( t )</td>
</tr>
<tr>
<td>( 3 &lt; t \leq 20 )</td>
<td>3 to 2( t )</td>
</tr>
<tr>
<td>( t &gt; 20 )</td>
<td>( \geq 0.8t )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Throat thickness of the test piece, ( a ) (mm)</th>
<th>Range of qualifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a &lt; 10 )</td>
<td>0.75( a ) to 1.5( a )</td>
</tr>
<tr>
<td>( a \geq 10 )</td>
<td>( \geq 7.5 )</td>
</tr>
</tbody>
</table>

1.4.5.5.4 Welding position

Provided that comparable welding parameters are used for the included welding positions a test in any one position qualifies for welding in all positions except for vertical downwards (PG) position where in any case separate welding procedure test is required.

1.4.5.5.5 Type of joint

The range of approval for the types of joint in relation to the type of joint used in the procedure qualification test is as follows:

- butt-joint welded from one side with backing qualifies also for welding from both sides with gouging;
- butt-joint welded from one side without backing qualifies also for welding from one side with backing, from both sides with gouging and from both sides without gouging;
- butt-joint welded from both sides with gouging only qualifies that condition,
- butt-joint welded from both sides without gouging qualifies also for welding from both sides with backing.

1.4.5.5.6 Welding process

The approval is valid only for the welding process used in the welding procedure test. It is not permitted to change a multi run deposit into a single run (or single run on each side) or vice versa for a given process. In the case of a multi-process procedure, the approval is only valid for applying the processes in the order used during the procedure qualification tests.

Note: For multi-process procedures each welding process may be approved separately or in combination with other processes. Similarly one or more processes may be deleted from an approved WPS provided the joint thickness is within the approved thickness range of the relevant welding process to be applied.

1.4.5.5.7 Welding consumables

The welding consumable used in the qualification tests qualifies:

1) Approved welding consumables of the same strength as the consumable used in the procedure qualification tests.
2) Approved welding consumables of higher strength than the consumable used in the procedure qualification tests.

The qualification given to shielding gas and backing gas is restricted to the gas/gas mixture used in the welding procedure test, see HRN EN ISO 14175 or other recognised standards for gas designations.
1.4.5.5.8 Type of current

Changes in the type of current (AC, DC, pulsed) and polarity require a new welding procedure qualification.

1.4.5.5.9 Preheat and interpass temperature

The lower limit of approval is the preheat temperature applied at the start of the welding procedure test.

The upper limit of approval is the interpass temperature reached in the welding procedure test.

1.4.5.5.10 Post-weld heat treatment or ageing

Addition or deletion of post weld heat treatment or ageing is not permitted except that artificial ageing for 6000 series alloys gives approval for prolonged natural ageing.

1.4.5.5.11 Other variables

The range of approval relating to other variables may be taken as specified in HRN EN ISO 15614-2.
Figure 1.4.4.6.4-3
Welding positions according to AWS-Code – Butt welds

Figure 1.4.4.6.4-4
Welding positions according to AWS-Code – Fillet welds
1.5 WELDING CONSUMABLES

1.5.1 General

1.5.1.1 All welding consumables used for welding of structures referred to in 1.1.1 shall be tested and approved by the Register.

1.5.1.2 The Register shall grant the approval for the welding consumables on the basis of the manufacturer's application, technical documentation (1.5.1.3) as well as on the basis of the results obtained from the testing carried out under the supervision of the Register and with the approved program according to the present Chapter.

1.5.1.3 Application for approval shall be submitted to the Register by the manufacturer of the welding consumable accompanied with the documentation including the following:

- name of the manufacturer of the welding consumables,
- trade name, mark, and type,
- grade of the welding material, including additional symbols (if necessary) in compliance with these Rules,
- recommended area of application, including for example, base material, welding positions and similar,
- chemical composition and mechanical properties of weld metal,
- sizes (diameters, lengths),
- instructions manual (current, polarity), backing, heat treatment etc.,
- classification (EN, ISO etc.),
- marking, packaging,
- proposed testing laboratory and date of test.

1.5.1.4 On the ground of satisfactory testing results the Register shall issue the Certificate on the type approval and testing of welding consumables and shall enlist it in its List of type approved products and manufacturers. With such an approval the manufacturer is liable to ensure that, during manufacture the composition and properties of the products comply with those of the tested welding consumables.

1.5.1.5 The manufacturer is liable to enter the information on the approval certificate into its catalogue of the list of approval and testing of welding consumables.

1.5.1.6 Unless otherwise agreed, the approved welding consumables shall be in accordance with 1.5.2 - 1.5.4, tested annually in the presence of a Surveyor to the Register to prove that the material properties comply with those of the tested welding consumables.

1.5.1.7 In case of any change of the properties, chemical composition of the approved material or the technology of its production, the tests shall be repeated.

1.5.1.8 Welding consumables which are not covered by these Rules (e.g. for welding of high-alloy steels, etc.) shall be tested for the approval in accordance with the special program approved by the Register.

1.5.1.9 When the results of any testing fail to meet the requirements that testing shall be repeated on duplicate re-test specimens.

For that purpose test specimen may be taken from the same batch as the former test pieces. In case that re-testing does not give satisfactory results, the causes shall be traced and the whole testing repeated.

1.5.2 Approval of consumables for welding normal and higher strength structural steels

1.5.2.1 General

1.5.2.1.1 Scope

1.5.2.1.1.1 These requirements give the conditions of approval and inspection of welding consumables used for hull structural steels according to Rules, Part 25 - Metallic Materials, Section 3.2 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 Section 1.5.3.

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

1.5.2.1.1.2 Categories of products

The concerned welding consumables are divided into several categories as follows:

- covered electrodes for manual welding and gravity welding,
- wire/flux combinations for two run or multi-run submerged arc welding,
- solid wire/gas combinations for arc welding,
- flux cored wires with or without gas for arc welding,
- consumables for use in electroslag and electrogas vertical welding

1.5.2.1.2 Grading

1.5.2.1.2.1 Basic groups and grades

Filler metals are divided into three groups:

- 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/mm²,
- higher strength filler metals for welding normal and higher strength hull structural steels with minimum yield strength up to 390 N/mm².

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

Each filler metal group is further divided into several grades:

- Grades 1, 2 and 3 for ordinary-strength filler metals,
- Grades 1Y, 2Y, 3Y and 4Y for higher strength filler metals for steels up to 355 N/mm² yield strength,
- Grades 2Y 40, 3Y 40, 4Y 40 and 5Y 40 for higher strength filler metals for steels up to 390 N/mm² yield strength.

The Grade assignment is given in respect of Charpy V-notch impact test requirements.

For each strength basic group, welding consumables, which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower toughness grade.

1.5.2.1.2.2 Correlation of welding consumables to hull structural steel grades.

The correlation between the hull steel grades and the welding consumables grades that must be used for the hull steel welding, is stated in the following Table 1.5.2.1.2.2.

<table>
<thead>
<tr>
<th>Grades of welding consumables (see notes)</th>
<th>Hull structural steel grades</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1, 1S, 1T, 1M, 1TM, IV</td>
<td>X</td>
</tr>
<tr>
<td>1YS, 1YT, 1YM, 1YTM, 1YV</td>
<td>X</td>
</tr>
<tr>
<td>2, 2S, 2T, 2M, 2TM, 2V</td>
<td>X</td>
</tr>
<tr>
<td>2Y, 2YS, 2YT, 2YM, 2YTM, 2YV</td>
<td>X</td>
</tr>
<tr>
<td>2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V</td>
<td>1)</td>
</tr>
<tr>
<td>3, 3S, 3T, 3M, 3TM, 3V</td>
<td>X</td>
</tr>
<tr>
<td>3Y, 3YS, 3YT, 3YM, 3YTM, 3YV</td>
<td>X</td>
</tr>
<tr>
<td>3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V</td>
<td>1)</td>
</tr>
<tr>
<td>4Y, 4YS, 4YT, 4YM, 4YTM, 4YV</td>
<td>X</td>
</tr>
<tr>
<td>4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V</td>
<td>1)</td>
</tr>
<tr>
<td>5Y40, 5Y40S, 5Y40T, 5Y40M, 5Y40TM, 5Y40V</td>
<td>1)</td>
</tr>
</tbody>
</table>

Notes:
(a) When joining normal to higher strength structural steel, consumables of the lowest acceptable grade for either material being joined may be used.
(b) When joining steels of the same strength level but of different toughness grade, consumables of the lowest acceptable grade for either material being joined may be used.
(c) It is recommended that controlled low hydrogen type consumables are to be used when joining higher strength structural steel to the same or lower strength level, except that other consumables may be used at the discretion of the Register when the carbon equivalent is below or equal to 0.41%. When other than controlled low hydrogen type electrodes are used appropriate procedure tests for hydrogen cracking may be conducted at the discretion of the Register.
(d) The welding consumables approved for steel Grades A40, D40, E40 and/or F40 may also be used for welding of the corresponding grades of normal strength steels subject to the special agreement with the Register.
(e) When joining higher strength steels using Grade 1Y welding consumables, the material thicknesses should not exceed 25 mm.
1.5.2.1.2.3 Hydrogen marks

Welding consumables of Grades 2 and 3 and Grades 2Y, 3Y and 4Y and of Grades 2Y 40, 3Y 40, 4Y 40 and 5Y 40 for which the hydrogen content has been controlled in accordance with paragraph 1.5.2.4.5.3 are identified by the mark H15, H10 or H5.

1.5.2.1.3 Manufacture

1.5.2.1.3.1 The manufacturer's plant, methods of production and quality control of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.5.2.2 Approval procedure

1.5.2.2.1 Plant inspection

1.5.2.2.1.1 The Surveyor is to be satisfied that the manufacturer's plant, methods of production and quality control of welding consumables are to be such as to ensure a reasonable uniformity in manufacture, as mentioned in 1.5.2.1.3.1 above.

1.5.2.2.2 Test assemblies

1.5.2.2.2.1 Preparation

The test assemblies are to be prepared under the supervision of the Surveyor, and all tests are to be carried out in his presence.

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.

1.5.2.2.2.2 Welding conditions

The welding conditions used such as amperage, voltage, travel speed, etc are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler material is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.

1.5.2.2.3 Firms with several factories - sister firms

When a filler product is manufactured in several factories of the same company, the complete series of approval tests should be carried out in one of the works only. In the other factories, 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 the Register.

1.5.2.2.4 Annual inspection and tests

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 reappraisal. On these occasions, samples of the approved consumable are to be selected by the Surveyor and subjected to the tests detailed in subsequent sections of these requirements. 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. Equivalent alternative arrangements may be accepted subject to special agreement with the Register.

1.5.2.2.5 Alterations to approved consumables

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 the Register. Additional tests may be necessary.

1.5.2.2.6 Upgrading and uprating

Upgrading and uprating of welding consumables will be considered only at manufacturer's request, preferably at the time of annual testing. Generally, for this purpose, tests from butt weld assemblies will be required in addition to the normal annual approval tests.

1.5.2.2.7 Additional tests

The Register may request, in a particular case, additional tests or requirements as may be considered necessary.

1.5.2.3 Mechanical testing procedure

1.5.2.3.1 Test specimens

1.5.2.3.1.1 Specimens dimensions

Deposited metal and butt weld tensile, butt weld bend and Charpy V-notch impact test specimens are to be machined to the dimensions given in the Rules, Part 25 - Metallic materials, Chapter 2 – Test specimens and mechanical testing procedures for material.

1.5.2.3.1.2 Specimens location and preparation

1) Deposited metal tensile

The longitudinal axis must coincide with the centre of the weld and:

a) the mid thickness of the weld in the deposited metal test assemblies.

b) the mid thickness of the 2nd run in the two-run welded test assemblies.

The specimens may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal prior to testing.
2) Butt weld tensile
The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

3) Butt weld bend
The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm.

4) Charpy V-notch impact
The test specimens shall be cut with their longitudinal axes transverse to the weldlength and:
   a) at mid thickness of the weld in the deposited metal and butt weld test assemblies with multi-run technique;
   b) on the 2nd run side, 2 mm maximum below the surface in the two-run welded test assemblies;
   c) 2 mm maximum below one surface in the electroslag or electrogas welded test assemblies.

   The notch shall be cut in the face of the test piece perpendicular to the surface of the plate and shall be positioned in the centre of the weld and, for electroslag and electrogas welded test assemblies, also at 2 mm from the fusion line in the deposited metal.

1.5.2.3.2 Testing procedures

1.5.2.3.2.1 Tensile
Tensile tests are to be carried out on an approved tensile testing machine. On deposited metal test specimens, the values of yield stress, tensile strength and elongation are to be recorded. On butt weld specimens, the values of tensile strength are to be recorded together with the position of fracture.

1.5.2.3.2.2 Bend
The test specimens are to be capable of withstanding, without fracture or crack, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen. However, superficial cracks of less than 3 mm long on the outer surface should not be taken into consideration.

   For each set of bend tests one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension except in the electroslag or electrogas welded test assemblies, where side bend tests are carried out in lieu of face and root bend tests.

1.5.2.3.2.3 Charpy V-notch impact
Impact tests are to be carried out on a Charpy impact machine of an approved type. A set of three test specimens is to be prepared and tested. The average absorbed energy value is to comply with the requirements of subsequent sections. One individual value may be less than the required average value provided that it is not less than 70% of this value.

   The test temperature for Grades 2, 2Y, 2Y 40, 3, 3Y, 3Y 40, 4Y, 4Y 40 and 5Y 40 test pieces is to be controlled to within ±2°C of the prescribed temperature.

1.5.2.3.3 Re-test procedures

1.5.2.3.3.1 Tensile and bend
Where the result of a tensile or bend test does not comply with the requirements, duplicate test specimens of the same type are to be prepared and satisfactorily tested. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the number of runs) as the original assembly, only the duplicate re-test specimens needs to be prepared and tested. Otherwise, all test specimens should be prepared as for re-testing.

1.5.2.3.3.2 Charpy V-notch impact
Re-test requirements for Charpy impact tests are to be in accordance with the Rules, Part 25 - Metallic materials, Chapter 2 - Test specimens and mechanical testing procedures for material. Further re-tests may be made at the Surveyor’s discretion, but these must be made on a new welded assembly and must include all tests required for the original assembly, even those which were previously satisfactory.

1.5.2.4 Covered electrodes for manual arc welding

1.5.2.4.1 General

1.5.2.4.1.1 Grades
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/mm²: Grades 2Y and 3Y (Grade 1Y not applicable for manual welding).
   – for higher strength steels with minimum yield strength up to 390 N/mm²: Grades 2Y 40, 3Y 40, 4Y 40 and 5Y 40.

1.5.2.4.1.2 Hydrogen marks

If the electrodes are in compliance with the requirements of the hydrogen test given in 1.5.2.4.5 hereafter, a suffix H15, H10 or H5 will be added to the Grade mark.

1.5.2.4.2 Deposited metal tests

1.5.2.4.2.1 Preparation of deposited metal test assemblies

Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 1.5.2.4.2, one with 4 mm diameter electrodes and the other with the
largest size manufactured. If an electrode is available in one diameter only, one test assembly is sufficient. Any grade of ship structural steel may be used for the preparation of these test assemblies.

The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C but not below 100°C, the temperature being taken in the centre of the weld, on the surface of the seam. After welding, the test assemblies are not to be subjected to any heat treatment.

1.5.2.4.2.2 Chemical analysis

At the discretion of the Register, the chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying element.

1.5.2.4.2.3 Execution of tests

One tensile and three impact test specimens are to be taken from each test assembly as shown in Figure 1.5.2.4.2. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. Tests are to be performed according to Section 1.5.2.3 of these requirements.

1.5.2.4.2.4 Results of tests and requirements

The results of all tests are to comply with the requirements of Table 1.5.2.4-1 as appropriate.

Figure 1.5.2.4.2
Deposited metal test assembly
Table 1.5.2.4-1
Requirements for deposited metal test (covered manual electrodes)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Minimum yield stress (N/mm²)</th>
<th>Tensile strength (N/mm²)</th>
<th>Minimum elongation on 50 mm gauge length (L₀ = 5 d) (%)</th>
<th>Charpy V-notch impact test Test Temperature (°C)</th>
<th>Minimum Average Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>305</td>
<td>400-560</td>
<td>22</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>305</td>
<td>400-560</td>
<td>22</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>3</td>
<td>305</td>
<td>400-560</td>
<td>22</td>
<td>-20</td>
<td>47</td>
</tr>
<tr>
<td>2Y</td>
<td>375</td>
<td>490-660</td>
<td>22</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>3Y</td>
<td>375</td>
<td>490-660</td>
<td>22</td>
<td>-20</td>
<td>47</td>
</tr>
<tr>
<td>4Y</td>
<td>375</td>
<td>490-660</td>
<td>22</td>
<td>-40</td>
<td>47</td>
</tr>
<tr>
<td>2Y 40</td>
<td>400</td>
<td>510-690</td>
<td>22</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>3Y 40</td>
<td>400</td>
<td>510-690</td>
<td>22</td>
<td>-20</td>
<td>47</td>
</tr>
<tr>
<td>4Y 40</td>
<td>400</td>
<td>510-690</td>
<td>22</td>
<td>-40</td>
<td>47</td>
</tr>
<tr>
<td>5Y 40</td>
<td>400</td>
<td>510-690</td>
<td>22</td>
<td>-60</td>
<td>47</td>
</tr>
</tbody>
</table>

1.5.2.4.3 Butt weld tests

1.5.2.4.3.1 Preparation of butt weld test assemblies

Butt weld assemblies as shown in Fig. 1.5.2.4.3 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward and overhead) for which the electrode is recommended by the manufacturer, except that electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position subject to the agreement of the Register.

Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

For the preparation of the test assemblies one of the steel grades as listed below for the individual electrode grades shall be used:

- Grade 1 electrodes: A.
- Grade 2 electrodes: A, B, D.
- Grade 3 electrodes: A, B, D, E.
- Grade 2Y electrodes: A32, A36, D32, D36, E32, E36.
- Grade 3Y electrodes: A32, A36, D32, D36, E32, E36, F32, F36.
- Grade 2Y 40 electrodes: A40, D40.
- Grade 3Y 40 electrodes: A40, D40, E40, F40.
- Grade 4Y 40 electrodes: A40, D40, E40, F40.
- Grade 5Y 40 electrodes: A40, D40, E40, F40.

Where higher strength steel with minimum yield strength 315 N/mm² is used for grade 2Y, 3Y and 4Y electrodes, the actual tensile strength of the steel is to be not less than 490 N/mm².

The chemical composition including the content of grain refining elements is to be reported.

1.5.2.4.3.2 Sequence of welding

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured.

Downhand (b) Where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured.

Horizontal - vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3.25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

For all assemblies 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.

For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

Normal welding practice is to be used, and between each run the assembly is to be left in still air until it has cooled to less than 250°C but not below 100°C, the temperature being taken in the centre of the weld, on the surface of the seam. After welding, the test assemblies are not to be subjected to any heat treatment.
1.5.2.4.3 Radiographic examination

It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

1.5.2.4.3.4 Execution of tests

The test specimens as shown in Figure 1.5.2.4.3 are to be prepared from each test assembly.

Tests are to be performed according to Section 1.5.2.3 requirements.

1.5.2.4.3.5 Result of tests and requirements

The results of all tensile and impact tests are to comply with the requirements of Table 1.5.2.4-2 as appropriate. The position of fracture in the transverse tensile test is to be reported. The bend test specimens can be considered as complying with the requirements if, after bending, no crack or defect having any dimensions exceeding 3 mm can be seen on the outer surface of the test specimen.

![Butt weld test assembly](image)

**Figure 1.5.2.4.3**
Butt weld test assembly

**Table 1.5.2.4-2**
Requirements for butt weld test (covered manual electrodes)

<table>
<thead>
<tr>
<th>Quality grade of consumables</th>
<th>Tensile strength (transverse test) (N/mm²)</th>
<th>Test temperature (°C)</th>
<th>Charpy V-notch impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Downhand, horizontal-vertical, overhead</td>
<td>Vertical (upward and downward)</td>
</tr>
<tr>
<td>1</td>
<td>400</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td>-20</td>
<td>47</td>
</tr>
<tr>
<td>2Y</td>
<td>490</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>3Y</td>
<td>490</td>
<td>-20</td>
<td>47</td>
</tr>
<tr>
<td>4Y</td>
<td>490</td>
<td>-40</td>
<td>47</td>
</tr>
<tr>
<td>2Y 40</td>
<td>510</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>3Y 40</td>
<td>510</td>
<td>-20</td>
<td>47</td>
</tr>
<tr>
<td>4Y 40</td>
<td>510</td>
<td>-40</td>
<td>47</td>
</tr>
<tr>
<td>5Y 40</td>
<td>510</td>
<td>-60</td>
<td>47</td>
</tr>
</tbody>
</table>
1.5.2.4.4 Hot cracking test

1.5.2.4.4.1 Hot cracking test may be required at the discretion of the Register.

1.5.2.4.5 Hydrogen test

1.5.2.4.5.1 Hydrogen marks

At the request of the manufacturer, electrodes may be submitted to a hydrogen test. A suffix H15, H10 or H5 will be added to the grade number to indicate compliance with the requirements of this test.

1.5.2.4.5.2 Execution of hydrogen test

The mercury method or thermal conductivity detector method according to standard ISO 3690 is to be used. Four weld assemblies are to be prepared. The temperature of the specimens and minimum holding time are to be complying with following, according to the measuring method respectively.

<table>
<thead>
<tr>
<th>Measuring Method</th>
<th>Test temperature (°C)</th>
<th>Minimum Holding Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Conductivity Detector</td>
<td>Gas Chromatography</td>
<td>45</td>
</tr>
<tr>
<td>Method¹</td>
<td></td>
<td>150</td>
</tr>
</tbody>
</table>

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

Four test specimens are to be prepared, measuring 12 mm by 25 mm in cross section by about 125 mm in length. The parent metal may be any grade of ship structural steel and, before welding, the specimens are to be weighed to the nearest 0.1 gram. On the 25 mm surface of each test specimen, a single bead of welding is to be deposited, about 100 mm in length by a 4 mm electrode, fusing 150 mm of the electrode. The welding is to be carried out with an arc as short as possible and with a current of about 150 amp.

The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer. 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 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.

The specimens are to be kept immersed in the glycerine for a period of 48 hours and, after removal, are to be cleaned in water and spirit dried and weighed to the nearest 0.1 gram to determine the amount of weld deposit. The amount of gas involved is to be measured to the nearest 0.05 cm³ and corrected for temperature and pressure to 0°C and 760 mm Hg.

1.5.2.4.5.3 Results to be obtained

The individual and average diffusible hydrogen contents of the four specimens are to be reported, and the average value in cm³ per 100 grams is not to exceed the following:

<table>
<thead>
<tr>
<th>Mark</th>
<th>Diffusible Hydrogen Contents</th>
<th>Measuring Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>H15</td>
<td>15¹</td>
<td>Mercury Method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thermal Conductivity Detector Method</td>
</tr>
<tr>
<td>H10</td>
<td>10²</td>
<td>Glycerine Method</td>
</tr>
<tr>
<td>H5</td>
<td>5</td>
<td>Mercury Method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thermal Conductivity Detector Method</td>
</tr>
</tbody>
</table>

Notes:
1) 10 cm³ per 100 grams where the glycerine method is used.
2) 5 cm³ per 100 grams where the glycerine method is used.

Note: The glycerine method is not to be used for the welding consumables with H5 mark.
1.5.2.4.6 Covered electrodes for manual fillet welding

1.5.2.4.6.1 General

Where an electrode is submitted only to approval for fillet welding and to which the butt weld test provided in 1.5.2.4.3 is not considered applicable, the first approval tests are to consist of the fillet weld tests given in 1.5.2.4.6.2, and deposited metal tests similar to those indicated in 1.5.2.4.2.

Where an electrode is submitted to approval for both butt and fillet welding, the first approval tests may, at the discretion of the Register, include one fillet weld test as detailed hereunder and welded in the horizontal-vertical position.

1.5.2.4.6.2 Fillet weld test assemblies

When the electrode is proposed only for fillet welding, fillet weld assemblies as shown in Figure 1.5.2.4.6-1, are to be prepared for each welding position (horizontal-vertical, vertical upwards, vertical downwards or overhead) for which the electrode is recommended by the manufacturer. The length of the test assemblies L is to be sufficient to allow at least the deposition of the entire length of the electrode being tested.

The grade of steel used for the test assemblies is to be as detailed in 1.5.2.4.3.1.

The first side is to be welded using the maximum size of electrode manufactured and the second side is to be welded using the minimum size of electrode manufactured and recommended for fillet welding. The fillet size will in general be determined by the electrode size and the welding current employed during testing.

1.5.2.4.6.3 Tests on fillet weld assemblies

1) Macrographs

Each test assembly is to be sectioned to form three macro-sections each about 25mm thick. They are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosities and slag inclusions.

2) Hardness

At the discretion of the Register, the hardness of the weld, of the heat affected zone (HAZ) and of parent metal may be determined, and reported for information (see Figure 1.5.2.4.6-2).

3) Fracture

One of the remaining sections of the fillet weld is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld, on the second side by closing the two plates together, submitting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined and there should be no evidence of incomplete penetration, or internal cracking and they should be reasonably free from porosity.

Figure 1.5.2.4.6-1
Fillet weld test assembly
1.5.2.4.7 Covered electrodes for gravity or contact welding

Where an electrode is submitted solely to approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, fillet weld tests (see 1.5.2.4.6) and, where appropriate, but weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

Where a covered electrode is submitted to approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, fillet weld and, where appropriate, but weld tests, using the gravity of other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

In the case of a fillet welding electrode using automatic gravity or similar contact welding devices, the fillet welding should be carried out using the welding process recommended by the manufacturer, with the longest size of the electrode manufactured. The manufacturer's recommended current range is to be reported for each electrode size.

Where approval is requested for the welding of both normal strength and higher strength steel, the assemblies are to be prepared using higher strength steel.

1.5.2.4.8 Annual tests and upgrading

1.5.2.4.8.1 Annual tests and periodical inspection of manufacturer's plant

All establishments where approved electrodes are manufactured shall be subject to annual inspection.

The annual tests are to consist of at least the following:

1) Covered electrode for normal manual arc welding

Two deposited metal test assemblies are to be prepared in accordance with 1.5.2.4.2. The mechanical properties (one tensile test, 3 Charpy V impact tests on each assembly) are to be in accordance with Table 1.5.2.4-1. This also applies to electrodes which are approved only for fillet welding.

At the discretion of the Register a butt weld test to be welded in down-hand or in vertical position, can be required in lieu of the deposited metal test 4 mm electrodes. Three Charpy V-notch impact test specimens are to be taken from the butt weld assembly.

For Mark H 10 and Mark H 5 covered electrodes, a hydrogen test following 1.5.2.4.5 can also be required for each annual test at the discretion of the Register.

2) Covered electrodes for gravity or contact welding

Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer. If this electrode is approved also for normal manual arc welding the annual test is to be performed according to 1.5.2.4.8.1-1).

1.5.2.4.8.2 Upgrading and uprating of electrodes

1) Upgrading and uprating will be considered only at the manufacturer's request, preferably at the time of annual testing. Generally, for this purpose, tests on butt-weld assemblies will be required in addition to the normal reapproval tests.

2) Upgrading refers to notch toughness and consequently, only Charpy V impact tests are required from the respective butt-weld assemblies as required by 1.5.2.4.3 (downhand, horizontal vertical, vertical up or/and down, overhead, as applicable), and have to be performed at the upgraded temperature.

These butt-weld tests are to be made in addition to the normal requirements for annual deposited metal tests (which have, of course, to take into consideration the upgraded temperature for Charpy V specimens).

3) Uprating refers to the extension of approval in order to cover the welding of higher strength steels; of course, welding of normal strength steels continue to be covered by the extended approval, as stated in 1.5.2.1.2.1.

For this purpose all butt-weld tests are to be made again, as required in 1.5.2.4.3 and using higher strength steel, as parent metal.
1.5.2.5 Wire flux combinations for submerged arc welding

1.5.2.5.1 General

1.5.2.5.1.1 Categories

Wire flux combinations for single electrode submerged arc automatic welding are divided into the following categories:

- For use with the multi-run technique
- For use with the two run technique

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

1.5.2.5.1.2 Grades

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/mm²: Grades 1Y, 2Y, 3Y or 4Y.
- For higher strength steels with minimum yield strength up to 390 N/mm²: Grades 2Y 40, 3Y 40, 4Y 40 or 5Y 40.

The suffixes T, M or TM will be added after the grade mark to indicate approval for the two run technique, multi-run technique or both techniques, respectively.

1.5.2.5.1.3 Multiple electrode submerged arc welding

Wire-flux combinations for multiple electrode submerged arc welding will be subject to separate approval tests. They are to be carried out generally in accordance with the requirements of this section.

1.5.2.5.1.4 Mechanical tests on assemblies

Mechanical tests on assemblies with submerged arc welding for wire/flux approval are given in Table 1.5.2.5-1.

1.5.2.5.2 Approval tests for multi-run technique

1.5.2.5.2.1 Grades of steel

Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

For deposited metal test assembly any grade of ship structural steel may be used.

For butt weld test assembly one of the grades of steel as listed below for the individual grades of wire-flux combinations shall be used:

- Grade 1 wire-flux combinations: A
- Grade 2 wire-flux combinations: A, B, D
- Grade 3 wire-flux combinations: A, B, D, E
- Grade 1 Y wire-flux combinations: A32, A36
- Grade 2Y wire-flux combinations: A32, A36, D32, D36
- Grade 3Y wire-flux combinations: A32, A36, D32, D36, E32, E36
- Grade 4Y wire-flux combinations: A32, A36, D32, D36, E32, E36, F32, F36
- Grade 2Y 40 wire-flux combinations: A40, D40
- Grade 3Y 40 wire-flux combinations: A40, D40 E40
- Grade 4Y 40 wire-flux combinations: A40, D40, E40, F40
- Grade 5Y 40 wire-flux combinations: A40, D40, E40, F40

1.5.2.5.2.2 Deposited metal test assembly

1) Preparation

One deposited metal test assembly is to be prepared as shown in Figure 1.5.2.5-1. Welding is to be carried out in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag is to be removed. Between each run the assembly is to be left in still air until it has cooled to less than 250 °C, but not below 100 °C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm.

The weld conditions, including amperage, voltage and rate of travel speed are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

2) Chemical analysis

At the discretion of the Register, the chemical analysis of the deposited weld metal in this test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements.

3) Execution of tests

In accordance with Table 1.5.2.5-1, the test specimens as shown in Figure 1.5.2.5-1 are to be prepared from each test assembly. Tests are to be performed according to Section 1.5.2.3 requirements.

4) Results and requirements

The results of all tests are to comply with the requirements of Table 1.5.2.5-2, as appropriate.
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All dimensions in mm unless otherwise indicated

Figure 1.5.2.5-1
Deposited metal test assembly

Table 1.5.2.5-1
General table giving the mechanical tests on assemblies with submerged arc welding for wire/flux approval

<table>
<thead>
<tr>
<th>M (multi-run technique)</th>
<th>T (two-run technique)</th>
<th>TM (two-run and multi-run technique)</th>
<th>Butt weld assembly</th>
<th>Multi-run technique</th>
<th>Two-run technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposited metal assembly</td>
<td>Butt weld assembly (minimum thickness)</td>
<td>Butt weld assembly (maximum thickness)</td>
<td>Deposited metal assembly</td>
<td></td>
<td>Minimum thickness</td>
</tr>
<tr>
<td>3CV</td>
<td>2TT</td>
<td>2TT</td>
<td>2TT</td>
<td>2TT</td>
<td>2TT</td>
</tr>
<tr>
<td>2LT</td>
<td>4TB</td>
<td>2TB</td>
<td>2TB</td>
<td>4TB</td>
<td>2TB</td>
</tr>
<tr>
<td></td>
<td>3CV</td>
<td>3CV</td>
<td>3CV</td>
<td>3CV</td>
<td>3CV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1LT</td>
<td>1LT</td>
<td></td>
<td>1LT</td>
</tr>
</tbody>
</table>

Symbol definitions:
TT Transverse Tensile Test on the butt weld assembly
TB Transverse Bend Test on the butt weld assembly
CV Charpy V-Impact Test in axis of the weld
LT Longitudinal Tensile Test in the weld
Table 1.5.2.5-2
Requirements for deposited metal tests (wire-flux combination)

<table>
<thead>
<tr>
<th>Grades of welding consumables</th>
<th>Yield stress (N/mm²) minimum</th>
<th>Tensile strength (N/mm²)</th>
<th>Elongation on 50 mm gauge length (L₀ = 5d) % minimum</th>
<th>Charpy V-notch impact test</th>
<th>Test temperature (°C)</th>
<th>Average energy (J), minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>305</td>
<td>400-560</td>
<td>22</td>
<td></td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td>34</td>
</tr>
<tr>
<td>1Y</td>
<td>375</td>
<td>490-660</td>
<td>22</td>
<td></td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>2Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>3Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td>34</td>
</tr>
<tr>
<td>4Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
<td>34</td>
</tr>
<tr>
<td>2Y 40</td>
<td>400</td>
<td>510-690</td>
<td>22</td>
<td></td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>3Y 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td>39</td>
</tr>
<tr>
<td>4Y 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
<td>39</td>
</tr>
<tr>
<td>5Y 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-60</td>
<td>39</td>
</tr>
</tbody>
</table>

1.5.2.5.2.3 Butt weld test assembly

1) Preparation

One butt weld test assembly is to be prepared as shown in Figure 1.5.2.5-2 in the downhand 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.

The welding is to be carried out by the multi-run technique and the welding conditions are to be the same as those adopted for the deposited metal test assembly.

The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

After welding the test assembly is not to be subject to any heat treatment.

2) Radiographic examination

It is recommended that the welded assembly be subject to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3) Execution of tests

The test specimen to be prepared from the welded assembly are given in Table 1.5.2.5-1 and shown in Fig. 1.5.2.5-2. The tests are to be performed according to the requirements of Section 1.5.2.3.

3) Results of tests and requirements

The results of all tensile and impact tests are to comply with the requirements of Table 1.5.2.5-3 as appropriate. The position of the fracture in the transverse tensile test is to be reported.

The bend test specimens can be considered as complying with the requirements if, after bending, no crack or defect, having any dimension exceeding 3 mm can be seen on the outer surface of the test specimen.
All dimensions in mm unless otherwise indicated

**Figure 1.5.2.5-2**
Multi-run butt weld test assembly (submerged arc welding)

**Table 1.5.2.5-3**
Requirements for butt weld tests (wire-flux combination)

<table>
<thead>
<tr>
<th>Grade of welding consumables</th>
<th>Tensile strength (transverse test) (N/mm²)</th>
<th>Charpy V-notch impact tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Test temperature (°C)</td>
</tr>
<tr>
<td>1</td>
<td>400</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td>-20</td>
</tr>
<tr>
<td>1Y</td>
<td>490</td>
<td>20</td>
</tr>
<tr>
<td>2Y</td>
<td>490</td>
<td>0</td>
</tr>
<tr>
<td>3Y</td>
<td>490</td>
<td>-20</td>
</tr>
<tr>
<td>4Y</td>
<td>490</td>
<td>-40</td>
</tr>
<tr>
<td>2Y 40</td>
<td>510</td>
<td>0</td>
</tr>
<tr>
<td>3Y 40</td>
<td>510</td>
<td>-20</td>
</tr>
<tr>
<td>4Y 40</td>
<td>510</td>
<td>-40</td>
</tr>
<tr>
<td>5Y 40</td>
<td>510</td>
<td>-60</td>
</tr>
</tbody>
</table>
1.5.2.5.3 Approval tests for two-run technique

1.5.2.5.3.1 Number of test assemblies

Where approval for use with the two-run technique is requested, two but weld test assemblies are to be prepared using the following thicknesses:

- For grades 1 and 1Y: 12 to 15 mm and 20 to 25 mm
- For grades 2, 2Y, 3, 3Y and 4Y: 20 to 25 mm and 30 to 35 mm
- For grades 2Y 40, 3Y 40, 4Y 40 and 5Y 40: 20 to 25 mm and 30 to 35 mm

A limitation of the approval to the medium range (up to the maximum welded plate thickness) may be agreed to by the Register. Test assemblies shall then be welded using plates of 12 to 15mm and 20 to 25mm irrespective of the grade for which the approval is requested.

When a wire-flux combination is offered to approval for use with the two-run technique only, it is reminded that no deposited metal test assemblies have to be done. In this case approval tests are limited to the butt welds on two-run assemblies described in 1.5.2.5.3.2 hereafter.

Where approval is requested for welding of both normal strength and higher strength steel two assemblies are to be prepared using higher strength steel. Two assemblies prepared using normal strength steel may also be required at the discretion of the Register.

1.5.2.5.3.2 Butt weld tests assemblies

1) Preparation of assemblies

The maximum diameter of wire, grades of steel plate and edge preparation to be used are to be in accordance with Fig. 1.5.2.5-3. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The root gap should not exceed 1 mm.

Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of manufacturer and normal good welding practice.

After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

After welding, the test assemblies are not to be subjected to any heat treatment.

2) Radiographic examination

It is recommended that the welded assemblies are subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3) Execution of tests

The test specimens indicated in Table 1.5.2.5-1 and shown in Figure 1.5.2.5-4 are to be prepared from each test assembly. Tests are to be performed according to Section 1.5.2.3 requirements. The Charpy V-notch impact test specimens are to be machined from each welded assembly from the positions and with the orientations shown in Fig. 1.5.2.5-5.

4) Results of tests and requirements

The results of all tensile and impact tests are to comply with the requirements of table 5b and 5c as appropriate. The position of fracture in the transverse tensile test is to be reported. The bend test specimens can be considered as complying with the requirements if, after bending, no crack or defect having any dimensions exceeding 3 mm can be seen on the outer surface of the test specimen.

5) Chemical analysis

The chemical analysis of the weld metal is to be supplied by the manufacturer, and is to include the content of all significant alloying elements.
### Table 1.5.2.5-3

Butt weld test assemblies (two-run technique)

<table>
<thead>
<tr>
<th>Plate thickness (mm)</th>
<th>Recommended preparation (mm)</th>
<th>Maximum diameter of wire (mm)</th>
<th>Grade wire-flux combination</th>
<th>Grade of normal strength steel</th>
<th>Grade of higher strength steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>about 12-15</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>5</td>
<td>1</td>
<td>A</td>
<td>-</td>
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<tr>
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<td></td>
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<td></td>
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<td>A32, A36, D32, D36</td>
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<td>A40, D40</td>
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<td>A40, D40, E40</td>
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<td>4Y</td>
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<tr>
<td></td>
<td></td>
<td>4Y 40</td>
<td>A40, D40, E40, F40</td>
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<tr>
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<td></td>
<td>5Y 40</td>
<td>A40, D40, E40, E40, F40</td>
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<td><img src="image3.png" alt="Diagram" /></td>
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<td>-</td>
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<td></td>
<td></td>
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<td>A32, A36, D32, D36</td>
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<tr>
<td></td>
<td></td>
<td>2Y 40</td>
<td>A40, D40</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>A, B, D or E</td>
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<td>E32, E36, F32, F36</td>
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<td></td>
<td>5Y 40</td>
<td>A40, D40, E40, E40, F40</td>
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</table>
1.5.2.5.4 Annual tests – upgrading

1.5.2.5.4.1 Annual tests

All establishments where approved wire/flux combinations are manufactured shall be subject to annual inspection.

Annual tests are to consist of at least the following:

a) multi-run technique: on deposited metal assembly and tests: 1 tensile and 3 impact tests.

b) two-run technique: one butt weld assembly with 20 mm minimum thickness plate and tests: 1 transverse tensile, 2 transverse bends and 3 impact tests. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

The assemblies are to be prepared and tested in accordance with the requirements for initial approval.

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 1.5.2.5.4.1 b).
1.5.2.5.4.2 Upgrading and rating

1.5.2.5.4.2.1 Upgrading of wire-flux combinations in connection with the impact properties will be considered as detailed in 1.5.2.4.8.2-2), and for wire-flux combinations approved for two runs welding, a butt-weld in the maximum thickness approved is to be made and sampled for Charpy-V testing in accordance with 1.5.2.5.3.2-3).

1.5.2.5.4.2.2 Upgrading of wire-flux combinations in connection with the tensile properties will be considered as detailed in 1.5.2.4.8.2-3).

1.5.2.6 Wires and wire-gas combinations for metal arc welding

1.5.2.6.1 General

1.5.2.6.1.1 Categories

Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:

a) For use in semi-automatic multi-run welding.

b) For use in single electrode automatic multi-run welding.

c) For use in single electrode automatic two-run welding.

NOTE:
The term semi-automatic is used to describe processes in which the weld is made manually by a welder holding a gun through which the electrode wire is continuously fed.

1.5.2.6.1.2 Grades and suffixes

1) 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/mm²: Grades 1Y, 2Y, 3Y and 4Y.
   - For higher strength steels with minimum yield strength up to 390 N/mm²: Grades 2Y 40, 3Y 40, 4Y 40 and 5Y 40.

2) A suffix "S" will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

3) For wires intended for automatic welding, the suffixes "T", "M" or "TM" will be added after the grade mark to indicate approval for two-run, multi-run, or both welding techniques, respectively.

4) For wires intended for both semi-automatic and automatic welding, the suffixes will be added in combination.

1.5.2.6.1.3 Composition of shielding gas

1) Where applicable, the composition of the shielding gas is to be reported. Unless otherwise agreed by the Register, additional approval tests are required when a shielding gas is used other than that used for the original approval tests.

2) The approval of a wire in combination with any particular gas can be applied or transferred to any combination of the same wire and any gas in the same numbered group as defined in Table 1.5.2.6-1, subject to the agreement of the Register.

Table 1.5.2.6-1

<table>
<thead>
<tr>
<th>Group</th>
<th>CO₂</th>
<th>O₂</th>
<th>H₂</th>
<th>Ar</th>
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<tbody>
<tr>
<td>M1</td>
<td></td>
<td></td>
<td>&gt; 0 to 5</td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>2</td>
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<td></td>
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<td>&gt; 0 to 3</td>
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<td></td>
</tr>
<tr>
<td>M2</td>
<td></td>
<td></td>
<td>&gt; 0 to 5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>&gt; 5 to 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&gt; 5 to 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td></td>
<td></td>
<td>&gt; 0 to 5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>&gt; 25 to 50</td>
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<td></td>
<td></td>
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<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&gt; 25 to 50</td>
<td></td>
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<tr>
<td>C</td>
<td></td>
<td></td>
<td>&gt; 0 to 30</td>
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<td>1</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>Rest</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1) Argon may be substituted by Helium up to 95% of the Argon content.
2) Approval covers gas mixtures with equal or higher Helium contents only.
1.5.2.6.1.4 Low hydrogen approval

1) Flux-cored or flux-coated wires which have satisfied the requirements for Grades 2, 2Y, 2Y 40, 3, 3Y, 3Y 40, 4Y, 4Y 40 and 5Y 40 may, at manufacturer's option, be submitted to the hydrogen test as detailed in 1.5.2.4.5, using the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weight of weld deposit per sample similar to that deposited when using manual electrodes.

2) A suffix H15, H10 or H5 will be added to the grade mark, in the same conditions as for manual arc welding electrodes (see 1.5.2.4.5.3 above) to indicate compliance with the requirements of the test.

1.5.2.6.2 Approval for semi-automatic multi-run welding

1.5.2.6.2.1 General

Approval tests for semi-automatic multi-run welding are to be carried out generally in accordance with Section 1.5.2.4, except as required by 1.5.2.6.2, using the semi-automatic multi-run technique for the preparation of all test assemblies.

1.5.2.6.2.2 Preparation of deposited metal assemblies

1) Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 1.5.2.4.2, one using the smallest diameter, and the other using the largest diameter of wire intended for the welding of ship structures. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

2) The weld metal is to be deposited according to the practice recommended by themanufacturer, and the thickness of each layer of weld metal is to be between 2 and 6 mm.

1.5.2.6.2.3 Chemical analysis

The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer, and is to include the content of all significant alloying elements.

1.5.2.6.2.4 Mechanical tests

On each assembly, tests are to be made in accordance with 1.5.2.4.23, and the results are to comply with the requirements of 1.5.2.4.24, appropriate to the required grade.

1.5.2.6.2.5 Preparation of butt weld assemblies

1) Butt weld assemblies as shown in Fig. 1.5.2.4.3 are to be prepared for each welding position (downhand, horizontal-vertical, vertical upwards, vertical downwards and overhead) for which the wire or wire-gas combination is recommended by the manufacturer.

2) The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

3) Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using wires of different diameter from those required by 1.5.2.6.2.5-2). Where only one diameter is manufactured, only one downhand butt weld assembly is to be prepared.

4) The butt weld assemblies in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and, for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

1.5.2.6.6 Radiographic examination

It is recommended that the welded assemblies are subjected to radiographic examination to ascertain if there are any defects in the welds prior to the preparation of test specimens.

1.5.2.6.7 On each assembly, tests are to be made in accordance with 1.5.2.4.3.4, and the results are to comply with the requirements of 1.5.2.4.3.5.

1.5.2.6.2.8 Fillet weld tests

Fillet weld test assemblies are required to be made in accordance with 1.5.2.4.6.1 and 1.5.2.4.6.2, and tested in accordance with 1.5.2.4.6.3.

1.5.2.6.3 Approval for automatic multi-run welding

1.5.2.6.3.1 General

Approval tests for automatic multi-run welding are to be carried out generally in accordance with section 1.5.2.5 multi-run approval, except as required by 1.5.2.5.2, using the automatic multi-run technique for the preparation of all test assemblies.

1.5.2.6.3.2 Preparation of deposited metal assembly

One deposited metal assembly is to be prepared as shown in Fig. 1.5.2.5-1. Welding is to be as detailed in 1.5.2.5.2.2.1, except that the thickness of each layer is to be not less than 3 mm.

1.5.2.6.3.3 Chemical analysis

The chemical analysis of the deposited weld metal in this test assembly is to be supplied by the manufacturer, and is to include the content of all significant alloying elements.
1.5.2.6.3.4 Mechanical tests

Tests on this assembly are to be made in accordance with 1.5.2.5.2.3, and the results are to comply with the requirements of 1.5.2.5.2.2-4).

1.5.2.6.3.5 Preparation of butt weld weld assemblies

One butt weld assembly is to be prepared in each welding position which is to be approved.

Generally, this will be the downhand position only, in which case only one assembly is required. Preparation of the assembly is to be in accordance with 1.5.2.5.2.3-1).

1.5.2.6.3.6 Radiographic examination

It is recommended that each assembly be subjected to a radiographic examination to ascertain any defect in the weld prior to testing.

1.5.2.6.3.7 Mechanical tests

Tests are to be made on each assembly in accordance with 1.5.2.5.2.3-3) and the results are to comply with the requirements of Table 1.5.2.5.3. Where more than one assembly is prepared and tested, the number of transverse tensile and bend test specimens from each assembly may be halved.

1.5.2.6.3.8 Discretionary approval

At the discretion of the Register, wires or wire-gas combinations approved for semi-automatic multi-run welding may also be approved, without additional tests, for automatic multi-run welding approval.

This is generally the case when automatic multi-run welding is performed in the same conditions of welding current and energy as semi-automatic welding with the concerned wire-gas combination.

The only difference between the two welding processes in this case is that the welding gun is held by an automatic device instead of the welder's hand.

1.5.2.6.4 Approval for automatic two-run welding

6.4.1 General

Approval tests for automatic two-run welding are to be carried out generally in accordance with the requirements of Section 1.5.2.5.3, except as required by 1.5.2.6.4, using the automatic two-run welding technique for the preparation of all test assemblies.

1.5.2.6.4.2 Preparation of butt weld assemblies

1) Two butt weld test assemblies are to be prepared, generally as detailed in 1.5.2.5.3.1 and 1.5.2.5.3.2, using plates 12-15 mm and 20-25 mm in thickness. 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.

2) The plate preparation of the test assemblies is to be as shown in Fig. 1.5.2.6. 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.

3) The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.
1.5.2.6.3 Radiographic examination

It is recommended that the welded assemblies be subjected to radiographic examination to ascertain any defect in the weld prior to testing, and to confirm full penetration continuously along the major part of the welded length of each assembly.

1.5.2.6.4.4 Mechanical tests

Tests are to be made on each assembly in accordance with 1.5.2.5.3.2-3 to 1.5.2.5.3.2-5 and the results are to comply with the requirements of 1.5.2.5.2.2-4) and Table 1.5.2.5-3.

1.5.2.6.4.5 Chemical analysis

The chemical analysis of the deposited weld metal on the second side welded, is to be reported for each assembly.

1.5.2.6.5 Annual tests and up-grading

1.5.2.6.5.1 Annual tests

Annual tests are to consist of at least:

a) Wires approved for semi-automatic or both semi-automatic and automatic multi-run welding: one deposited metal test assembly prepared in accordance with 1.5.2.6.2.2 using a wire of diameter within the range approved for the semi-automatic multi-run welding of ship structures.

b) Wires approved for automatic multi-run welding: one deposited metal test assembly prepared in accordance with 1.5.2.6.3.2 using a wire of diameter within the range approved for automatic multi-run welding of ship structures.

c) Wires approved for automatic two-run welding: one butt weld test assembly prepared in accordance with 1.5.2.6.4.2 using plates of 20-25 mm in thickness. The wire diameter used is to be reported.

The test specimens are to be prepared and tested in accordance with the requirements of this Section, except that only the following tests are required:

a) For deposited metal assemblies (semi-automatic and automatic multi-run): one tensile and three impact tests.

b) For butt weld assemblies (automatic two-run): one transverse tensile, two bend and three impact tests. One longitudinal tensile test is also required where the wire is approved solely for automatic two-run welding.

Note:

At the discretion of the Register, hydrogen test can be carried out following 1.5.2.4.5.

1.5.2.6.5.2 Up-grading and up-rating

1) Up-grading of flux cored wires and wire-gas combinations in connection with the impact properties will be considered as detailed in 1.5.2.4.8.2-2.)

2) Up-rating of flux cored wires and wire-gas combinations with the tensile properties will be considered as detailed in 1.5.2.4.8.2-3).

1.5.2.7. Consumables for use in electroslag and electrogas vertical welding

1.5.2.7.1 General

1.5.2.7.1.1 The requirements for the two-run technique as detailed in Section 1.5.2.5 are applicable for the approval of
special consumables used in electro-slag and electro-gas vertical welding with or without consumable nozzles except as otherwise required by the following requirements especially as regards the number and kind of the test-pieces used for the mechanical tests and taken from the butt welded assemblies.

1.5.2.7.1.2 For Grades 1Y, 2Y, 3Y, 4Y, 2Y 40, 3Y 40, 4Y 40 and 5Y 40 approval of the consumables may be restricted for use only with specific types of higher strength steel. This is in respect of the content of grain refining elements, and if general approval is required, a niobium treated steel is to be used for the approval tests.

1.5.2.7.1.3 For these special welding consumables, the prescription 1.5.2.1.2.1 may not be entirely applicable for technical reasons.

Where approval is requested for welding of both normal strength and higher strength steel two assemblies are to be prepared using higher strength steel. Two assemblies prepared using normal strength steel may also be required at the discretion of the Register.

1.5.2.7 Butt weld tests

1.5.2.7.2 Preparation of test assemblies

Two butt weld test assemblies are to be prepared, one of them with plates 20/25 mm thick, the other with plates 35/40 mm thick or more. The grade of the steel to be used for each one of these assemblies must be selected according to the requirements given in the Figure 1.5.2.5-3 for two-run submerged arc welding.

The chemical composition of the plate, including the content of grain refining elements is to be reported.

The welding conditions and the edge preparation are to be those recommended by the welding consumable manufacturer and are to be reported.

1.5.2.7.2.2 Radiographic examination

It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

1.5.2.7.2.3 Test series

Each assembly shall be cut to give test specimens according to Figure 1.5.2.7.

The length of the assembly should be sufficient to allow the selection of all the test specimens:

- 2 longitudinal tensile test specimens with their axis at the centre of the weld.
- 2 transverse tensile test specimens.
- 2 sets of 3 Charpy-V notch impact test specimens in accordance with Figure 1.5.2.7:
  - 1 set with the notch in the axes of the weld,
  - 1 set with the notch at 2 mm from the fusion line in the deposited metal.
- 2 macro-sections to the weld (towards the middle of the weld and towards one end).

1.5.2.7.2.4 Results to be obtained

The results of the tensile, bend and impact tests are to comply with the requirements of paragraph 1.5.2.5.3 (two-run welding) for the class of filler product in question.

1.5.2.7.3 Annual tests and up-grading

1.5.2.7.3.1 All factories which manufacture approved consumables for use in electroslag and electrogas welding must be subject to an annual inspection and tests in accordance with 1.5.2.2.4.

1.5.2.7.3.2 One test assembly must be prepared from plates 20/25 mm thick, and tested as indicated in 1.5.2.7.2. The following specimens are to be selected:

- 1 longitudinal tensile specimen from the axis of the weld,
- 1 transverse tensile specimen,
- 2 side bend specimens,
- 3 Charpy-V specimens notched at the centre of the weld (position 1 Fig. 1.5.2.7),
- 3 Charpy-V specimens cut out transverse to the weld with their notches at 2 mm from the fusion line, in the weld,
- macro section.

1.5.2.7.3.3 The results to be obtained should meet the requirements given in 1.5.2.5.3 (two-run welding) for the class of the consumables in question.

1.5.2.7.3.4 Upgrading and uprating

Upgrading and uprating will be considered only at the manufacturer's request, at the time of annual testing. Generally, for this purpose, full tests from butt weld assemblies as indicated in 1.5.2.7.2 will be required, irrespective of the other tests requested if the concerned consumable is also approved (and possibly upgraded or uprated) according to Section 1.5.2.5 or Section 1.5.2.6.
1.5.3 Approval of Welding Consumables for High Strength Steels for Welded Structures

1.5.3.1 General

1.5.3.1.1 Scope

These requirements supplements the 1.5.2 and give the conditions of approval and inspection of welding consumables used for high strength steels for welded structures according to the Rules, Part 25 – Metallic materials, Section 3.4 with yield strength levels from 420 N/mm² up to 960 N/mm² and impact grades A, D, E and F, except that impact grade F is not applicable for 890 N/mm² and 960 N/mm² yield strength levels. Where no special requirements are given, those of 1.5.2 apply in analogous manner.

1.5.3.1.2 The welding consumables preferably to be used for the steels concerned are divided into several categories as follows:

- covered electrodes for manual welding,
- wire-flux combinations for multi-run submerged arc welding,
- solid wire-gas combinations for arc welding (including rods for gas tungsten arc welding),
- flux cored wire with or without gas for arc welding.

Figure 1.5.2.7
Electroslag and electrogas butt weld test assembly
*) Wire-flux combinations for single or two-run technique are subject to special consideration of the Register.

1.5.3.1.2 Grading, Designation

1.5.3.1.2.1 Based on the yield strength of the weld metal, the welding consumables concerned are divided into *eight* (yield) strength groups:

- Y42 - for welding steels with minimum yield strength 420 N/mm²
- Y46 - for welding steels with minimum yield strength 460 N/mm²
- Y50 - for welding steels with minimum yield strength 500 N/mm²
- Y55 - for welding steels with minimum yield strength 550 N/mm²
- Y62 - for welding steels with minimum yield strength 620 N/mm²
- Y69 - for welding steels with minimum yield strength 690 N/mm²
- Y89 - for welding steels with minimum yield strength 890 N/mm²
- Y96 - for welding steels with minimum yield strength 960 N/mm²

1.5.3.1.2.2 Each of the *eight* (yield) strength groups is further divided into three main grades in respect of Charpy V-notch impact test requirements (test temperatures):

- Grade 3, test temperature -20°C
- Grade 4, test temperature -40°C
- Grade 5, test temperature -60°C

1.5.3.1.2.3 Analogously to the designation scheme used in 1.5.2 the welding consumables for high strength steels are subject to classification designation and approval as follows:

- According to 1.5.3.1.2.2 with the quality grade 3, 4 or 5.
- With the added symbol Y and an appended code number designating the minimum yield strength of the weld metal corresponding to 1.5.3.1.2.1: Y42, Y46, Y50, Y55, Y62, Y69, Y89 and Y96.
- With the added symbol H10 or H5 for controlled hydrogen content of the weld metal.
- With the added symbol S (semi-automatic) for semi-mechanised welding.
- With the added symbol M designating multi-run technique (and is applicable only to welding consumables for fully mechanised welding).

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

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 for which they have been approved.

Where the design requirements permit undermatching weld joint, then welding consumables within the scope of this section can be considered subject to Register discretion and Manufacturer’s recommendations.

The Register may, in individual cases, restrict the range of application in (up to) such a way, that approval for any one strength level does not justify approval for any other strength level.

1.5.3.1.3 Manufacture, testing and approval procedure

1.5.3.1.3.1 Manufacturer’s plant, production methods and quality control measures shall be such as to ensure reasonable uniformity in manufacture, see also 1.5.2.

1.5.3.1.3.2 Testing and approval procedure shall be in accordance with sections 1.5.2.2 and 1.5.2.3 and as required in 1.5.2 for the individual categories (types) of welding consumables mentioned in 1.5.3.1.1.2 above.

1.5.3.2 Testing of the Weld Metal

1.5.3.2.1 For testing the deposited weld metal, test pieces analogous to those called for in sections 1.5.2.4.2, 1.5.2.5.2, 1.5.2.6.2 or 1.5.2.6.3 respectively shall be prepared, depending on the type of the welding consumables (and according to the welding process). The base metal used shall be a fine-grained structural steel comparable with the properties of the weld metal, or the side walls of the weld shall be buttered with a weld metal of the same composition.

1.5.3.2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in 1.5.2.4.2.2. 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.

1.5.3.2.3 Depending on the type of welding consumables (and according to welding process), the test specimens prescribed in 1.5.2.3.1, 1.5.2.4.2, 1.5.2.6.2 or 1.5.2.6.3 respectively shall be taken from the weld metal test pieces in a similar manner.

<table>
<thead>
<tr>
<th>Consumable Grade</th>
<th>Steel Grades covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Y...</td>
<td>D., and A.,</td>
</tr>
<tr>
<td>4 Y...</td>
<td>E., D., and A.,</td>
</tr>
<tr>
<td>5 Y...</td>
<td>F., E., D., and A.,</td>
</tr>
</tbody>
</table>
1.5.3.2.4 The mechanical properties shall meet the requirements stated in Table 1.5.3-1 and Table 1.5.3-2. The provisions of 1.5.2 apply in analogous manner to the performance of tests, including in particular to the maintenance of the test temperature in the notched bar impact test and the carrying out of results.

**Table 1.5.3-1**
Required toughness properties of the weld metal

<table>
<thead>
<tr>
<th>Quality grade</th>
<th>Test temperature [°C]</th>
<th>Minimum notch impact energy [J]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-20</td>
<td>Y42 : ≥ 47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y46 : ≥ 47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y50 : ≥ 50</td>
</tr>
<tr>
<td>4</td>
<td>-40</td>
<td>Y55 : ≥ 55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y62 : ≥ 62</td>
</tr>
<tr>
<td>5</td>
<td>-60</td>
<td>Y69 : ≥ 69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y89 : ≥ 69&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y96 : ≥ 69&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Note:**
1) Charpy V-notch impact test specimen, mean value of three specimens; for requirements regarding minimum individual values and re-tests, see 1.5.2.3.3.2.
2) Quality grade 5 is not applicable for Y89 and Y96 grade consumables.

**Table 1.5.3-2**
Required strength properties of the weld metal

<table>
<thead>
<tr>
<th>Symbols added to quality grade</th>
<th>Minimum yield strength or 0.2% proof stress [N/mm²]</th>
<th>Tensile strength [N/mm²]</th>
<th>Minimum elongation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y42</td>
<td>420</td>
<td>520 - 680</td>
<td>20</td>
</tr>
<tr>
<td>Y46</td>
<td>460</td>
<td>540 - 720</td>
<td>20</td>
</tr>
<tr>
<td>Y50</td>
<td>500</td>
<td>590 - 770</td>
<td>18</td>
</tr>
<tr>
<td>Y55</td>
<td>550</td>
<td>640 - 820</td>
<td>18</td>
</tr>
<tr>
<td>Y62</td>
<td>620</td>
<td>700 - 890</td>
<td>18</td>
</tr>
<tr>
<td>Y69</td>
<td>690</td>
<td>770 - 940</td>
<td>17</td>
</tr>
<tr>
<td>Y89</td>
<td>890</td>
<td>940 - 1100</td>
<td>14</td>
</tr>
<tr>
<td>Y96</td>
<td>960</td>
<td>980 - 1150</td>
<td>13</td>
</tr>
</tbody>
</table>
1.5.3.3 Testing on welded joints

1.5.3.3.1 Depending on the type of the welding consumables (and according to the welding process), the testing on the welded joints shall be performed on butt-weld test pieces in analogous manner to sections 1.5.2.4.3, 1.5.2.5.2, 1.5.2.6.2, 1.5.2.6.3, or 1.5.2.6.4 respectively.

1.5.3.3.2 Depending on the type of the welding consumables (and according to the welding process), the butt-weld test pieces called for in 1.5.3.3.1 shall be welded in a manner analogous to that prescribed in 1.5.2. The base metal used shall be a high-strength fine-grained structural steel with minimum yield strength and tensile strength matching the consumable grade being approved and compatible with the added symbol for which application is made.

1.5.3.3.3 Depending on the type of the welding consumables (and according to the welding process), the test specimens described in 1.5.2. shall be taken from the butt-weld test pieces.

1.5.3.3.4 The mechanical properties must meet the requirements stated in Table 1.5.3-3. The provisions of 1.5.2 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.

1.5.3.3.5 Where the bending angle required in Table 1.5.3-3 is not achieved, the specimen may be considered as fulfilling the requirements, if the bending elongation on a gauge length \( L_0 \) fulfills the minimum elongation requirements stated in Table 1.5.3-2. The gauge length \( L_0 = L_s + t \) (\( L_s \) = width of weld, \( t \) = specimen thickness), see Figure 1.5.3 below.

<table>
<thead>
<tr>
<th>Quality grade</th>
<th>Added symbol</th>
<th>Minimum tensile strength [N/mm²]</th>
<th>Minimum notch impact energy, test temperature</th>
<th>Minimum bending angle¹)</th>
<th>Bend ratio ( D/t²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 5 in accordance with Table 1.5.3-1</td>
<td>Y42</td>
<td>520</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Y46</td>
<td>540</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Y50</td>
<td>590</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Y55</td>
<td>640</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Y62</td>
<td>700</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Y69</td>
<td>770</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Y89</td>
<td>940</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Y96</td>
<td>980</td>
<td></td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

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

²) \( D \) = mandrel diameter, \( t \) = specimen thickness.

1.5.3.4 Hydrogen Test

1.5.3.4.1 The welding consumables, other than solid wire-gas combinations, shall be subjected to a hydrogen test in accordance with the mercury method prescribed in ISO 3690, or any other method, such as the gas chromatographic method which correlates with that method, in respect of cooling rate and delay times during preparation of the weld samples, and the hydrogen volume determinations.

1.5.3.4.2 The diffusible hydrogen content of the weld metal determined in accordance with provisions of 1.5.2.4.5, shall not exceed the limits given in Table 1.5.3-4.

<table>
<thead>
<tr>
<th>Yield strength group</th>
<th>Hydrogen symbol</th>
<th>Maximum hydrogen content (cm³/100 g deposited weld metal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y55</td>
<td>H10</td>
<td>10</td>
</tr>
<tr>
<td>Y62</td>
<td>H5</td>
<td>5</td>
</tr>
<tr>
<td>Y69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y89</td>
<td>H5</td>
<td>5</td>
</tr>
<tr>
<td>Y96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.5.7.5 Annual Repeat Test

The annual repeat tests specified in 1.5.2 shall entail the preparation and testing of weld metal test pieces as prescribed under 1.5.3.2. For grades Y69 to Y96 annual hydrogen test is required. In special cases, the Register may require more extensive repeat tests.
1.5.4 Requirements for welding consumables for aluminium alloys

1.5.4.1 General

1.5.4.1.1 Scope

The following provisions give conditions for approval and inspection of welding consumables to be used for hull construction and marine structure aluminium alloys according to Rules, Part 25 - Metallic materials, Chapter 5 – Aluminium alloys. Where no special requirements are given herein, e.g. for the approval procedure or for the welding of test assemblies and testing, those of 1.5.2 apply in analogous manner.

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

\[ W = \text{wire electrode} \ \text{I and wire-gas combination for metal-arc inert gas welding} \]

\[ R = \text{rod-gas combination for tungsten inert gas arc welding} \ \text{TIG} \ (141) \ \text{or plasma arc welding} \ (15) \]

1.5.4.2 Grading, Designation

1.5.4.2.1 The consumables concerned are graded as mentioned in Table 1.5.4-1, in accordance with the alloy type and strength level of the base materials used for the approval tests.

1.5.4.2.2 Approval of a wire or a rod will be granted in conjunction with a specific shielding gas acc. to Table 1.5.4-2 or defined in terms of composition and purity of a special gas to be designated with group sign S. The composition of the shielding gas is to be reported. 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 1.5.4-2, subject to the agreement of the Register.

### Table 1.5.4-1

<table>
<thead>
<tr>
<th>Consumable quality grade (Symbol)</th>
<th>Base material for the tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alloy designation</td>
</tr>
<tr>
<td></td>
<td>Numerical</td>
</tr>
<tr>
<td>RA/WA</td>
<td>5754</td>
</tr>
<tr>
<td>RB/WB</td>
<td>5086</td>
</tr>
<tr>
<td>RC/WC</td>
<td>5083</td>
</tr>
<tr>
<td></td>
<td>5383</td>
</tr>
<tr>
<td></td>
<td>5456</td>
</tr>
<tr>
<td></td>
<td>5059</td>
</tr>
<tr>
<td>RD/WD</td>
<td>6005A</td>
</tr>
<tr>
<td></td>
<td>6061</td>
</tr>
<tr>
<td></td>
<td>6082</td>
</tr>
</tbody>
</table>

### Table 1.5.4-2

<table>
<thead>
<tr>
<th>Group</th>
<th>Gas composition (Vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Argon</td>
</tr>
<tr>
<td>I - 1</td>
<td>100</td>
</tr>
<tr>
<td>I - 2</td>
<td></td>
</tr>
<tr>
<td>I - 3</td>
<td>Rest</td>
</tr>
<tr>
<td>I - 4</td>
<td>Rest</td>
</tr>
<tr>
<td>I - 5</td>
<td>Rest</td>
</tr>
<tr>
<td>S</td>
<td>Special gas, composition to be specified, see 1.5.4.1.2.2</td>
</tr>
</tbody>
</table>

Note:  
1) Gases of other chemical composition (mixed gases) may be considered as “special gases” and covered by a separate test.
1.5.4.1.3 Manufacture, testing and approval procedure

1.5.4.1.3.1 Manufacturer’s plant, production methods and quality control measures shall be such as to ensure reasonable uniformity in manufacture, see also 1.5.2.

1.5.4.1.3.2 Testing and approval procedure shall be in accordance with 1.5.2.2 and 1.5.2.3 and as required in 1.5.2 for the individual categories (types) of welding consumables, shielding gases and their mixtures mentioned in 1.5.4.1.2 above.

1.5.4.2 Testing, required properties

1.5.4.2.1 Testing of the deposited weld metal

1.5.4.2.1.1 For the testing of the chemical composition of the deposited weld metal, a test piece according to Figure 1.5.4-1 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.

1.5.2.2.1.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in 1.5.2.6.2.3. The results of the analysis shall not exceed the limit values specified by the manufacturer.

![Figure 1.5.4-1 Deposited weld metal test assembly](image_url)

1.5.4.2.2 Testing of butt weld assemblies

1.5.4.2.2.1 The testing of the welded joints shall be performed on butt-weld test assemblies according to Figure 1.5.4-2 and Figure 1.5.4-3, made from materials as given in Table 1.5.4-1, in an analogous manner to 1.5.2.4.3, 1.5.2.6.2.5, 1.5.2.6.3.5 or 1.5.2.6.4.2 respectively.

1.5.4.2.2.2 Butt weld test assemblies according to Figure 1.5.4-2 with a thickness of 10 to 12 mm are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position subject to the agreement of the Register.

1.5.4.2.2.3 Additionally one test assembly according to Figure 1.5.4-3 with a thickness of 20 to 25 mm is to be welded in the downhand position only.

1.5.4.2.2.4 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.

1.5.4.2.2.5 The test specimens shown in Figure 1.5.4-2 and Figure 1.5.4-3 and described in 1.5.2 shall be taken from the butt weld test assemblies.

1.5.4.2.2.6 The mechanical properties must meet the requirements stated in Table 1.5.4-3. The provisions of 1.5.2 apply in analogous manner to the performance of the tests, including the requirements regarding the annual repeat tests and retesting. The position of the fractures is to be stated in the report. The macrographic specimen shall be examined for imperfections such as lack of fusion, cavities, inclusions, pores or cracks.
Notes:
1) Edge preparation is to be single V or double V with 70° angle.
2) Back sealing runs are allowed in single V weld assemblies.
3) In case of double V assembly both sides shall be welded in the same welding position.

Figure 1.5.4-2
Butt weld test assembly for positional welding

Notes:
1) Edge preparation is to be single V with 70° angle.
2) Back sealing runs are allowed.

Figure 1.5.4-2
Additional butt weld test assembly in downhand position
Table 1.5.4-3
Requirements for the transverse tensile and bend tests

<table>
<thead>
<tr>
<th>Grade</th>
<th>Base material used for the test</th>
<th>Tensile strength ( R_{\text{m}} ) [N/mm²] min.</th>
<th>Former diameter</th>
<th>Bending angle ¹) [°] min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA/WA</td>
<td>5754</td>
<td>190</td>
<td>3 t</td>
<td></td>
</tr>
<tr>
<td>RB/WB</td>
<td>5086</td>
<td>240</td>
<td>6 t</td>
<td>180°</td>
</tr>
<tr>
<td>RC/WC</td>
<td>5083 or 5383 or 5456 or 5059</td>
<td>275 or 290 or 330</td>
<td>6 t</td>
<td></td>
</tr>
<tr>
<td>RD/WD</td>
<td>6061, 6005A or 6082</td>
<td>170</td>
<td>6 t</td>
<td></td>
</tr>
</tbody>
</table>

Note:
¹) During testing, the test specimen shall not reveal any one single flaw greater than 3 mm in any direction. Flaws appearing at the corners of a test specimen shall be ignored in the evaluation, unless there is evidence that they result from lack of fusion.

1.5.4.4 Annual repeat tests
1.5.4.4.1 The annual repeat tests shall entail the preparation and testing of the deposited weld metal test assembly as prescribed under 1.5.4.2.1.1 (Figure 1.5.4-1) and of the downhand butt weld test assembly according to 1.5.4.2.2.2 (Figure 1.5.4-2).

1.6 OVERWELDABLE SHOP PRIMERS

1.6.1 General

1.6.1.1 Overweldable shop primers applied to plates, sections etc. shall not significantly impair the quality of welded joints.

Overweldable shop primers for which the Register has issued Certificate on approval on the basis of a porosity test may be used. Even if the Certificate on approval has been issued, overweldable shop primers intended for welding may be approved for automatic double fillet welding only after a special welding procedure test in the users work.

1.6.2 Testing and approval of shop primers

1.6.2.1 Application for approval of the shop primer shall be submitted by the manufacturer to the Register together with the following information:

- Manufacturer (and licensor, where applicable),
- Brand name (and licensors brand name, where applicable) together with the original brand name in the case of commercial designations used for marketing,
- Code number/symbol identifying the formulation,
- Characteristic pigment base,
- Characteristic binding agent base

- 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.

1.6.2.2 The porosity test shall be performed by neutral, properly equipped testing authorities recognized by the Register for that purpose. Testing should be performed in accordance HRN EN ISO 17652-2.

1.6.2.3 The identity of the sample submitted for testing shall be established and recorded in the test report.

1.6.2.4 The Certificate on approval issued by the Register, imposes on the manufacturer the responsibility for ensuring that the composition and characteristics of the shop primer remain constant. Any modifications shall be reported automatically to the Register and shall necessitate new tests in compliance with 1.6.2.2.

1.6.2.5 Approval is valid for 3 year. On application by the manufacturer it may be extended by a further 3 years at 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.
2  FABRICATION AND INSPECTION OF WELDED JOINTS

2.1  FABRICATION OF WELDED JOINTS

2.1.1  General

2.1.1.1  This Chapter contains the general guidances applicable to the performance of welding work extending from the weld preparation to the completion of the welded joint.

2.1.1.2  All workshops wishing to perform welding works shall comply with the requirements of this Rules specified in 1.2, 1.3, 1.4 and, where necessary 2.3. Each workshop shall maintain up-to-date records on the compliance with the relevant requirements and shall submit them to the Surveyor to the Register, at his request.

2.1.1.3  Welding may be performed on materials whose identity and weldability, under the given production conditions, can be uniformly established (by reference to markings, certificates etc.).

2.1.1.4  Welding consumables tested in compliance with 1.5 of these Rules, approved by the Register and of a quality grade appropriate to the base material, may be used for welding. Welding consumables for the special welding procedures, approved on the basis of the welding procedure test, may be used only for the range of application specified in the relevant approval certificate.

2.1.1.5  Overweldable shop primers applied to plates, sections, etc. which are not removed prior to welding shall be tested and approved by the Register in compliance with 1.6 of these Rules.

2.1.1.6  Welded joints shall be performed in accordance with approved drawings, welding practice or company standards approved by the Register. Exceptions to these Rules are subject to the Registers agreement in each particular case.

2.1.2  Weld preparation

2.1.2.1  Weld preparation may be carried out by thermal cutting or machining. Groove edges shall be free from impurities and defects which may impair the quality of the welded joint.

2.1.2.2  When preparing and assembling components, care shall be taken to ensure compliance with the weld shapes and root openings specified in the approved documentation. For single- and double-bevel butt welds, provision shall be made for adequate root openings to enable sufficient root penetration.

The root opening shall not exceed twice the specified gap. The size of the gap may be reduced locally by the build-up welding of the side walls in agreement with the Surveyor to the Register.

2.1.2.3  Components which are butt welded shall be aligned as accurately as possible. Therefore sections welded to plating shall be left unwelded at the ends for this purpose.

2.1.2.4  Tack welds shall be performed as much as possible, by trained personnel. The places where their quality does not meet the requirements applicable to the welded joint, shall be carefully removed before permanent welding. Clamping plates, temporary ties and aligning pins shall be made from the same or similar material as base material and shall not be used more than necessary. Any damage caused during their removal shall be competently repaired.

2.1.3  Weather protection, preheating

2.1.3.1  The areas which shall be welded shall be adequately protected against climatic influences such as wind, damp and cold and shall be preheated where necessary. The need for preheating and the preheating temperature shall be determined by various factors such as chemical composition, plate thickness, heat dissipation and ambient temperature. Details regarding this requirement are given in 2.2. Preheating shall be applied uniformly throughout the thickness of the plate over width of four times the plate thickness, but not less than 100 mm.

2.1.4  Welding positions and welding sequence

2.1.4.1  Welding shall be performed, as a rule, in the optimum welding position.

The welding sequence shall ensure minimum relieving stresses and deformations in welded structures. In particular cases, the Register may require the welding schedule to be submitted.

2.1.5  Performance of welding work

2.1.5.1  The welding shop shall ensure that the specified welding parameters are adhered to and that the welding work is expertly performed. Components which have not been fully welded and which shall be handled or turned shall have welded joints of adequate strength. Cracked tack welds shall not be welded over, but they shall be machined out prior to welding. Welds shall have sufficient penetration and shall display a clean, regular surface with smooth transition to the base material. Excessive weld metal, undercuts or notches which may affect the weld quality shall be avoided.

2.1.6  Straightening and tolerances

2.1.6.1  Straightening operations (thermal or mechanical) shall not impair the quality of the materials and welded joints. Register may require verification of the suitability of the straightening method (e.g. by means of a welding procedure test). Tolerances for welded structures are stated in the manufacturing documentation and shall be in accordance with one of the recognized standards (e.g. HRN EN ISO 13920).
2.1.7 Post-weld treatment

2.1.7.1 When the post-weld treatment is intended to be carried out to improve the surface finishing in case of dynamic loading, such treatment shall not impair the characteristics of the welded joints.

For post-weld heat treatment, see 2.2 and for the surface treatment for non-destructive testing see 2.3.

2.2 HEAT TREATMENT

2.2.1 General

2.2.1.1 This Chapter apply to the preheating prior to and during the welding as well as to heat treatment of welded joints.

2.2.2 Equipment and appliances for heat treatment

2.2.2.1 When heat treatment is carried out in furnaces, the furnaces shall be equipped with calibrated devices for temperature control, monitoring and temperature recorders. The furnace dimensions and heating system shall enable the component to be evenly heated to the required temperature. The furnace shall be properly serviced and examined at regular intervals.

2.2.2.2 If no furnaces of sufficient size are available, heat treatment may be carried out in specially designed equipment. Such equipment shall comply with the requirements of 2.2.2.1. regarding control, monitoring and temperature recording.

2.2.2.3 If no heat treatment units of sufficient size are available, heat treatment may be carried out in sections in agreement with the Register. Requirements regarding control, monitoring and temperature recording, specified in 2.2.2.1, shall be complied with also in this case and for this equipment.

2.2.2.4 Preheating may be carried out in furnaces or by means of heating appliances such as gas burners or resistance mats. Their use imposes the method of pre-heating temperature monitoring as well as interpass temperature through the welding operation. Temperature may be monitored by means of suitable appliances such as contact thermometers, temperature sensitive crayons or similar.

2.2.3 Weather protection, preheating

2.2.3.1 The area in which welding work is performed shall be sheltered from wind, damp and cold. Where gas-shielded arc welding is carried out, special attention shall be paid to adequate draught protection.

At ambient temperature below +5°C, additional measures shall be taken, such as shielding of components, preliminary heating and preheating, especially when welding with a rather low heat input (laying down of thin fillet welds or welding of thick-walled components).

Wherever possible, no welding shall be performed at ambient temperatures below -10°C.

2.2.3.2 The need for preheating and the preheating temperature depend on a number of factors. The most considerable are:

- chemical composition of the base material,
- the workpiece thickness and the type of weld joint,
- the welding process and welding parameters,
- temperature dependence on mechanical properties of the weld metal and the heat-affected zone,
- diffusible hydrogen content of the weld metal.

The operating temperature to be maintained (minimum preheating temperature and maximum interpass temperature) for (hull) structural steels may be determined in accordance with HRN EN 1011-2. Guide values for the preheating temperature are contained in Figures 2.2.3-a and 2.2.3-b shown below for two different energy inputs per unit length of weld and hydrogen contents \( H_5 \) of the weld metal together with the various carbon equivalents \( CET \):

1) Energy input per unit length of weld:

\[
E = \frac{U \cdot I \cdot M}{100} \text{ [kJ/mm]} = \frac{U \cdot I \cdot \text{welding time [min]}}{100} \text{ [kJ]} \quad \text{length of weld [mm]}
\]

2) Hydrogen content:

\[
\begin{align*}
H_5 &= \text{max. } 5 \text{ ml diffusible hydrogen per } 100 \text{ g of weld metal} \\
H_{15} &= \text{max. } 15 \text{ ml diffusible hydrogen per } 100 \text{ g of weld metal}
\end{align*}
\]

3) Carbon equivalent:

\[
CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40}
\]

When the temperature of a component being welded is lower than the preheating temperature (calculated on the basis of above data) preheating is necessary.

Various methods of preheating may be applied:

- continuous heating prior to and during the welding,
- alternate heating and welding,
- heating only prior to start of welding. When the heat input during welding is sufficient to maintain the minimum preheating and interpass temperatures.

The heating method may be chosen at ones discretion, provided that it does not affect material by local overheating or cause nuisance by making the welding area dirty.

Irrespective of the data referred to in Figures 2.2.3-a and 2.2.3-b, at the area where auxiliary erection welds are carried out (e.g. handling lugs) shall be preheated as well as all unalloyed steels with thickness of 20 mm and over and all alloyed steels.

For austenite steels, drying of the areas to be welded by heating shall be sufficient.

Preheating shall be applied uniformly throughout the thickness of material over the width of 4 x the materi-
al thickness, but not less than 100 mm on both sides of the weld. Local overheating shall not be permitted. The preheating temperatures specified in Figures 2.2.3-a and 2.2.3-b may be applied to tack welds.

![Figure 2.2.3-a](image)

Minimum preheating temperatures (operating temperatures) applicable to welding processes with a relatively low heat input (energy input per unit length) \( E \geq 0.5 \text{ kJ/mm} \) as a function of the carbon equivalent CET on the base material and hydrogen content of the weld metal.

![Figure 2.2.3-b](image)

Minimum preheating temperatures (operating temperatures) applicable to welding processes with a relatively high input (energy input per unit length) \( E \geq 3.5 \text{ kJ/mm} \) as a function of the carbon equivalent Ceq on the base material and the hydrogen content of the weld metal.
Table 2.2.3 gives guide values of the carbon equivalent CET for some of the grades of hull structural steels (based on the information of steel manufacturer).

<table>
<thead>
<tr>
<th>Hull steel grades</th>
<th>Ceq [% in weight]</th>
<th>Average value&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Maximum value&lt;sup&gt;1)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.27</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0.26</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>D36</td>
<td>0.33</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>E36TM</td>
<td>0.27</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>D40</td>
<td>0.27</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>E40TM</td>
<td>0.24</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

1) For product thickness up to 50 mm.

2.2.4 Post weld heat treatment

2.2.4.1 Post weld heat treatment shall be carried out on welded joints in accordance with 3.1 to 3.4.

Guide values for stress relief heat treatment are given in Table 2.2.4.1.

The stress relief heat treatment shall be carried out by means of slow, even heating of the components to the prescribed temperature ranges, holding in these ranges for two minutes per mm of wall thickness (but not less than 30 minutes), slow cooling down to 400° and after that complete cooling in still air. For thick-walled components, the holding time need not be longer than 150 minutes.

Table 2.2.4.1

<table>
<thead>
<tr>
<th>Category in accordance with HR CEN ISO/TR 15608</th>
<th>Steel grades</th>
<th>Examples of appropriate steels in accordance with the Register's Rules or the Standards&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Heat treatment temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Normal-strength hull structural steels and comparable structural steels, grade of steel forgings and castings</td>
<td>Grades A - E</td>
<td></td>
<td>550-600</td>
</tr>
<tr>
<td>1.2 Higher-strength hull structural steels and comparable structural steels, grades of steel forgings and castings</td>
<td>Grades A36 - E36</td>
<td></td>
<td>530-580</td>
</tr>
<tr>
<td>1.2 High-temperature, low Mo alloy steels</td>
<td>16 Mo 3</td>
<td></td>
<td>550-620</td>
</tr>
<tr>
<td>2 Normalised or thermo-mechanically processed fine-grained steels with yield strengths &gt; 360 N/mm²</td>
<td>Grades A39 - E39 S460 tm</td>
<td></td>
<td>550-600</td>
</tr>
<tr>
<td>3 Quenched and tempered fine-grained structural steels with yield strengths &gt; 360 N/mm²</td>
<td>S690 QL</td>
<td></td>
<td>530-580</td>
</tr>
<tr>
<td>5 Steels with a max. Cr content of 10%, max. Mo content of 1.2%</td>
<td>13 Cr Mo 4-5 10 Cr Mo 9-10, 11 Cr Mo 9-10</td>
<td></td>
<td>630-680 670-720</td>
</tr>
<tr>
<td>7 Nickel steels with a max. Ni content of 10%</td>
<td>13 Mn Ni 6-3 (0.5% Ni) 12 Ni 14 (3.5% Ni) 12 Ni 19 (5% Ni) X 8 Ni 9 (9% Ni) X 7 Ni 9 (9% Ni)</td>
<td></td>
<td>530-560 530-560 550-560 2) 2)</td>
</tr>
</tbody>
</table>

Note:

1) Steel grades not listed here are to be classed with comparable grades.
2) Heat treatment should be avoided.
2.3 NON-DESTRUCTIVE TESTING OF WELDS

2.3.1 General

This Chapter apply to the performance of non-destructive tests of welded joints according to the methods and scopes prescribed in the individual sections of Chapter 3 for various fields of application. The present part shall also apply to the non-destructive tests of welded joints specified in other Parts of the Rules for which no specific details are given therein. The standards specified in the following paragraphs of this Chapter are integral part of these Rules and shall be complied with when performing the non-destructive weld tests. When the standards differ from the Rules, the latter shall take precedence.

The works’ inspection department shall be independent and free from the fabrication department what is necessary to ensure that the testing and evaluation of the results are carried out objectively. This applies to outside inspection bodies in analogous manner.

Additionally to the requirements of 2.3.2 to 2.3.14, non-destructive testing of ship hull steel welds during new building and ship repair shall be performed in accordance with the requirements specified in the work instruction QW 122 Non-destructive testing of ship hull steel welds (IACS Recommendation 20).

2.3.2 Test methods, appliances and test equipment

The choice of the test method to be applied in each particular case shall be determined, among other things, by the weld shape, the material and the defects to be expected (type and position). The following basic requirements shall be mostly complied with:

a) For wall and weld thickness up to 30 mm, radiographic inspection shall be preferable method; for larger thickness, ultrasonic inspection shall be used as the basic test method.

b) For wall or weld thickness of 10 mm and above, either radiographic or ultrasonic examinations shall be applied in agreement with the Register.

c) For radiographic examination, X-ray sources shall be used wherever possible. Gamma-ray sources may be used only in agreement with the Register on the basis of examination and approval of the test method.

d) For magnetic materials, testing for surface cracks shall be carried out by the magnetic particle method; the use of penetrants for magnetic materials shall be in agreement with the Register.

The test method shall be such as to enable detecting of possible external or internal defects. Where necessary, two or more test methods may be used in combination. The particular test method to be used shall be stated in the inspection schedule. The test appliances as well as media used shall comply with the requirements of the relevant standards and shall be properly used and serviced.

2.3.3 Inspection personnel, supervisors

The non-destructive weld testing may be performed only by persons trained in the use of the relevant test method and appliances as well as having the practical experience. The Register is to be supplied with the appropriate documentary proof of such training and experience of the personnel for the particular non-destructive weld test methods.

2.3.4 Inspection schedule, inspection reports

Inspection schedule for the non-destructive weld test shall cover the following information:

- components of welded joints to be tested;
- scope and method of testing;
- areas to be inspected (location of sections, product);
- criteria to be complied with;
- test method and/or standard, if the different standards from those specified in these Rules, shall be applied.

The inspection schedule shall be submitted to the Register for approval.

The reports on testing shall be prepared on the basis of all testing results and shall be submitted to the surveyor to the Register with other relevant documentation.

2.3.5 Timing of testing

Non-destructive tests of welds shall, as a general rule, be carried out after all welding operations are completed on the components concerned. Prior to these tests, welded joints shall be visually inspected and all surface defects which may cause misinterpretation of test results or conclusion shall be removed. Components subjected to the post-weld heat treatment shall be, as a general rule, inspected after heat treatment. In case of higher strength, specially high-strength structural steels and similar where the delayed cracking are likely to occur (due to the presence of hydrogen in the weld metal) the tests shall not be carried out earlier than 48 hours after completion of the welding work. The Register may require longer waiting time (e.g. 72 hours up to a maximum of 7 days) or repeated tests (on a random sampling basis) after appropriate waiting time.

2.3.6 Preparation and performance of tests

The areas to be tested shall be sufficiently clean and smooth for the respective test method. Irregularities in the welded joint remains of auxiliary welds, welding spatter, slag remains etc. and any protective coatings shall be removed before the tests, if they are liable to prevent them from being performed properly. In special cases (e.g. ultrasonic testing for transverse defects), machining of the weld and the associated edge surface may be required. Non-destructive tests are specified in 2.3.11. to 2.3.14.
2.3.7 Evaluation of test results

In the case of radiographic testing and individual methods of surface testing, the symbols specified in Table 2.3.7-a shall be used to identify test defects (HRN EN ISO 6520-1).

For evaluation of particular sections of steel welded structures, the evaluation categories in compliance with HRN EN ISO 5817, shall be used, and for evaluation of particular sections of aluminium alloys welded structures the evaluation categories in compliance with HRN EN ISO 10042 shall be used.

The test results shall be evaluated by the quality control department, while the ultimate evaluation shall be made by a surveyor to the Register.

In the case of radiographic examination, the results shall be rated in accordance with Table 2.3.7-c and for ultrasonic examination the results shall be rated in two categories: "acceptable" and "not acceptable" (repaired or rejected).

Acceptability of welded joints (radiographically tested) may be evaluated by applying the evaluation category with three or five grades.

Evaluation of quality, according to the evaluation category with five grades, shall be performed under the Table 2.3.7-c or under the standard recognized by the Register.

Evaluation of quality, according to the evaluation category with three grades, shall be performed in accordance with HRN EN ISO 5817 or HRN EN ISO 10042 respectively of base material.

The quality of welded joints shall comply with the requirements set forth in Table 2.3.7-b.

Table 2.3.7-a
Symbols denoting defects (taken from HRN EN ISO 6520-1)

<table>
<thead>
<tr>
<th>Symbol No. / symbol according to MIZ</th>
<th>Description 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 E</td>
<td>Cracks</td>
</tr>
<tr>
<td>101 Eₐ</td>
<td>Longitudinal cracks</td>
</tr>
<tr>
<td>102 Eₐ</td>
<td>Transverse cracks</td>
</tr>
<tr>
<td>104 Eₐ</td>
<td>End crater cracks</td>
</tr>
<tr>
<td>2011 Aₐ</td>
<td>Pore</td>
</tr>
<tr>
<td>2015 Aₐ</td>
<td>Elongated cavity</td>
</tr>
<tr>
<td>2016 Aₐ</td>
<td>Worm hole</td>
</tr>
<tr>
<td>2024 K</td>
<td>End crater cavity</td>
</tr>
<tr>
<td>301 B₃</td>
<td>Slog inclusion</td>
</tr>
<tr>
<td>304 H</td>
<td>Metallic inclusion</td>
</tr>
<tr>
<td>4011 -</td>
<td>Lack of side-wall fusion</td>
</tr>
<tr>
<td>4012 -</td>
<td>Lack of inter-run fusion</td>
</tr>
<tr>
<td>4013 D</td>
<td>Lack of root fusion</td>
</tr>
<tr>
<td>402 D</td>
<td>Incomplete penetration</td>
</tr>
<tr>
<td>5011 F</td>
<td>Undercut, continuous</td>
</tr>
<tr>
<td>5012 F</td>
<td>Undercut, intermittent</td>
</tr>
<tr>
<td>5013 -</td>
<td>Root notch</td>
</tr>
<tr>
<td>502 -</td>
<td>Excessive weld reinforcement (butt weld)</td>
</tr>
<tr>
<td>503 -</td>
<td>Excessive convexity (fillet weld)</td>
</tr>
<tr>
<td>504 -</td>
<td>Excessive root reinforcement</td>
</tr>
<tr>
<td>507 -</td>
<td>Misalignment of edges</td>
</tr>
<tr>
<td>510 -</td>
<td>Burn-through</td>
</tr>
<tr>
<td>511 -</td>
<td>Incompletely filled groove</td>
</tr>
<tr>
<td>515 -</td>
<td>Root concavity</td>
</tr>
<tr>
<td>517 -</td>
<td>Poor restart</td>
</tr>
</tbody>
</table>

Table 2.3.7-b
Quality of Welded Joints

<table>
<thead>
<tr>
<th>Structure</th>
<th>Category</th>
<th>Minimum permissible grade According to Table 2.3.7-b</th>
<th>According to HRN EN ISO 5817 or HRN EN ISO 10042</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull</td>
<td>I</td>
<td>3*</td>
<td>B</td>
</tr>
<tr>
<td>Heat exchangers and pressure vessels</td>
<td>II</td>
<td>2</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td>Pipings</td>
<td>I</td>
<td>2</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td>Machinery and gears</td>
<td>On agreement with the Register</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Depending on the loads applied to welded joints, the Register may increase or decrease the required grade, stated in the Table.
### Table 2.3.7-c
Evaluation ratings

<table>
<thead>
<tr>
<th>Findings</th>
<th>Rating</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld free from detectable defects</td>
<td>1 = excellent</td>
<td>-</td>
</tr>
<tr>
<td>Minor defects such as isolated pores and small slag inclusions which do not reduce the strength of the welded joints</td>
<td>2 = serviceable</td>
<td>-</td>
</tr>
<tr>
<td>Acceptable defects such as small rows or clusters of pores, small slag lines, short root defects and minor lack of fusion</td>
<td>3 = leave as is</td>
<td>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.</td>
</tr>
<tr>
<td>Defects to be avoided, e.g. coarse slag inclusions, pore accumulations, root defects, lack of fusion, small isolated cracks</td>
<td>4 = to be repaired</td>
<td>Repair required</td>
</tr>
<tr>
<td>Extensive major defects and cracks</td>
<td>5 = to be replaced</td>
<td>Replacement of the sections of weld or of the entire welded joints required</td>
</tr>
</tbody>
</table>

**2.3.8 Extension of the scope of inspection**

If the percentage of defects exceeds that of the prescribed, the Register may extend the scope of inspection.

**2.3.9 Repairs, re-inspection**

Welded joints shall be repaired in agreement with the Register. Repaired welds shall be re-inspected and shall be specially indicated in the inspection report and on the radiographs (R= repair).

**2.3.10 Visual examination**

Visual examination shall cover (using the optical appliances, where necessary) as follows:
- completeness; (if welded all required)
- dimensional accuracy;
- compliance with the specified weld shape;
- presence of inadmissible external defects.

The dimensional accuracy shall be checked by means of suitable measuring instruments, on a random sampling basis.

When checking the shape and external defects, special attention shall be paid to:
- weld reinforcement or depression;
- weld edge angle;
- misalignment of edges;
- undercuts;
- visible porosity and slag inclusions;
- fused weld spatter;
- arc strikes on the base material;
- concave root surface and incomplete root fusion;
- cracks;
- unequal side lengths (with fillet welds).

Tolerances are referred to in 2.3.7. Repair of visible cracks is mandatory.

**2.3.11 Radiographic examination**

X-ray sources shall be used for the radiographic inspection. In particular cases, in agreement with the Register, gamma-ray sources may be used. Radiographic parameters prescribed in the HRN EN ISO 17636-1 for the test category A shall be preferably used in shipbuilding and for test category B, in steam boiler, pressure vessel and pipeline manufacture. In applying several films to inspect the welds (e.g. for circumferential radiographs) they shall overlap at the ends. When pipes are inspected having an outside diameter ≤ 90 mm, elliptical radiograph may be made.

Each radiograph shall include one image quality indicator in accordance with HRN EN ISO 19232-1 (wire indicator). Each radiograph shall also include the appropriate symbols (marks) to uniformly indicate its relation to the structure as well as to the test report. The inspection report shall cover the following information together with explanatory sketches (where necessary):
- work number, component, inspection schedule number, inspection position;
- material, welding process;
- workpiece or weld thickness;
- date and time of test;
- radiation source;
- tube voltage during inspection;
- radiographic parameters (to HRN EN ISO 17636-1), position of wire indicator;
- type of film;
- test category, image quality index;
- symbol denoting defect, to Table 2.3.7-a.

The initial evaluation shall be usually carried out by the quality control department and the ultimate evaluation on the basis of the radiographs and relevant reports shall be carried out by the Surveyor to the Register.
2.3.12 Ultrasonic examination

The test appliances, probes and other accessories shall be in accordance with relevant standards (e.g. HRN EN ISO 7963 or HRN EN ISO 17640). Calibration of the instruments prior to inspection shall be performed on the calibration blocks to HRN EN ISO 7963.

Depending on the required echo sensitivity (height) setting of sensitivity shall be done to HRN EN ISO 16811.

The weld test surface shall be smooth and free from impurities, rust and spatter on both sides. Paint and protection coatings which are not likely to affect the test results need not be removed prior to testing. The testing process shall depend on the weld geometry and the possible orientation of defects.

Continuous echo indication which point at the systematic weld defects (e.g. root defects due to incomplete penetration or rows of pores), requires the repair even if the repair limit values are not attained. Echo indications which point at the presence of cracks necessitate repairs anyway. If the evaluation of echo indications gives rise to doubt regarding the need for repairs, the evaluation may be complemented with radiographic inspection as to obtain accurate assessment.

Inspection report (prescribed in HRN EN ISO 17640) shall be prepared for all testing and shall contain essential information. Where echo indications below repair limit values are also stated in the report, each defect thus identified shall be marked (e.g. leave as it is or to be repaired: a - acceptable, or b - not acceptable).

2.3.13 Magnetic particle testing

The test appliances and media shall comply with the requirements of the relevant standards (e.g. HRN EN ISO 17638; HRN EN ISO 23278). The magnetising equipment shall be provided with measuring devices which indicate the magnetising current strength. Magnetic particles (black or fluorescent) in a suitable suspension under influence of magnetic current, shall accumulate at the limits of defects. The choice of the magnetisation method depend on the geometry of the component and shall be agreed with the Register. The testing surface shall be free from loose scale, rust, weld spatter and other impurities. Notches, indentations, scratches and edges which may cause false indications shall be removed prior to inspection. Thin, dry layers (e.g. coat thickness up to 20 μm) shall not be removed if they do not impede the inspection. Every spot of accumulation of magnetic particles which is not due to false indication shall be stated in testing-report and shall be repaired. In the case of small cracks, this may be done by grinding. Larger cracks shall be machined out and repair-welded.

Inspection report shall cover the following details:
- details on the component, or a weld tested;
- data on magnetisation;
- magnetising equipment data;
- test media;
- test results;
- place and time of testing, testing body and person performing the test.

2.3.14 Penetrant testing

The test appliances and media shall comply with the requirements of the relevant standards (e.g. HRN EN ISO 17635; HRN EN ISO 23277). Coloured or fluorescent penetrants may be used as penetrant media. Penetrant removers and developers shall be compatible with the penetrant used. The testing surface shall be completely free from scale, rust, greases, oils and paints before the penetrant is applied as to enable penetration into any surface defect. Also care shall be taken to ensure that defects are not mechanically sealed by preliminary cleaning. The testing surface shall be dry and the temperature of the workpiece shall be between 5° and 50°C. The penetration time shall be chosen in accordance with the manufacturers instructions but shall not be less than 15 minutes for workpiece temperatures of 15°C and over, or less than 30 minutes where the temperature is below 15°C. After this procedure the surplus penetrant shall be completely wiped off. The developer shall be applied evenly and thinly as possible on the dried surface. The developing time shall be the same as that of penetration.

Visual inspection shall be carried out upon the expiry of application time of the developer. The test results shall be assessed analogously as those in 2.3.13.

Test report shall cover the following:
- details on the component or a weld joint;
- test media (type, brand name);
- description of the test procedure;
- test results;
- place and time of testing, testing body and person performing the test.
3 WELDING IN THE VARIOUS FIELDS OF APPLICATION

3.1 WELDING OF HULL STRUCTURES

3.1.1 General

The requirements of this Chapter apply to all welding works carried out on the ships hull, superstructure and deckhouses including the components forming part of the ships structure (e.g. hatch covers, masts, deck cranes etc.) referred to in the Chapter 1.1.1 of these Rules.

3.1.2 Approval of shipyards and welding shops

All shipyards and welding shops intended to perform works on structures covered by these Rules under supervision of the Register, shall comply with the requirements referred to in the Chapter 1.2 of these Rules and shall be approved by the Register. Application for approval shall be submitted to the Register before starting the welding and shall contain information and documentation prescribed in the Chapter 1.2 of these Rules.

3.1.3 Quality control

Shipyards and welding shops shall ensure regular quality control during the manufacture. The welding works shall be in compliance with these Rules, approved workshop documentation and good welding practice.

3.1.4 Materials, weldability

Welded structures shall be fabricated only using base materials of proven weldability. Materials shall comply with the Rules, Part 25 - Metallic Materials.

3.1.5 Welding consumables

All the welding consumables used for welding the structures referred to in 3.1.1 shall be approved by the Register in compliance with 1.5 of these Rules. Choice and grades of welding consumables for hull structural steels shall be in compliance with the Table 1.5.2.1.2.2 - Correlation of welding consumables to hull structural steels.

The welding consumables may only be used in the approved welding positions and in accordance with the requirements and recommendations of the manufacturer.

3.1.6 Welding processes and welding procedure tests

Welding processes shall, regularly, be tested by the Register in compliance with 1.4.

The requirements to which the welded joints of the hull structural steels shall be complied with are detailed in 1.4.

3.1.7 Welding of clad steels

Edge preparation of the welded joint shall be in accordance with the standards or drawings approved by the Register. Edges shall be machined or ground. The edges of parts to be assembled shall fit each other closely and shall not be out of alignment on the clad surface. Corrosion resistance and the thickness of the clad side shall be equal to that of the clad material. The chemical composition of weld metal, except of that in the root size, shall correspond to that of clad material.

As a rule, the plate surface opposite to the clad surface shall be welded first and then on the clad side. The non clad side shall be welded so that no melting of the cladding layer is likely to occur. Prior to welding on the clad side, the root of the unalloyed weld shall be cleaned to sound metal by machining or grinding and given a concave shape. For a back sealing run the same welding consumables shall be used as for welding the cladding layer. The cladding layer shall be welded so as to reduce the interpenetration of alloyed and unalloyed materials to a minimum. For welding the cladding layer, welding electrodes and wires of the smallest possible diameter shall be used.

The welding shall be carried out at the lowest possible rate of energy input. The weld on the clad face shall be made at least two layers. Transverse weaving of the electrode in welding the cladding layer shall not be permitted. Where the top layer width is such that it should be deposited in several runs, the last run shall be made along the middle of the weld. When the two-side welding of clad steel pipes is not possible, the entire joint shall be welded by welding consumables appropriate for the cladding material.

Thin steel plates shall be welded by welding consumables appropriate for the cladding material.

3.1.8 Welding of castings and forgings

Steel castings and forgings regardless of the ambient temperature, shall be pre-heated or subjected to other technological measures prior to welding, to ensure the required quality of welding. The defects in the new steel forgings and castings may be rectified by welding only in case the weldability of the steel concerned has been previously checked with due regard to the special conditions of the cast or forged element.

The repair shall be carried out prior to the final heat treatment. Welding after the final heat treatment shall be permitted only exceptionally. The repair of castings and forgings by welding shall not be permitted if the same defects appear repeatedly. The welding of defects in castings shall be carried out after spues and heads have been removed and the castings thoroughly cleaned of sand, scale and inclusions. The surfaces to be repaired shall be ground to sound metal so as to ensure the full penetration throughout the welded area. The surfaces to be welded shall be horizontal and shall be without sharp corners.

The repair shall be carried out prior to the final heat treatment. Welding after the final heat treatment shall be permitted only exceptionally. The repair of castings and forgings by welding shall not be permitted if the same defects appear repeatedly. The welding of defects in castings shall be carried out after spues and heads have been removed and the castings thoroughly cleaned of sand, scale and inclusions. The surfaces to be repaired shall be ground to sound metal so as to ensure the full penetration throughout the welded area. The surfaces to be welded shall be horizontal and shall be without sharp corners.

The normal strength hull structural steels do not require preheating. However, with large cross sections (e.g. steel castings or forgings where unfavourable design or welding technology apply, uniform preliminary heating of the areas surrounding the welded joints is advisable. Higher strength hull structural steels shall general-
ly be preheated if the temperature of the workpiece is less than 5°C.

If it is higher than this, preheating shall be carried out upwards of a specific threshold wall thickness with respect to other factors referred to in Table 3.1.9.

For an average carbon equivalent and an average heat input (energy applied per unit length of weld) the wall thickness $t$ and preheating temperature $T$ shown in Fig. 3.1.9 may be used as a guide.

Table 3.1.9
Influence of various factors on the preheating temperature

<table>
<thead>
<tr>
<th>Lower preheating temperature</th>
<th>Factors influencing preheating</th>
<th>Raised preheating temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-alloyed steels</td>
<td>Chemical composition (hardening properties) of the base material, e.g. expressed by the carbon equivalent.</td>
<td>higher-alloyed steels</td>
</tr>
<tr>
<td>small</td>
<td>Thickness of workpiece (heat dissipation, rigidity, state of residual stresses)</td>
<td>large</td>
</tr>
<tr>
<td>Butt welded joints (uniting two plates) thick (multiplepass) seam</td>
<td>Type of joint, shape and dimensions of weld, heat input, heat dissipation</td>
<td>T-joints(uniting three plates), thin (single-pass) seams</td>
</tr>
<tr>
<td>high</td>
<td>Ambient temperature, temperature of workpiece (heat dissipation)</td>
<td>low</td>
</tr>
<tr>
<td>high</td>
<td>Heat input during welding (energy applied per unit length of weld)</td>
<td>low</td>
</tr>
<tr>
<td>low</td>
<td>Hydrogen content of weld metal (type and re-baking of welding consumables and auxiliary materials)</td>
<td>high</td>
</tr>
</tbody>
</table>

3.1.9 Preheating

Necessity and degree of preheating shall be in accordance with Table 3.1.9.7

![Figure 3.1.9](image)

Wall thickness and preheating temperatures for higher-strength hull structural steels (guide values)

Preheating shall be applied uniformly throughout the thickness of the plate and to a distance four times the plate thickness, but not more than 100 mm on both sides of the weld. Localized preheating shall not be permitted. The preheating temperature shall be kept constant throughout the duration of the welding work.

3.1.10 Welding of aluminium and its alloys

The welding operations on aluminium and on its alloys referred to in 1.1.1. shall be performed by certified welders approved by the Register.

Welding consumables and the welding procedure applied shall be approved by the Register and the welders shall be qualified and certified. The welding operations shall be so performed as to ensure a good quality joint, its maximum strength, chemical composition similar to that of the base metal and the sufficient corrosion resistance. Edge preparation prior to welding shall be carried out in compliance with the standards or technical documentation approved by the Register. The joints shall be arranged so as to make it possible to weld them in the most convenient position. Where scalloped constructions are concerned, the welding shall be performed round the ends of all lugs.

The reinforcement of edges shall be removed only if stated in the drawings. Just before welding, the joint edges of aluminium and aluminium are to be degreased and cleaned from dirt with stainless steel wire brush. In case of multitrun welding, each run of deposit shall be brushed before the next run is applied.

In case of the double-sided welding prior to welding of the reverse side, the root of the weld shall be cleaned to the sound metal. In way of riveted structures made of aluminium alloys, all major welding operations shall be completed before riveting.

Welded joints shall have no machining or painting whatsoever when submitted for acceptance. Application of non-destructive methods other than radiography shall be specially considered by the Register.
The requirements to which the welded joints of aluminium alloys shall be complied with are shown in Table 3.1.10.

### Table 3.1.10

<table>
<thead>
<tr>
<th>Base material</th>
<th>Chemical symbol</th>
<th>Tensile strength $[\text{N/mm}^2]$</th>
<th>Bending angle$^{(2)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5754</td>
<td>Al Mg 3</td>
<td>190</td>
<td>180$^\circ$</td>
</tr>
<tr>
<td>5086</td>
<td>Al Mg 4</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>5083</td>
<td>Al Mg 4,5 Mn 0,7</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>5383</td>
<td>Al Mg 4,5 Mn 0,7</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>6005A</td>
<td>Al Si Mg (A)</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>6061</td>
<td>Al Mg Si 1 Cu</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>6082</td>
<td>Al Si 1 Mg Mn</td>
<td>170</td>
<td></td>
</tr>
</tbody>
</table>

$^{(1)}$ Using a weld consumable of a quality grade in accordance with 1.5.8.1

$^{(2)}$ Bending mandrel diameter to be selected in accordance with 1.5.8.3

### 3.1.11 Inspection of welding and welded joints

#### 3.1.11.1 Inspection of welding operations and welded joints

Inspection of welding operations and welded joints during manufacture and repairs of structures and components shall be performed through the inspection authorities of the working organizations. The inspection results shall be registered by the working organization and filed until the commissioning of the item and shall be submitted to the Surveyor to the Register on his request, for supervision. When necessary, the working organization shall perform the following tests of welded joints:

1. Tightness test;
2. Strength test;
3. Non-destructive testing.

The method of these testing shall comply with the requirements of the relevant Parts of the Rules, or with standards approved by the Register. The welds shall be examined by the following non-destructive methods:

- Visual inspection;
- Radiographic examination;
- Ultrasonic examination;
- Magnetic particle examination;
- Liquid penetrant examination.

Other methods may be applied on agreement with the Register. Personnel performing the non-destructive testing methods shall be specially qualified and their qualifications shall be confirmed by the competent authorities (in accordance with the recommendations of the Croatian Association for Non-destructive testing).

At request of the Surveyor, the additional number of welded joints may be examined.

#### 3.1.11.2 The number of radiographs at radiographic examination or controlled weld lengths at the ultrasonic examination of welded joints in hull structures referred to in 3.1.11.3 shall be determined by the formula:

$$n = \frac{\eta \cdot L}{100 \cdot 0,5},$$

where:

- $n$ = number of the controlled weld lengths,
- $L$ = total length of welded joints, m;
- $0,5$ = controlled weld length, m;
- $\eta$ = ratio of the controlled weld lengths and total weld lengths in percentage (in accordance with Fig. 3.1.11.3).

Where the controlled weld length is less than 0.5 m, the real value of controlled weld length shall be substituted in the formula. The working organization shall determine the percentage of weld defects, once every six months at least, on the basis of the examination results and shall report these data to the Register. The percentage of defects $K$ shall be determined by the formula:

$$K = \frac{\ell \cdot 100}{L},$$

where:

- $\ell$ = total length of welds found defective during the examination, m;
- $L$ = total weld length controlled, m

If the percentage of defects is more than 5 percent, Register reserves the right to require, for every percent of rejected welds exceeding 5 percent, an increase in the number of the controlled weld lengths by 10 percent. The number of controlled weld lengths may be reduced if the Register finds the general standard of welding operations satisfactory. The sections of welded joints where the major defects are found shall be cut and re-welded. Rectified sections shall be re-tested and the testing results reported to the Register.

#### 3.1.11.3 Number of welded joints to be subjected to a non-destructive examination shall comply with the approved scheme and their positions on the relevant object shall be determined by the manufacturers quality control in agreement with the Register after welding operations are complied with. In addition to the number of controlled weld lengths in accordance with the Figure 3.1.11.3 and Table 3.1.11.3, the following welded joints shall be controlled:
### Table 3.1.11.3

<table>
<thead>
<tr>
<th>Location of welded joints to be examined</th>
<th>Percentage of the total number of controlled weld lengths</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength deck (deck plating)</td>
<td>20</td>
<td>See note</td>
</tr>
<tr>
<td>Bottom plating, including bilge strake</td>
<td>20</td>
<td>See note</td>
</tr>
<tr>
<td>Side plating</td>
<td>10</td>
<td>See note</td>
</tr>
<tr>
<td>Hatch coamings and second deck girders</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Hatch coamings and strength deck girders</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Watertight bulkhead plating</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Stern frame</td>
<td>5</td>
<td>See 3.1.11.3.5</td>
</tr>
<tr>
<td>Double bottom plating and other parts of hull structure subjected to high loads</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

*Note:*

2/3 of the total number of controlled weld lengths shall be of butt transverse welds and 1/3 of butt longitudinal welds.

but not less than one controlled weld length per butt;

3. butts of the sheerstrake lying amidship, but not less than one controlled weld length per butt;

4. mounted butt weld joints of hull members lying amidships at least:
   - one controlled weld length for every 5 butts of longitudinal framing members,
   - one controlled weld length for 10 butts of transverse framing members.

5. joints of stern, sternframe and ice belt of ship with 1 AS, 1 A, 1 B, 1C and 1D ice category and icebreakers, the number of weld length shall be agreed with the Register.

6. T-joints between deck stringer plate and sheerstrake, examination is required for 20 percent of the length of welds.

7. when welding into a rigid contour is carried out, the welded joints shall be controlled along whole length.

Besides, the welded joints of all structures exposed to heavy loads such as cargo masts and posts, cantilever beams etc. shall be also subject to control. When the quality grade of weld is not achieved, two additional lengths of the same weld shall be controlled at another two places. Should these lengths reveal any defects, further control shall be undertaken along the same weld in both directions until satisfactory results are obtained.

Where conversion or repair is concerned, the number of controlled weld lengths shall be determined by the Register depending on the extent of the welding operations as well as on the class of structure.

### 3.1.11.4

The evaluation category of welded joints of ships hull is specified in 2.3.7 of the *Rules*.

---

**Diagram of the part of welded joints to be controlled**

![Diagram of the part of welded joints to be controlled](image-url)
3.2 WELDING OF STEAM BOILERS AND PRESSURE VESSELS

3.2.1 General

The requirements of this Chapter apply to the welding of steam boilers and pressure vessels manufactured from base metal and welding consumables which comply with the requirements of the present part of the Rules as well as with those of the Part 25 - Metallic Materials.

3.2.2 Execution of welded joints

Welded joints of boilers shall be so marked as to make it possible to identify the operator (welder) who has performed the welding. Longitudinal and transversal welds of boiler shells shall be performed by full penetration welding, except where the welding coefficient of the welded joint in accordance with the Rules, Part 10 - Boilers, Heat Exchangers and Pressure Vessels, paragraph 2.1.5.1, is adopted to be \( \leq 0.8 \). Longitudinal and transversal joints of boiler shells as well as those of pressure vessels shall be butt welded. If butt welding cannot be applied, the type of weld and the welding procedure shall be specially considered by the Register in each particular case. Any welding of fastenings, catches and similar components for erecting purposes on the boiler shell, shall be considered by the Register in each particular case. When the openings in boilers are closed up by means of plugs fixed by welding the requirements of standards approved by the Register shall be complied with.

Worn-out shell plates of boilers and pressure vessels can be repaired by building-up only on agreement with the Register.

The built-up area shall not exceed \( 500 \text{ cm}^2 \) and its depth shall not be over 30 per cent of the plate thickness. If these conditions cannot be fulfilled, the defect area shall be repaired by inserting a new plate.

3.2.3 Heat treatment

Heat treatment of boilers and pressure vessels shall be carried out in compliance with the standards or information of the base material manufacturer. Welded joints which are oversized or which are of special design and cannot be subjected to stress relief heat treatment as a whole, shall be heat treated partly in agreement with the Register. Such heat treatment shall be performed by uniform heating along the welded joint (see 2.2.3.2). Oxyacetylene heat treatment shall not be permitted to be applied locally.

3.2.4 Inspection of welded joints

The mechanical properties and macrostructure of the welded joints when manufacturing boilers, heat exchangers and pressure vessels classified in accordance with the Rules, Part 10 - Boilers, Heat Exchangers and Pressure Vessels, paragraph 1.3.1.2., shall be examined within the following extent:

1. Boilers and pressure vessels of class I
   In case of the individual and serial production, each longitudinal joint for each plate thickness shall be tested. Transverse joint shall be tested only in case the welding procedure is substantially different from that applied to the longitudinal joint or when a pressure vessel is manufactured with a transverse joint only.
   In case of serial production of pressure vessels which are welded solely applying a transverse joint, one test assembly shall be prepared for each 30 m of joint length. Welded joint on a separately prepared test assembly shall be as equivalent as possible to the transverse joint on the vessel.

2. Boilers and pressure vessels of class II
   In case of the individual production, each longitudinal joint for each plate thickness shall be tested.
   In case of serial production, one test assembly shall be prepared for each 40 m of the longitudinal and transverse joint length.

3. Pressure vessels of class III
   In case of individual production, one test assembly shall be prepared and in serial production for each 40 m of the longitudinal and transversal joint length, one test assembly shall be prepared.
   Test assemblies shall be attached to the longitudinal joint of a boiler or pressure vessel so that the test plate joint to be welded is a continuation of the joint of the relevant part. The test assembly shall be manufactured from the same plate as that of the boiler shell or the relevant pressure vessel, and the welding procedure shall be the same as employed in the welding of the boiler or pressure vessel joint. Dimensions of test assembly shall be sufficient to enable the preparing of test pieces as well as the re-tests. Prior to heat treatment, test assembly shall be straightened. For that purpose, it may be heated to the temperature which is lower than that for heat treatment. Test assemblies shall be heat treated simultaneously in the same furnace integral with the items to which they belong. They are separated from the boiler shell after being marked by the Register. A test assembly thus prepared shall provide:
   - one transverse tensile test specimen;
   - two transverse bend test specimens (one with the face of the weld in tension, the other with the root of the weld in tension);
   - three impact test specimens.

   The longitudinal axis of the test specimen shall be perpendicular to the weld and shall run through the middle of the plate parallel with its surface. The notch in the test specimen shall be perpendicular to the plate surface nearly to the middle of the weld.

   Class I
   - one transverse tensile test specimen;
   - one transverse bend test specimen (the root of the weld in tension)

   Class II
   - one transverse tensile test specimen.

   But welded joints of boilers, heat exchangers and pressure vessels shall be examined by one of the non-
destructive methods to the extent referred to in the Table 3.2.4, depending on the class of construction (see 1.3.1.2, *Part 10, Boilers, Heat Exchangers and Pressure Vessels*).

<table>
<thead>
<tr>
<th>Class</th>
<th>Length of tested welds, in per cent, compared to total weld length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Longitudinal</strong></td>
</tr>
<tr>
<td>I</td>
<td>100</td>
</tr>
<tr>
<td>II</td>
<td>25</td>
</tr>
<tr>
<td>III</td>
<td>On agreement with the Register</td>
</tr>
</tbody>
</table>

The evaluation category of welded joints of boilers and pressure vessels is specified in 2.3.7 of the *Rules*.

### 3.3 WELDING OF PIPELINES

#### 3.3.1 General

The type of welded joints in pipes shall be in compliance with the standards.

#### 3.3.2 Execution of welded joints

The butt welded joints of pipes shall be carried out with full root penetration. Welding with the removable backing rings shall be permitted. The use of remaining backing rings in butt welds of pipelines shall be permitted only where these rings do not adversely affect the performance. But joints of flanges with pipes shall not be carried out with the remaining backing rings.

Welded joints of pipes shall be heat treated in the following cases:

1. in pipes of low-alloy steel;
2. in case of welding of main steam pipelines at temperature above 350°C.

The welded joints of piping depending on the class indicated in Table 1.2.2, *Part 8, Piping*, shall be radiographed to the extent as stated below:

- Class I piping with the outer diameter of pipe ≥ 75 mm-100% butt joints;
- Class I piping with the outer diameter of pipe < 75 mm-10% of butt joints;
- Class II piping with the outer diameter of pipe ≥ 100 mm-10% of butt joints;
- Class II piping with the outer diameter of pipe < 100 mm-random check of butt joints.

When 10% of the butt joints are radiographed, not less than one joint from the total number made by a particular welder shall be controlled.

If required by the Register, the scope of testing may be extended depending on the type of material or welding procedure.

The Class III piping shall be examined visually but the Register may require a random check of welds by radiography.

Where, for technical reasons, the Class I and II piping cannot be radiographed, the Register may permit other methods of examination.

In some cases, the ultrasonic examination may be applied instead of radiography.

For controlling fillet welds of Class I and II piping, magnetic particle method may be applied on agreement with the Register, depending on the type of material, thickness, outer diameter and on the composition of the working medium.

In the case of automatic and semi-automatic welding of pipes, or in the case of serial production of pipes, the scope of radiographic examination may be reduced on agreement with the Register.

The acceptance criteria of welded piping are specified in 2.3.7 of these *Rules*.

The repair of pipeline damaged areas by welding in each case shall be subject to special consideration of the Register.

### 3.4 WELDING OF MACHINERY COMPONENTS

#### 3.4.1 General

The requirements of this Chapter apply to the welding of the ship machinery structures manufactured from base materials and welding consumables which comply with the requirements of the present Part of the *Rules* as well as with the *Part 25 - Metallic Materials*. The structures may also be manufactured from the equivalent material if agreed with the Register.

#### 3.4.2 Execution of welded joints

The welded joints in structures exposed to dynamic loads shall be welded with full penetration. The transition from the base metal to the weld shall be smooth. Where the structure is intended to operate at high temperature or in a chemically aggressive medium, these conditions shall be taken into account when selecting the welding consumables.

The application of welding to shafting and crank shafts shall be specially considered by the Register in each particular case. Conditions to be fulfilled shall be as follows:

- 100 per cent of testing shall be carried out by one of non-destructive methods;
- the fatigue strength of welded joint adopted in calculation shall be guaranteed.

Scope of test welding as well as the test program prior to welding procedure shall be agreed with the Register. The application of welding, building-up, metal pulverisation and other similar methods, when manufacturing or repairing ship machinery items, may be permitted in case the testing results are satisfactory in accordance with the method approved by the Register and provided that such a method proves that it may be applied successfully with a particular workshop.

Ships shafts of carbon steel, up to 0.45 per cent carbon content, which have been worn out or have surface
cracks may be repaired by building-up provided that the extent of wear or the depth of a cracking does not exceed 5 per cent of shaft diameter, but not over 15 mm. The building-up shall be performed according to the procedure agreed with the Register. Welding may be performed in areas of components where cold forming has been carried out, including the adjoining surfaces over width of 5 times the plate thickness t, provided that the requirements specified in Table 3.4.2 are complied with.

The evaluation category of welded piping is specified in 2.3.7 of the Rules.

Scope of examination of constructions which are not listed in 3.1 up to 3.4 with non destructive methods, shall be agreed with the Register.

<table>
<thead>
<tr>
<th>Ratio $r/t$</th>
<th>Elongation, $\varepsilon$ [%]</th>
<th>Acceptable plate thickness, $t$ [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 10$</td>
<td>$&lt; 5$</td>
<td>any</td>
</tr>
<tr>
<td>$\geq 3.0$</td>
<td>$\leq 14$</td>
<td>$\leq 24$</td>
</tr>
<tr>
<td>$\geq 2$</td>
<td>$\leq 20$</td>
<td>$\leq 12$</td>
</tr>
<tr>
<td>$\geq 1.5$</td>
<td>$\leq 25$</td>
<td>$\leq 8$</td>
</tr>
<tr>
<td>$\geq 1.0$</td>
<td>$\leq 33$</td>
<td>$\leq 8$</td>
</tr>
</tbody>
</table>
ANNEX I

CROATIAN REGISTER OF SHIPPING

APPLICATION FOR APPROVAL OF SHIYARD / WELDING SHOP TO PERFORM WELDING WORKS IN SHIPBUILDING AND THE MACHINERY COMPONENTS THEREOF

In accordance with the Rules of the Croatian Register of Shipping, Part 26-Welding,

we Company: ____________________________

Address: ____________________________________________

hereby make application to the CRS for approval together with following documents:

Nature of the approval sought | Approval for shipyard/welding shop | Extension
---|---|---
1. Application from shipyard/welding shop | ☐ | ☐
2. Description of shipyard/welding shop in accordance with Appendix II | ☐ | ☐
   “Range of application” appendix(es) to description of shipyard/welding shop | ☐ | ☐
3. Proof of qualifications for welding supervisor(s) | ☐ | ☐
4. List of qualified welders | ☐ | ☐
5. Descriptions of welding procedures (WPS) | ☐ | ☐
6. List of qualified welding procedures | ☐ | ☐
7. List of inspection (supervising) personnel | ☐ | ☐
8. Other proofs, approvals (e.g. proof of compliance with the quality requirements: | ☐ | ☐
   - in accordance with HRN EN ISO 3834-2, or | ☐ | ☐
   - in accordance with HRN EN ISO 3834-3 or | ☐ | ☐
   - in accordance with HRN EN ISO 3834-4 | ☐ | ☐

Note:

1) Only if changes have been made since first approval.

Place, ____________________________  Date, ____________________________  Applicant, ____________________________________________
ANNEX II

CROATIAN REGISTER OF SHIPPING

DESCRIPTION OF SHIPYARD/WORKSHOP FOR APPROVAL
TO PERFORM WELDING WORKS IN
SHIPBUILDING AND THE MACHINERY COMPONENTS THEREOF

SHIPYARD/ WORKSHOP

Address:

Telephone: Fax: e-mail:

Responsible person:

Range of welding work:

1. WELDING PERSONNEL

1.1 Supervisor(s)
   (welding engineer, welding technician, foreman)

1.2 qualified welders

   a) Certificates and records, renewal, withdrawal
   b) Welders file
   c) Intervals and shop control of welders
   d) Welders activities to Certificate
   e) Welders marks
   f) Promotion of welders, new welders
   g) Supervision of the welders performance
   h) Existing number of welders

2. WELDING CONSUMABLES

2.1 Warehouse

   a) Records (input-output)
   b) Drying
   c) Dispatch
2.2 Type of welding consumables

3. BASE MATERIALS, (PLATES, PROFILES,PIPES)

3.1 Warehouse

   a) Records
   b) Marking

3.2 Grade of material

4. WELDING EQUIPMENT

4.1 Electric sources

   a) Types (prospectus)
   b) Records (file of sources)
   c) Maintenance (with respect to the Protection at Work Requirements and technological performance properties)
   d) Number of existing electrical sources

4.2 Welding equipment

   a) Control units for MIG/MAG, TIG, plasma, SMAW

4.3 Welding jigs

   a) Positioners
   b) Turnovers
   c) Other

5. PERFORMED WELDING PROCEDURES AND WELDERS QUALIFICATION TESTS

5.1 Performed welding procedure qualification tests

5.2 Performed welders qualification tests

6. SUPERVISION AND CONTROL

6.1 Organisational scheme and control position
6.2 Non-destructive examination of welds (internal)

6.3 Qualifications of supervising personnel

6.4 Non-destructive examination of welds (external)

7. DOCUMENTATION

7.1 Workshop documentation and its review from the technological point of view

7.2 Technological instructions (instruction sheets) for integral welding

7.3 Scope and method of welded joints examination

8. MISCELLANEOUS

8.1 Heat treatment (equipment)

8.2 Protection at work with respect to welding

9. REFERENCES

Welding supervisor:

Place, date, Name