8. For welding of austenitic stainless steels to one another and to hull structural steels, welding consumables and auxiliary materials shall be selected in accordance with Tables 5.21 to 5.23 in Chapter 1, Section 5 and the manufacturers' recommendations, taking the corrosion resistance and strength requirements and the welding metallurgy (including resistance to hot cracking) into account, and specified in a welding schedule, which is to be submitted for approval.

9. For welding aluminium alloys, the welding consumables and auxiliary materials shall be selected according to the type and condition of the material (cf. Rules for Materials, II/1/3) in accordance with Table 5.28 in Section 5 of Chapter 1 taking the required mechanical properties of the welded joints into account (cf. Rules for Construction I, Part 1, Chapter 1, Section 19, C.2.8) and shall be indicated in the production documents to be submitted for approval.

10. Welding consumables and auxiliary materials specified in a welding shop or procedure approval (cf. F.) may only be replaced by equivalent consumables approved by the Society with an appropriate quality grade if this is explicitly stated in the respective approval document. Failing this, the Society's agreement shall be obtained.

11. The welding consumables and auxiliary materials may only be used in the approved welding positions. The manufacturer's recommendations and instructions for welding (e.g. type of current and polarity) shall be followed.

12. The welding consumables and auxiliary materials (especially hydrogen-controlled, basic covered electrodes and basic welding fluxes) shall be re-dried before use in accordance with the manufacturer's instructions (observe maximum drying time!) and stored in a dry place (in heated containers or the like) at the workplace.

Note:
The guideline DVS 0504 "Handling, storage and re-drying of covered electrodes" and guideline DVS 0914 "Use and storage of welding fluxes for submerged-arc and electro-slag welding" issued by the German Welding Society (Deutscher Verband für Schweißtechnik e.V) contain detailed instructions for this.

F. Welding procedure, procedure qualification tests

1. General

1.1 Beneath the requirements for qualification tests of welding procedure intended for hull constructions are stated. Procedure qualification tests intended for other use like pipeline systems, pressure vessel and steam boiler, machinery structures but also for the industrial sector, e.g. Offshore or steel constructions, are not included in this Section. After GL's agreement, the following requirements can be applied in a corresponding manner.

1.2 The procedure qualification tests concerning special hull construction e.g. for liquid gas tanks are settled in the GL Rules I – Ship Technology, Part 1 – Seagoing Ships, Chapter 6 – Liquefied Gas Carriers, Section 6.

1.3 Only those welding procedures are allowed to be applied, which qualification is proved by a qualification test and by the following requirements.

1.4 The following requirements are valid for the welding processes commonly used in shipbuilding like manual metal arc welding, gas metal arc welding, flux cored arc welding, metal inert gas welding, submerged arc welding, tungsten inert gas welding and electrogas welding.

1.5 Procedure qualification test programs concerning special welding processes and procedures respectively like e.g. laser welding, stud welding, friction welding, robotic welding have to be agreed with GL.

1.6 GL may additionally require welding procedure tests for specific (difficult) component shapes or combinations of materials, environmental conditions (e.g. underwater welding), particular weld shapes, process variants or combinations, and also for particular welding consumables and auxiliary materials. This is analogously valid for other joining processes or (surface) finishing techniques such as thermal cutting or flame straightening.

1.7 The information in the preceding and following paragraphs, especially the information on test pieces, form of specimens, tests and requirements, applies to the normal materials, welding processes and weld shapes in current use in shipbuilding, which properties are proved under operating conditions and has been verified by test results. In case of doubt, GL can require supplementary and/or other test pieces, forms of specimen and qualification tests showing that the properties of application are sufficient.

1.8 In the case of welding processes whose characteristics result in weld shapes other than those verified by test results (e.g. those with a considerable notch effect), the influence of the weld shape on the fatigue strength behaviour of the welded joints may be investigated in addition to carrying out the prescribed tests. The same applies in analogous manner to other characteristics of the welded joints, e.g. corrosion resistance.
1.9 GL may approve certain welding procedures such as vertical-down welding, build-up welding on rudderstocks or underwater welding (cf. H.13.3), but make their application depending on an approval of every single case, e.g. after examination of the load conditions the use of which is, however, dependent upon authorization, for example following an examination of the load conditions, in each individual case. For welding processes or applications of this nature, GL may also stipulate restrictions in the operation of the vessel (e.g. in the operating area).

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

1.11 For the welding procedure approval the welding procedure qualification test is to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

1.12 Welding procedure approvals are generally non-transferable. Exceptions are only possible after the acceptance by GL and this only for workshops under the same technical and quality management. GL may, however, require proof as to whether the welding processes are being applied correctly and the mechanical properties are adequate by means of non-destructive tests and/or production tests with mechanical-technological test specimens.

1.13 Welding procedure tests performed according to other rules under the supervision of other independent testing bodies can be accepted on demand and after examination by GL. For this purpose, test reports indicating the results, the welding procedure specification and the approval certificate of the other testing body have to be submitted to GL.

2. Test schedule and welding procedure specifications

2.1 Preliminary welding procedure specification (pWPS) and welding procedure specification (WPS)

The shipyard or the manufacturer has to prepare a welding procedure specification intended for the welding procedure qualification test. This welding procedure specification is also called preliminary welding procedure specification (pWPS). In the pWPS, all relevant welding and procedure variables have to be specified. If deemed necessary, the pWPS can be adjusted and completed during the welding procedure test.

2.2 The scope of welding procedure tests shall be laid down in an application and submitted for approval prior to the tests. Before starting the procedure test, a pWPS as well as copies of the base material certificates have to be submitted together with the application to GL. The application for approval and for the performance of a procedure test based upon the pWPS has to be sent to GL Head Office, with simultaneous notification of the local Surveyor, giving the following details:

- Range of application (components, materials, plate / wall thickness, diameter of pipe)
- Welding process
- Welding positions
- Welding equipment, welding parameters
- Weld shapes, weld building up
- Welding consumables and auxiliary materials
- Joint preparation
- Cold- or hot-forming operations prior to welding
- Overweldable shop primer
- Welding jigs, weather protection
- Preheating and heat input during welding
- Post-weld heat treatment, other after-treatment
- Welder
- Date of the testing
- Location of the testing.

If possible, a proposal of test schedule including sketch and dimension of the test pieces and scheduled test specimens and testing has to accompany the application. In case that the above required details and data are basing upon workshop standards or other (welding) specifications, these documents have to be also enclosed to the application.

2.3 If the test pieces, which are welded under the supervision of GL according to the pWPS, show insufficient results, the shipyard or the manufacturer has to adjust and modify the pWPS considering the improvements. A new revised pWPS shall be prepared and the test pieces shall be welded again under the supervision of GL and according to the new pWPS.

2.4 The final welding procedure specification (WPS) is the basis for the manufacturers welding production. If the test results of the test pieces welded in accordance with the pWPS comply with the requirements, GL can approve the welding procedure specification (WPS) within the scope of welding procedure approval for the shipyard or the welding workshop respectively.

3. Qualification of the welding procedures

3.1 General

3.1.1 The preparation and welding of the test pieces have to be carried out in accordance with the
preliminary welding procedure specification (pWPS) and under the general condition of production welding which it represent.

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

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

3.1.4 If butt and fillet welding is applicable during production relevant welding procedure test pieces of butt and fillet weld have to be welded. Only in case of application and overwelding of shop primer, test pieces of fillet weld are to be qualified separately from butt welds.

3.2 Base materials, welding consumables and auxiliaries

3.2.1 The base materials used for welding procedures have to be identified by means of material marking and certificates.

3.2.2 In case of welding procedure tests for high heat input welding, the weldability of the base material has to be proved to GL concerning the maximum applied heat input by the steel manufacturer.

3.2.3 The welding consumables and auxiliary materials shall if possible have already been tested and approved by GL; however, they may be tested and approved at the same time as the welding procedure. Approvals of this type are generally restricted to the user's works and are valid for a maximum of one year, unless repeat tests are performed as required for the welding consumables.

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

4. Welding procedure qualification tests for normal and higher strength hull structural steels, forgings and steel castings with a minimum specified yield strength of $R_{\alpha} \leq 400 \text{ N/mm}^2$

4.1 The following requirements are valid for normal and higher strength hull structural steels, forgings and steel castings according to the GL Material Rules. Other comparable steels and materials respectively can only be used with previous consent of GL.

4.2 Butt welds

The following provisions refer to butt welds on plates. For butt welds on pipelines, please refer to Section 4.

4.2.1 Assembly and dimension of test pieces

4.2.1.1 The test assembly has to be great enough in order to ensure a reasonable heat distribution. The dimension of the test piece has to be adjusted to the welding procedure and to the number of test specimens. Following minimum dimensions of test piece are required:

- manual or semi-automatic welding:
  - width $= 2a$, $a = 3 \times t$, min. 150 mm
  - length $b = 6 \times t$, min. 350 mm

- automatic welding:
  - width $= 2a$, $a = 4 \times t$, min. 200 mm
  - length $b = 1000$ mm

The test assembly is represented in Fig. 1.1:

4.2.1.2 Where, in order to establish the mechanical and technological characteristics of the welded joints, especially in fully mechanized and/or automatic welding processes, test piece lengths are selected which are considerably smaller than the weld lengths to be laid down during later fabrication, the first fabrication welds shall be included as part of the welding procedure tests and, as a minimum requirement, shall be subjected to a visual inspection and non-destructive testing to ensure a trouble-free welding procedure and to detect any imperfections in the weld.

For hull structural steel plates impact tested in the longitudinal direction (CVN-L), the butt weld of the test piece is perpendicular to the rolling direction of the two plates.

4.2.2 Scope of testing and test specimens

The butt weld test assemblies are to be examined non-destructively and destructively in accordance with the following requirements and with Fig. 1.2:

- Visual testing 100 %
- Surface crack detection 100 %
  (dye penetrant testing or magnetic particle testing)
- Radiographic or ultrasonic testing 100 %
- Transverse tensile test two specimens
  (see section 4.2.2.2)
- Longitudinal tensile test one specimen
  (see section 4.2.2.3)
- Transverse bend test four specimens
  (see section 4.2.2.4)
- Charpy V-notch impact test required
  (see section 4.2.2.5)
- Macro examination one specimen
  (see section 4.2.2.6)
- Hardness test required
  (see section 4.2.2.7)
Fig. 1.1 Test assembly for butt weld
4.2.2.1 Non-destructive testing

Test assemblies have to be examined by visual and non-destructive testing prior to the cutting of test specimens. In case that any post-weld heat treatment is required or specified, the non-destructive testing has to be performed after the heat treatment. GL may require specific testing intervals to be adhered to between completion of the welding work and performance of the crack tests, unless a heat treatment has been executed. Imperfections detected by visual or non-destructive testing have to be assessed in accordance with ISO 5817, quality level “B” (except for excess weld metal and excess of penetration for which the quality level “C” applies).

4.2.2.2 Transverse tensile test

The testing has to be carried out in accordance with EN 895 / ISO 4136. In case of great plate thicknesses more test specimens have to be intended for testing in order to cover the whole cross section. If not stated otherwise prior to the testing, the tensile strength recorded for each specimen has not to be less than the minimum required for the base material. The welding procedure minimum tensile test requirements for hull structural steels are shown in Table 1.2. When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength.

Fig. 1.2 Test sampling
4.2.2.3 Longitudinal tensile test

The testing has to be carried out in accordance with Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Section 5, C.2. Longitudinal tensile test of deposited weld metal taken lengthwise from the weld is required for cases where the welding consumable or auxiliaries is not GL approved or that a greater influence on the weld metal is expected due to the character of the procedure. Tensile strength, yield strength and elongation of the specimen has not to be less than the minimum tensile strength, minimum yield strength and minimum elongation of the required quality/strength grade of the welding consumable. Table 1.2 shows the requirements for the minimum tensile strength, yield strength and elongation of the weld metal.

Where more than one welding process or type of consumable has been used to make the test weld, test specimens are to be taken from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

4.2.2.4 Bend test

Transverse bend tests have to be carried out in accordance with EN 910 / ISO 5173. Two of the four test specimens have to be bent with final pass in tension and the other two have to be bent with the root pass in tension. In case of specimen thicknesses ≥ 12 mm, four side bend test specimens can be alternatively tested. For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

The bending tests are to be performed using a mandrel with a diameter equal to 4 times the thickness of the specimen. The required bending angle of 180 ° under the test conditions specified in EN 910 / ISO 5173 is deemed to have been attained when the specimen has been thrust between the supporting rolls to the minimum distance indicated in this standard. The required bending elongation shall be attained before the first incipient crack appears. Minor pore exposures or the like up to a maximum length of 3 mm may be tolerated. The fracture surfaces of ruptured test specimens shall be evaluated.

4.2.2.5 Impact tests

The specimen position, the test temperature and the requirements of the notched-bar impact tests have to be in line with the following requirements. The dimensions of the specimens and the tests have to follow EN 875 / ISO 9016. Charpy V-specimens with the notch perpendicular to the surface of the plate in accordance with EN 875 / ISO 9016 transversal to the weld are required. The notched bar impact test specimens shall be taken from the last side welded and this 1-2 mm below the surface of the base material, in case of larger plate thicknesses they have to be taken from both sides. In case of very great plate thicknesses or welding procedure tending to centre segregation, additional notched-bar impact specimens have to be taken from the middle of the plate thickness. Figure 1.3 and Figure 1.4 show the position of specimen depending on heat input, plate thickness and weld preparation. Table 1.2 presents the impact requirements.

For the impact tests the average value out of three impact test specimens (for each notch location, weld metal, fusion line, HAZ) applies.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.
a) $t \leq 50 \text{ mm}$ \(^{(1)}\)

Notch locations:
- a: center of weld “WM”
- b: on fusion line “FL”
- c: in HAZ, 2mm from fusion line

Note: (1) For one side welding with thickness over 20 mm notch locations “a” is to be added on root side.

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

Notch locations:
- a: center of weld “WM”
- b: on fusion line “FL”
- c: in HAZ, 2mm from fusion line

Fig. 1.3 Locations of V-notch for butt weld of normal heat input (heat input $\leq 50 \text{ KJ/cm}$)
Fig. 1.4 Locations of V-notch for butt weld of high heat input (heat input > 50 KJ/cm)

Note: (1) For one side welding with thickness over 20 mm notch locations "a", "b" and "c" are to be added on root side.

b) t>50mm

Notch locations:
  a : center of weld “WM”
  b : on fusion line “FL”
  c : in HAZ, 2mm from fusion line
  d : in HAZ, 5mm from fusion line
  e : in HAZ, 10mm from fusion line in case of heat input > 200kJ/cm
### Table 1.2 Requirements applicable to welded hull structural steel in the scope of welding procedure tests

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield strength (weld metal) [N/mm²]</th>
<th>Tensile strength (weld metal) [N/mm²]</th>
<th>Elongation (weld metal) [%]</th>
<th>Impact energy (1), (3), (4) [J]</th>
<th>Bending angle (D = 4 t)</th>
<th>Bending elongation gauge length 2 L₀ (2) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual and semi-mechanised</td>
<td>Full mechanised</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PA, PC, PE</td>
<td>PF, PG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A 5</td>
<td>305</td>
<td>400</td>
<td>22</td>
<td>47, 34, 34</td>
<td>180 °</td>
<td>22</td>
</tr>
<tr>
<td>B 5, D</td>
<td>± 0</td>
<td>± 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>± 20</td>
<td>± 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A 32</td>
<td>335</td>
<td>440</td>
<td>22</td>
<td>47, 34, 34</td>
<td>180 °</td>
<td>22</td>
</tr>
<tr>
<td>D 32</td>
<td>± 0</td>
<td>± 0</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>A 36</td>
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<td>490</td>
<td>22</td>
<td>47, 34, 34</td>
<td>180 °</td>
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</tr>
<tr>
<td>D 36</td>
<td>± 0</td>
<td>± 0</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>E 36</td>
<td>± 20</td>
<td>± 20</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>A 40</td>
<td>400</td>
<td>510</td>
<td>22</td>
<td>47, 39, 39</td>
<td>180 °</td>
<td>22</td>
</tr>
<tr>
<td>D 40</td>
<td>± 0</td>
<td>± 0</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>E 40</td>
<td>± 20</td>
<td>± 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F 40</td>
<td>– 40</td>
<td>– 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Charpy-V-notch specimen, average value of three specimens.
(2) The gauge length (L₀) = weld width (Lₘ) + half of the plate thickness on each side adjacent to the weld; see EN 910/ISO 5173
(3) In the case of plate thickness > 50 mm, the requirements of the impact energy have to be agreed with GL prior to testing
(4) The impact requirements are valid for test pieces with weld perpendicular to the rolling direction of the plates.
(5) For grade A / B, the minimum value of impact energy is 27 J in the fusion line (FL) and in the heat affected zone (HAZ).

Where the plate thickness is less than 10 mm, notched bar impact test specimens with a width corresponding to the plate thickness, and wherever possible 7.5 mm or 5 mm, may be used. In such cases the impact energy values specified in Table 1.2 shall be reduced in accordance with Table 1.3.

The notched bar impact test is generally dispensed with for plates less than 5 mm thick. However, other tests of resistance to brittle fracture may be stipulated.

### Table 1.3 Required impact energy values with specimens of reduced width

<table>
<thead>
<tr>
<th>Cross section of specimen [mm x mm]</th>
<th>Fraction of the required minimum impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 x 7,5</td>
<td>5/6</td>
</tr>
<tr>
<td>10 x 5,0</td>
<td>2/3</td>
</tr>
</tbody>
</table>
4.2.2.6 Macro examination

The examination of the macro-structure has to be executed on minimum one polished section. The polished surface of the section has to be taken perpendicular to the weld axis.

The macro specimen shall be of such a size and treated by grinding and etching in such a way as to reveal the nature and structure of the crystallization of the weld metal and the heat-affected zone as well as the texture of the base metal. For the macro examination, minimum 10 mm out off the heat affected zone from the base material has to be considered.

The polished sections shall be photographed and the photos appended to the inspection report. Macrographs shall normally be to a scale of 1:1 to 1:3; if the cross-sectional area of the weld is small, they may be magnified.

The specimen have to be assessed in accordance with ISO 5817, quality level “B”, except for excess weld metal and excess of penetration for which the quality level “C” applies.

4.2.2.7 Hardness test

The hardness test is required for steels with specified minimum yield strength of $R_{yH} \geq 355$ N/mm² and in general for steel cast and forgings. The Vickers method with a test strength of 98N (HV10) has normally to be used. The hardness has to be verified on ground and etched specimens, with test surface perpendicular to the weld axis. Other test methods have to be agreed with GL prior to testing. Two test rows are necessary in accordance with Figure 1.5. At least three individual indentations in the weld metal, the heat affected zones (both sides of the weld) and the base metal (both sides of the weld) are required in accordance with Figure 1.6. The distance between the indentations is 1 mm in case of Vickers HV10.

Fig. 1.5 Examples of hardness test with rows of indentations in butt welds
More examples concerning hardness indentations are presented in EN1043-1 / ISO 6507-1.

The results from the hardness test have not to exceed a hardness of 350 HV10 in case of higher strength steel, steel casting and forgings with a specified minimum yield strength of $R_{\text{eH}} \leq 400 \text{ N/mm}^2$.

### 4.3 Fillet welds

The following requirements refer to fillet welds on plates and sections. Concerning fillet weld on pipelines, see Section 4.

In case that a fillet welding procedure shall be used for plates and sections, coated with an overweldable shop primer, similarly coated plates have to be used during the procedure test for fillet welds in the same manner. The kind of the shop primer and dry-film thickness have to be indicated in the report.

Fillet weld test pieces (T-joint and/or double T-joint (cruciform) test pieces) have to be welded with root gaps not greater than 0.5 mm. Depending on the subsequent practice, tacks shall also be included in the test (and overwelded where applicable). The throat thickness of the fillet shall correspond to those used in subsequent fabrication, but shall not be greater than 0.5 times the plate thickness.

#### 4.3.1 Test assembly and dimension

Depending on the welding position to be qualified, T-joint and/or double T-joint (cruciform) test pieces are necessary. In case of vertical down welding (PG) double T-joint (cruciform) test pieces are always required for plates coated with shop primer and also for plates without shop primer. In case of the other welding positions (PA, PB, PD, PF) T-joint test pieces are sufficient but only for plates coated with shop primer. The evaluation of fillet welds on plates without shop primer coating in welding positions (PA, PB, PD, PF) can take place in the scope of butt weld procedure test after GL’s agreement.

#### 4.3.1.1 T-joint test pieces

The test assembly has to be great enough in order to ensure a reasonable heat distribution. The dimension of the test piece has to be adjusted to the welding procedure and to the number of test specimens. Following minimum dimensions of test piece are required:

- manual and semi-automatic welding:
  - width $a = 3 \times t$, min. 150 mm
  - length $b = 6 \times t$, min. 350 mm
- automatic welding:
  - width $a = 3 \times t$, min. 150 mm
  - length $b = 1000$ mm

The test assembly is represented in Figure 1.7.
4.3.1.2 Where, in order to establish the mechanical and technological characteristics of the welded joints, especially in fully mechanized and/or automatic welding processes, test piece lengths are selected which are considerably smaller than the weld lengths to be laid down during later fabrication, the first fabrication welds shall be included as part of the welding procedure tests and, as a minimum requirement, shall be subjected to a visual inspection or production tests shall be arranged to ensure a trouble-free welding procedure and to detect possible imperfections in the weld.

4.3.1.3 Double T-joint (cruciform) test pieces

The test assembly has to be great enough in order to ensure a reasonable heat distribution. The dimension of the test piece has to be adjusted to the welding procedure and to the number of test specimens. The minimum dimensions of test piece and the test assembly are shown in Figure 1.8 concerning manual and semi-automatic welding procedures and in Figure 1.9 concerning automatic welding procedures.

Fig. 1.7 Test assembly for fillet weld in welding positions PA, PB, PD, PF

Fig. 1.8 Double T-joint (cruciform) test pieces for manual and semi-automatic welding procedures (welding position PG)

Fig. 1.9 Double T-joint (cruciform) test pieces for automatic welding procedures
4.3.2 Welding of test pieces

For single run manual and semi-automatic fillet welding, a stop/restart has to be included in the test length and its position is to be clearly marked for subsequent examination. If tack welds are intended to be overwelded in the subsequent production, they have to be considered in the test piece as well. T-joint test pieces have to be welded on one side only. Only one welding position shall be used per test piece.

4.3.3 Examinations and tests

Test assemblies have to be examined non-destructively and destructively in accordance with the following:

4.3.3.1 Examinations and tests of T-joint test pieces

- Visual testing 100 %
- Surface crack detection 100 % (dye penetrant testing or magnetic particle testing)
- Macro examination 2 specimens (see section 4.3.3.4)
- Hardness test required (see section 4.3.3.5)
- Fracture test required (see section 4.3.3.5)

4.3.3.2 Examinations and tests of double-T joint (cruciform) test pieces

- Visual testing 100 %
- Surface crack detection 100 % (dye penetrant testing or magnetic particle testing)

As shown in Figures 1.8 and 1.9, one or more sets of test specimens shall be taken from the (cruciform) fillet-welded test pieces in accordance with Figure 1.10.

A set of (cruciform) fillet weld test specimens shall include the following specimens. The specimen shapes and dimensions have to be in line with Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Section 5. One set of test specimens has to include the following specimens:

- Cruciform tensile test specimens (Z) 3 specimen (see section 4.3.3.7)
- Macrographic examination (M) 2 specimen (see section 4.3.3.4)
- Hardness test required (see section 4.3.3.5)
- Fracture test required, from the remaining test piece on alternate side (see section 4.3.3.6)

4.3.3.3 Non-destructive testing

Test assemblies have to be examined by visual and non-destructive testing prior to the cutting of test specimens. In case that any post-weld heat treatment is required or specified, the non-destructive testing has to be performed after the heat treatment. GL may require specific testing intervals to be adhered to between completion of the welding work and performance of the crack tests, unless a heat treatment has been executed. Imperfections detected by visual or non-destructive testing have to be assessed in accordance with ISO 5817, quality level “B” (except for excess convexity and excess throat thickness for which the quality level “C” applies).

4.3.3.4 Macro examination

The examination of the macro-structure has to be executed on minimum two polished section. For single run manual and semi-automatic fillet welds one macro-section is necessary in the stop/restart area. The polished surface of the section has to be taken perpendicular to the weld axis.

The macro specimen shall be of such a size and treated by grinding and etching in such a way as to reveal the nature and structure of the crystalization of the weld metal and the heat-affected zone as well as the texture of the base metal. For the macro examination, minimum 10 mm out off the heat affected zone from the base material has to be considered.

The polished sections shall be photographed and the photos appended to the inspection report. Macrographs shall normally be to a scale of 1:1 to 1:3; if the cross-sectional area of the weld is small, they may be magnified.

The specimens have to be assessed in accordance with ISO 5817, quality level “B”, except for excess convexity and excess throat thickness for which the quality level “C” applies.

4.3.3.5 Hardness tests

The hardness test is required for steels with specified minimum yield strength of $R_{eH} \geq 355$ N/mm$^2$ and in general for steel cast and forgings. The Vickers method with a test strength of 98N (HV10) has nor-
nally to be used. The hardness has to be verified on ground and etched specimens, with test surface perpendicular to the weld axis. Other test methods have to be agreed with GL prior to testing. Two test rows are necessary in accordance with Figure 1.11. At least three individual indentations in the weld metal, the heat affected zones (both sides of the weld) and the base metal (both sides of the weld) are required in accordance with Figure 1.12. The distance between the indentations is 1 mm in case of Vickers HV10.

Further examples for hardness tests with indentations are given in EN 1043-1 / ISO 6507-1.

The results from the hardness test have not to exceed a hardness of 350HV10 in case of higher strength steel, steel casting and forgings with a specified minimum yield strength of $R_{eY} \leq 400 \text{ N/mm}^2$.

4.3.3.6 Fracture test

The fracture test has to be performed in accordance with EN 1320 / ISO 9017. Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration (penetration of the theoretical root point), to be assessed in accordance with ISO 5817, quality level “B”.

4.3.3.7 Cruciform tensile test

The cruciform tensile test specimens have to be evaluated in order to determine the tensile-shear strength of the weld metal according to Fig. 13. Before the performance of cruciform tensile tests, the fillet weld throat thicknesses and the width of the specimens have to be measured. The width of the specimen should be about 35 mm.

Measured on cruciform tensile test specimens, the minimum tensile (tensile-shear) strength of the weld section (fracture section in accordance with Fig. 1.13) shall meet the requirements stated in Table 1.4.
4.4 Re-testing

If the test specimen fails to comply with any of the requirements for visual or non-destructive testing one further test piece is to be welded and subjected to the same examination. If this additional test piece does not comply with the relevant requirements, the pWPS has to be regarded as not capable of complying with the requirements without modification.

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

If a tensile test specimen fails to meet the requirements, two more tensile tests may be performed. If both additional specimens comply with the requirement, the tensile test is passed. If one or both of the additional specimens do not comply with the requirement, the tensile test and thus the procedure test has been failed.

If there is a single hardness value above the maximum values allowed, additional hardness tests are to be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

When the average value of the three initial Charpy V-notch impact specimens fails to meet the stated requirement, or the value for more than one specimen is below the required average value, or when the value of any one specimen is below 70% of the specified average value, three additional specimens from the same test piece may be tested and the results added to those previously obtained to form a new average. However, of the six individual values only two may be below the required average value, of which only one individual value may be less than 70% of the prescribed average value. Otherwise the impact test and thus the procedure test has been failed.

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

4.5 Test record

Welding conditions for test assemblies and test results have to be recorded in a welding procedure test record and – signed by the tester and the testing supervisor – submitted to GL. The relevant items listed for the WPS of these requirements have to be included.

The welding procedure test record has to be signed by the Surveyor witnessing the test and submitted to GL together with the welding procedure specification for the final approval of the welding procedure.

5. Welding procedure qualification tests for high-strength (quenched and tempered) fine-grained steels with a specified minimum yield strength $R_{eH} > 400 \, N/mm^2$

Unless no further statements to the procedure tests are made in the following, the requirements given in the previous sections apply. For welding procedure tests on high-strength steels intended for hull structures the GL acceptance on a case by case decision is necessary. The requirements will be defined separately.

5.1 The following requirements apply for high-strength (quenched and tempered) fine-grained steels for welded structures according to the GL Material Rules. Comparable high-strength steels, suitable for welding, can only be used with GL’s agreement.

5.2 For high-strength and quenched and tempered steels with a specified minimum yield strength $R_{eH} > 400 \, N/mm^2$, the non-destructive test has to be carried out at least 48 hours after the welding, unless heat treatment has been carried out.

5.3 A round tensile test specimen is to be prepared in every case where the mechanical properties of the weld metal are inferior to those of the base material.

5.4 The bending tests have to be performed, depending of the specified minimum yield strength in the range of 420 N/mm² up to 500 N/mm² using a mandrel with a diameter of 5 times the specimen thickness, and in the range above 500 N/mm² up to 690 N/mm² using a mandrel with a diameter of 6 times the specimen thickness. The required bending angle is $180^\circ$.

5.5 For high-strength and quenched and tempered steels, where the impact energy has been demonstrated in transverse direction (CVN-T), the welding seam has to be arranged parallel to the rolling direction of both plates. The requirements for the impact energy and the test temperature are the same as for the base material.

5.6 The results of the hardness test for high-strength and quenched and tempered steels of a speci-
For fillet welds on high-strength and quenched and tempered steels with a specified minimum yield strength $R_{eh} > 400 \text{ N/mm}^2$ and $R_{eh} \leq 690 \text{ N/mm}^2$ shall not exceed a hardness of 420 HV10.

5.7 For fillet welds on high-strength and quenched and tempered steels with a specified minimum yield strength $R_{eh} > 460 \text{ N/mm}^2$ separately fillet weld procedure tests are required using double-T joint (cruciform) test specimens. If the fracture occurs in the base material, at least the minimum tensile strength of the base material is to be achieved. If the fracture occurs in the cross-section of the weld seam, the tensile-shear strength is to be determined, taking into consideration the actual cross-section of the weld seam. Where necessary, the melting depth has to be considered which exceeds the theoretical root point. The mean tensile-shear strength determined in the weld seam cross-section shall be at least 80% of the tensile strength of the base material used.

5.8 For the range of application see Section 9.

6. Austenitic stainless (clad) and austenitic-ferritic (duplex) steels

If no further statements are made regarding welding procedure tests in the following, the Rules Chapter 1 – General Requirements, Proof of Qualifications, Approvals, Section 4 or respectively the standards of series EN ISO 15614 are applicable.


6.2 The minimum properties specified in Chapter 1 – General Requirements, Proof of Qualifications, Approvals, Section 5, for the testing of welding consumables and auxiliary materials shall be met for butt weld specimens. In the case of joints between different types of steels, the strength values of the base material which has the lower strength, shall be used.

6.3 Unless otherwise agreed in an individual case, a bending mandrel diameter of three times the specimen thickness may be used for the bending test and a test temperature of minus 30 °C for the notched bar impact test performed on austenitic-ferritic (duplex) steels. For austenitic stainless materials normally no notched bar impact tests have to be performed unless the qualification of the welding procedures is necessary for a low temperature application. Hardness test for austenitic stainless materials have normally not to be performed as well. For such materials, dye penetration tests have to be carried out.

6.4 Depending on the field of application or if required for the base material, additional corrosion protection tests have to be performed within the scope of welding procedure tests, e.g. testing of resistance against intergranular corrosion.

6.5 For test specimens of austenitic-ferritic (duplex) steels a determination of the ferrite content is additionally necessary, which should not be less than 30% in both the welding material and in the heat affected zone.

7. Aluminium alloys

If in the following no statements are made for welding procedure tests, the requirements of the Rules in Chapter 1 General Requirements, Proof of Qualifications, Approvals, Section 4 or respectively the standards given in EN ISO 15614-2 are applicable.

7.1 For welding procedure tests and tests on production specimens relating to aluminium alloys, the values specified in Table 1.5 shall be used as standard values for butt weld specimens taken from 5000 and 6000 series alloys as stipulated in the GL Rules for Materials. Alloys of the 5000 and 6000 series separately to be qualified within the scope of welding procedure tests. Welding procedure tests on materials of higher strength in each of the 5000 and 6000 series include materials of a lower strength. In no case the tensile strength of the specimens shall not be less than the minimum stipulated value for the base material in its "soft" condition. During design and dimensioning operations, these differing values have to be considered, where applicable. The stipulated tensile strength values apply to test specimens retaining the weld reinforcement. Other aluminium alloys shall be classified in analogous manner, and the requirements for this are specified on a case-by-case basis under consideration the characteristics of the base material and the joint efficiency factors stipulated in EN ISO 15614-2.
Table 1.5 Requirements applicable to aluminium alloys

<table>
<thead>
<tr>
<th>Alloy no.</th>
<th>Material designation</th>
<th>0,2 %-proof stress $^2$ [N/mm²]</th>
<th>Tensile strength [N/mm²]</th>
<th>Bending angle $^3$ [degree]</th>
<th>Bending elongation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN AW-5083</td>
<td>AlMg4,5Mn0,7</td>
<td>125</td>
<td>275</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AW-5086</td>
<td>AlMg4</td>
<td>100</td>
<td>240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AW-5383</td>
<td>AlMg4,5Mn0,7mod.</td>
<td>145</td>
<td>290</td>
<td>180</td>
<td>18</td>
</tr>
<tr>
<td>EN AW-5754</td>
<td>AlMg3</td>
<td>80</td>
<td>190</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AW-5059</td>
<td>AlMg5,5Mn0,8ZnZr</td>
<td>160</td>
<td>330</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AW-6005A</td>
<td>AlSiMg(A)</td>
<td>115</td>
<td>170</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>EN AW-6061</td>
<td>AlMgSiCu</td>
<td>115</td>
<td>170</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AW-6082</td>
<td>AlSiMgMn</td>
<td>125</td>
<td>185</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$ Using a weld consumable of a quality grade in accordance with the base material according to Chapter 1, Section 5, J.

$^2$ As far as established (on additional samples which are to be agreed).

$^3$ Bending mandrel-∅ to be selected depending on the material group and condition according EN ISO 15614-2.

7.2 The required bending angle of 180° under the test conditions specified in EN 910/ISO 5173 is deemed to have been attained when the specimen has been forced between the supporting rolls to the minimum length specified in this standard. The required bending elongation shall be attained before the first incipient crack appears. Minor pore exposures or the like, up to a maximum length of 3 mm, may be tolerated. The fracture surfaces of ruptured test specimens shall be evaluated.

7.3 If fillet welding is applicable during the fabrication, separately fillet weld procedure tests are required using double-T joint (cruciform) test specimens. If the rupture occurs in the base material, at least the minimum tensile strength of the base material in its „soft“ condition has to be achieved. If the rupture occurs in the cross-section of the weld seam, the tensile-shear strength has to be determined, taking the actual cross-section of the weld seam into consideration. Where necessary, the melting depth which exceeds the theoretical root point has to be considered. The mean tensile-shear strength determined in the weld seam cross-section shall be at least 60 % of the tensile strength of the used base material. Necessary margins (if this value is not attained) have to be considered for the dimensioning of fillet joints.

7.4 For the welding procedure tests and tests on production specimens relating to aluminium alloys, unless otherwise stipulated in individual cases, the notch impact toughness test may be omitted. The requirements applicable to low temperature applications will be separately specified.

8. Other materials or welding processes

The requirements applicable to other materials or other test methods will be determined on a case-by-case basis in a manner analogous to that applied to the materials covered earlier, on the basis of their chemical composition, mechanical properties and other characteristics of the base materials and with due regard for the anticipated operating conditions, such as the lowest anticipated service temperature (design).

9. Scope of application

9.1 General

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

9.2 Changes outside of the ranges specified and approved by GL require a new welding procedure test.

9.3 Shop primers may have an influence on the quality of fillet welds. Therefore they have to be taken into account for the testing. Welding procedure qualification with shop primer will qualify those without shop primer, but not vice versa.
9.4 Base metal

9.4.1 Normal- and higher strength hull structural steels

The strength level (–, … 32, …36, …40) and the toughness grade (A/A…, B, D/D…, E/E…, F…) of the specimen are decisive for the scope of application.

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as the tested one.

b) For each toughness grade, welding procedures are considered applicable to the same and two lower strength levels as the tested one.

c) For applying the above a) and b) to high heat input processes above 50 kJ/cm, e.g. the two-run technique with either submerged arc or gas shielded metal arc welding, electro slag and electro gas welding, welding procedure is applicable to that toughness grade tested and one strength level below.

If steels used for construction are supplied with different delivery conditions as those tested, GL may require additional tests. Welding procedure tests of thermo-mechanically rolled (TM) steels do not include normalised steels, however vice versa.

9.4.2 High strength (quenched and tempered) steels with $R_{	ext{mH}} > 400 \text{ N/mm}^2$

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as the tested one.

b) For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as the tested one.

c) The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

9.4.3 Weldable C and C-Mn hull steel forgings

a) Welding procedures are considered applicable to the same and lower strength level as the tested one.

b) The approval of quenched and tempered hull steel forgings does not qualify other delivery conditions and vice versa. These have to be tested and qualified separately.

9.4.4 Weldable C and C-Mn hull steel castings

a) Welding procedures are considered applicable to the same and lower strength level as the tested one.

b) The approval of quenched and tempered hull steel castings does not qualify other delivery conditions and vice versa. These have to be tested and qualified separately.

9.5 Thickness

9.5.1 The qualification of a WPS carried out on a test assembly of thickness $t$ is valid for the thickness range given in Table 1.6.

9.5.2 In addition to the requirements of Table 1.6, the range of approval of throat thickness “a” for fillet welds is to be as follows:

- single run: “0.75 x a” to “1.5 x a”
- multi-run: as for butt welds with multi-run (i.e. $a = t$)

9.5.3 For the vertical-down welding, the test piece thickness “t” is always taken as the upper limit of the range of application.

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

Table 1.6 Approval range of thickness for butt and filled welds

<table>
<thead>
<tr>
<th>Thickness of test piece $t$ (mm)$^1$</th>
<th>Range of approval for Butt welds with single run or single run from both sides</th>
<th>Range of approval for Butt welds with multi-run and fillet welds$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3 &lt; t \leq 12$</td>
<td>$0.7 \times t$ to $1.1 \times t$</td>
<td>$3$ to $2 \times t$</td>
</tr>
<tr>
<td>$12 &lt; t \leq 100$</td>
<td>$0.7 \times t$ to $1.1 \times t^3$</td>
<td>$0.5 \times t$ to $2 \times t$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(max. 150 mm)</td>
</tr>
</tbody>
</table>

$^1$ For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval for the individual welding process.

$^2$ For fillet welds, the range of approval is to be applied to both base metals (web and flange thickness)

$^3$ For high heat input processes over 50 kJ/cm, the upper limit of range of approval is to be $1.0 \times t$.

$^4$ T-butt welds are in general qualified by butt welds. GL may additionally require welding procedure tests as T-joint welds, e.g. for particular weld shapes.
9.5.5 Notwithstanding the above, the approval of maximum thickness of base metal for any technique has to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated in 4.2.2.7, 4.3.3.5 and 5.6.

9.6 Welding positions
Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies have to be welded for highest heat input position (normally vertical-up position (PF)) and lowest heat input position (normally horizontal-vertical (PC)). The vertical-down welding position (PG), in general, has to be tested separately.

9.7 Welding process
9.7.1 The approval is only valid for the welding process(es) used in the welding procedure test. A change from a multi-run to a single run is not allowed.

9.7.2 For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process. It is also possible to make the welding procedure test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

9.7.3 In general, full mechanized and automatic (robot) welding procedures have to be qualified separately from the semi-automatic welding procedures.

9.8 Welding consumables
Welding consumables and auxiliary materials may be replaced by other equivalent, suitable, with corresponding quality grade and with GL approval, if this is explicitly stated in the welding procedure approval.

9.9 Heat input
9.9.1 The upper limit of heat input approved is 25 % greater than that used in welding the test piece or 55kJ/cm whichever is smaller, except that the upper limit is 10 % greater than that for high heat input processes over 50 kJ/cm.

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

9.10 Preheating and interpass temperature
9.10.1 The minimum preheating temperature has not to be less than that used in the beginning of the welding of the test piece. If necessary, for the higher range of thicknesses, the specification of the preheating temperature may be increased. For the necessity and amount of preheating see Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Section 3.

9.10.2 The maximum interpass temperature has not to be higher than that used when welding the test piece. The standard values for the maximum interpass temperature according to Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Section 3 have to be observed.

9.11 Post-weld heat treatment
The heat treatment used in the qualification test has to be maintained during manufacture. The holding time may be adjusted as a function of thickness. Further notes with reference to post-weld heat treatment see Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Section 3.

9.12 Type of joint
9.12.1 The range of approval depending on type of welded joints for test assembly is shown in Table 1.7.

9.12.2 A qualification test performed on a butt weld, if no shop primers are overwelded, will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 9.5.2 above.

Additional qualification tests, e.g. for T-joints, may be required by GL, e.g. if the edge preparation (root gap, included angle) has been changed and a lack of fusion, insufficient penetration or a negative influence on the mechanical-technological properties cannot be excluded.

Table 1.7 Range of approval for type of welded joint

<table>
<thead>
<tr>
<th>Type of welded joint for test assembly</th>
<th>Range of approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt welding</td>
<td></td>
</tr>
<tr>
<td>one side with backing</td>
<td>A, C</td>
</tr>
<tr>
<td>one side without backing</td>
<td>A, B, C, D</td>
</tr>
<tr>
<td>both side with gouging</td>
<td>C</td>
</tr>
<tr>
<td>both side without gouging</td>
<td>D, C, D</td>
</tr>
</tbody>
</table>