# Section 1

# Welding of Hull Structures

## A. General

### 1. Scope

**1.1** These rules apply to all welding work carried out on the ship's hull, including the superstructure and deckhouses, its internal and external structures, and equipment components forming part of the ship's structure, e.g. hatch covers, masts, king posts or crane substructures welded to the ship's hull. See also Chapter 1, Section 1, A.1. and A.2.

**1.2** They also apply in analogous manner to cargo tanks which are not an integral part of the ship's hull and are not pressure vessels within the meaning of Section 3 (e.g. prismatic type A tanks, according to the Rules for Construction I, Part 1, Chapter 6).

### 2. Other relevant rules and regulations

The design and dimensioning of welded joints is also governed by the provisions of the Rules for Construction I, Part 1, Chapter 1, Sections 19 "Welded Joints and 20 "Fatigue Strength" and the performance of the work is also subject to the provisions of Section 1, N. of the said Rules for Construction. For other relevant standards, see Chapter 1, Section 1, B. of these Rules for Welding.

### 3. Weld performance

Welded joints in hull structures shall be prepared, made and inspected in such a way that their quality characteristics are equivalent to those of the base materials to be joined. This means that they may not deviate from the prescribed form and internal condition by more than the limits allowed by the prescribed weld quality grades according to Table 1.9 or by the evaluation categories used as a basis for the notch category classification for the proof of fatigue strength (cf. Rules for Construction I, Part 1, Chapter 1, Section 20). The same applies in analogous manner to the other quality characteristics; cf. also C.

## B. Approval of Shipyards and Welding Shops, Welding Personnel

### 1. Works and subworks

**1.1** In the following paragraphs, the term "welding shop" refers to the shipyard or welding fabrication shop which may be considered an independent unit with regard to its physical and organizational situation.

**1.2** Branches and subcontractors are thus generally deemed to be "independent" welding shops which have to satisfy the requirements prescribed below. In particular, every welding shop must have a welding supervisor who is a permanent member of the welding shop staff (cf. Chapter 1, Section 2).

**1.3** Outside firms working in welding shops may be granted approval as independent welding shops. On this and on temporary workers, see also C.3. and Chapter 1, Section 1, F.

### 2. Requirements, scope of approval

**2.1** All shipyards and welding shops intending to perform welding work covered by these rules must satisfy the requirements relating to the welding shop and its personnel set out in Section 2 and must have been approved for this work by the Society. Applications for approval shall be submitted by the shipyards and welding shops in good time before starting the welding work, enclosing the information and documentation prescribed in Chapter 1, Section 2, A.3.

**2.2** Welding personnel (welders, operators and supervisory staff) and where applicable inspectors and test supervisors must meet the requirements set out in Chapter 1, Section 2, B.2., B.3. and B.4. and be recognized by the Society. For welder's qualification tests, see Chapter 1, Section 3.

**2.3** The scope of the approval is determined by the capabilities of the welding shop and by the intended range of application (materials, welding processes, welding positions, etc.). The intended range of application shall be specified in the application for approval; cf. the form "Description of Welding Shop" attached at Annex B of Chapter 1. For the period of validity of the approval, see Chapter 1, Section 2, A.4. and A.5.

**3. Basic approval, extensions**

**3.1** For welding hull structures, as a general rule (basic) approval is granted first of all on the basis of a works inspection and, if necessary, welder's qualification tests in accordance with Chapter 1, Section 3 (see also H.2.) normally for manual arc welding (welding process 111) and/or for semi-mechanized metal-arc active gas welding using solid and flux-cored wire electrodes (welding processes 135 and 136) of normal-strength hull structural steels A to D and other comparable grades of forged and cast steel. The thickness range is in this case determined by the scope of the valid welder's qualification tests.

**3.2** Exceptions to this rule are single-side welding and vertical-down welding using these processes (111, 135, 136), for which welding procedure tests shall be performed in every case. Cf. F. One-wire submerged-arc welding (welding process 121) may also be covered in the basic approval described in 3.1 on the basis of documentary proof in accordance with F.1.4 (for conventional welding in one run on each side [two-run technique] on plates 4 to 25 mm thick and for multi-pass welding up to 40 mm).

**3.3** Basic approval may be extended to include any welding procedure approvals on the basis of welding procedure tests as set out in Chapter 1, Section 4 (cf. also F.); in exceptional cases, however, limited approval may also only be granted (in conjunction with a works inspection) for a specific material and/or welding process.

## C. Quality Inspection, Responsibility

**1.** Shipyards and welding shops shall ensure by means of regular in-house quality inspections during fabrication and on completion of the welding work that this work has been performed competently and satisfactorily (cf. Chapter 1, Section 1, F.). For the duties and responsibilities of the welding supervisor, see also EN 719/ISO 14731.

**2.** The shipyards and welding shops are responsible for ensuring that the welding work conforms to these Rules, the approved manufacturing documents, any conditions stipulated in the approval documents, good shipbuilding practice and the latest state of welding practice. The inspections and checks to be performed by the Society's Surveyor do not relieve the welding shops of this responsibility.

**3.** With regard to quality inspections and the responsibilities involved in awarding subcontracts to independent branches or suppliers or to approved or non-approved outside firms working in the welding shop (subcontractors), see Chapter 1, Section 1, F. Subcontracting of work or employment of temporary workers shall be notified to the Society.

**4.** The scope of the required quality inspections depends on the construction project in question. It is essential to ensure, however, that the intended materials, welding consumables and auxiliary materials are used and that the weld preparation, assembly, execution of the tack and final welds and the dimensional accuracy and completeness of the welded joints meets the requirements stated in para. 2. For non-destructive testing of the welded joints, see I.

**5.** Following inspection and, if necessary, repair by the welding shop, the components shall be presented to the Society's Surveyor for checking at suitable stages of fabrication. For this purpose they shall be readily accessible and shall normally be uncoated. Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory workshop inspection and any necessary repair work has been performed.

**6.** If the quality or good working order of a component cannot be guaranteed or is in doubt due to inadequate or missing information in the manufacturing documents (e.g. production drawings), the Society may demand appropriate improvements. This applies in analogous manner to supplementary or additional components (e.g. reinforcements), even if these components were not stipulated when the drawings were scrutinized or could not be stipulated due to insufficiently detailed representation in the "class plans" (cf. the Rules for Construction I, Chapter 1, Section 1, G.).

**7.** The Society is not responsible for guaranteeing that all the components and welded joints inspected to the prescribed extent (generally on a random basis) by its surveyors have been fabricated in accordance with the conditions and meet the requirements in every respect. Components or welded joints which subsequently turn out to be defective may be rejected or their repair may be demanded even if acceptance testing has already been carried out.

## D. Materials, Weldability

**1.** Welded structures may only be fabricated using base materials of proven weldability. Materials must comply with the Society's Rules for Materials (Code II/1/-5). Other comparable materials (e.g. structural steels conforming to EN 10025) may only be used after the Society has given its approval in each individual case.

**2.** Any conditions relating to working and welding imposed by the approval certificate and the recommendations of the material producer shall be complied with. For the selection of materials for the ship's hull, see the Rules for Construction I, Part 1, Chapter 1, Section 2.

**3.** The weldability of normal-strength hull structural steels of quality grades A, B, D and E tested by the Society is considered proven. No measures above and beyond the provisions of these Rules for Welding are necessary when welding these steels.

**4.** The weldability of the higher-strength hull structural steels of quality grades A 32 to F 40 approved and tested by the Society in accordance with the Rules for Materials has been checked and can be taken for granted if the work is carried out in accordance with normal shipbuilding practice.

**5.** High-strength (quenched and tempered) fine-grained structural steels, steels tough at subzero temperatures, stainless structural steels and other (alloy) structural steels have to be specially approved by the Society. The weldability of the steel in question must have been verified in combination with welding processes and welding consumables.

**6.** Steel castings and forgings shall comply with the Rules for Materials and shall have been tested by the Society. The carbon content of components made from carbon and carbon-manganese steels/castings for welded structures shall not exceed 0,23 % C at ladle analysis (check analysis: max. 0,25 % C).

**7.** Light metal alloys must have been tested by the Society in accordance with the Rules for Materials. Their weldability must have been verified in combination with welding processes and welding consumables. It can generally be taken for granted in the case of the alloys mentioned in the Rules for Materials.

## E. Welding Consumables and Auxiliary Materials

**1.** All the welding consumables and auxiliary materials used (e.g. covered electrodes, wire-gas combinations, wire-flux combinations, etc.) must have been approved by the Society in accordance with Chapter 1, Section 5. The quality grade required depends on the base materials to be welded and is shown in the relevant tables in Chapter 1, Section 5, except for hull structural steels and other comparable structural steels, forged steels and cast steels.

**2.** The correlation of the required quality grades of welding consumables and auxiliary materials for welding hull structural steels to the respective hull structural steel quality grades is shown in Table 1.1. The correlation to other comparable structural steels, forged steels and cast steels shall be undertaken in analogous manner.

**3.** For welding of different quality grades of hull structural steel, welding consumables and auxiliary materials shall be correlated to the steels by their quality grades and added symbols as follows:

a) Normal-strength hull structural steels of different quality grades:

Welding consumables and auxiliary materials for whichever is the higher-quality (tougher) hull structural steel, e.g. A with D: quality grade 2 ....

b) Higher-strength hull structural steels of the same strength but with different quality grades:

Welding consumables and auxiliary materials for whichever is the higher-quality, (tougher) hull structural steel, e.g. A 36 with E 36: quality grade 3 Y ....

c) Normal-strength with higher-strength hull structural steels with comparable quality grades:

Welding consumables and auxiliary materials for the normal-strength hull structural steel quality grade in question, e.g. D with D 36: quality grade 2 .... (without added symbol Y)

d) Normal-strength with higher-strength hull structural steels with non-comparable quality grades:

Welding consumables and auxiliary materials having a quality grade for the higher-quality (tougher) hull structural steel but the strength of the normal-strength steel, e.g. A with D 36: quality grade 2 .... (without added symbol Y).

**4.** For welding very thick-walled, rigid components (approx. 30 mm and over) and welding of forgings and steel castings, hydrogen-controlled welding consumables and auxiliary materials of quality grade 3 H15(H) shall be used (for higher-strength hull structural steels, 3Y H10(HH)).

**5.** The use of hydrogen-controlled welding consumables and auxiliary materials is recommended for welding of higher-strength hull structural steels to one another (and to lower-strength steels) if the carbon equivalent of these steels is over 0,41 %. See also H.5.

**Table 1.1 Correlation of welding consumables and auxiliary materials to hull structural steel quality grades**

| **Quality grades of welding consumables and auxiliary materials (cf. also E.3.)** | **Hull structural steel quality grades** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **D** | **E** | **A 32/36** | **D 32/36** | **E 32/36** | **F 32/36** | **A 40** | **D 40** | **E 40** | **F 40** |
| 1; 1S, 1T, 1M, 1TM, 1V | × | | | | | | | | | | | |
| 1YS, 1YT, 1YM, 1YTM, 1YV | × | [1] | | | ×[2,3] | | | | | | | |
| 2, 2S, 2T, 2M, 2TM, 2V | × | × | × | | | | | | | | | |
| 2Y, 2YS, 2YT, 2YM, 2YTM, 2YV | × | × | × | | ×[3] | ×[3] | | | | | | |
| 2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V | [1] | [1] | [1] | | ×[3] | ×[3] | | | ×[3] | ×[3] | | |
| 3, 3S, 3T, 3M, 3TM, 3V | × | × | × | × | | | | | | | | |
| 3Y, 3YS, 3YT, 3YM, 3YTM, 3YV | × | × | × | × | ×[3] | ×[3] | ×[3] | | | | | |
| 3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V | [1] | [1] | [1] | [1] | ×[3] | ×[3] | ×[3] | | ×[3] | ×[3] | ×[3] | |
| 4Y, 4YS, 4YT, 4YM, 4YTM, 4YV | × | × | × | × | ×[3] | ×[3] | ×[3] | ×[3] | | | | |
| 4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V | [1] | [1] | [1] | [1] | ×[3] | ×[3] | ×[3] | ×[3] | ×[3] | ×[3] | ×[3] | ×[3] |

[1] Not to be used if possible, otherwise only with the Society's approval; cf. Chapter 1, Section 5; A.4.1 and A.4.2 apply in analogous manner.

[2] For A 32/36, welding consumables and auxiliary materials of quality grade 1 Y ... should where possible only be used when welding thinner plates (up to 25 mm max.).

[3] For plates over 50 to 70 mm thick, welding consumables and materials with **one** quality grade higher shall be used and for those over 70 and up to 100 mm thick those with **two** quality grades higher shall be used in each case in compliance with the higher base material requirements, cf. Rules for Materials.

***Note:***

*For steels F 32, F 36 and A 40 to F 40, no provision is made in the Rules for Materials for plates above 50 mm thick, but these shall be subject to special agreements where appropriate.*

**6.** Hydrogen-controlled welding consumables and auxiliary materials should also be used for components which are subjected to full load immediately after welding (e.g. lifting lugs or as a result of pressure tests) or where allowance has to be made for a high degree of residual stress due to the rigidity of the structure and, where applicable, a high yield strength or strength of a structure.

**7.** Hydrogen-controlled welding consumables and auxiliary materials shall always be used for welding high-strength (quenched and tempered) fine-grained structural steels and steels tough at sub-zero temperatures, cf. Chapter 1, Section 5, F.4. For steels with a yield strength or 0,2 % proof stress of up to 500 N/mm², welding consumables and auxiliary materials with the maximum added symbol H 10 (HH) should be used and for steels with a yield strength or 0,2 % proof stress of over 500 N/mm² those with a maximum added symbol H 5 (HHH) should be used.

**8.** For welding of austenitic stainless steels to one another and to hull structural steels, welding consumables and auxiliary materials shall be selected in accordance with Tables 5.21 to 5.23 in 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 Procedures, Welding Procedure Tests

### 1. General

**1.1** Only welding procedures whose suitability for the application in question is evident from general experience or has been verified by means of a welding procedure test in accordance with Chapter 1, Section 4 and the following provisions may be used. Table 4.1 in Chapter 1, Section 4 gives a list of the requisite verifications. The welding procedure must have been approved by the Society for the welding shop in question (cf. also B.).

***Note:***

*In principle, the Society recognizes all welding processes which satisfy the above conditions. General reservations only exist to the extent that the operationally safe handling of these processes and the quality attainable under field conditions is called into question or contradicted by practical experience. For instance, at present no approvals are being granted for vertical-down gas-shielded welding with solid wires under mixed gas containing less than approximately 30 % $CO_2$ due to the risk of lack of side wall fusion. Exceptions to this rule are possible if welding using robots is required, for which the welding parameters and the manipulation of the torch may be prescribed and followed so precisely that it can be verified that welding has been performed with good penetration within the narrow "safe" area.*

**1.2** The Society may approve specific welding processes such as vertical-down welding, build-up welding on rudderstocks or underwater welding (cf. H.13.3), 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, the Society may also stipulate restrictions in the operation of the vessel (e.g. in the operating area).

**1.3** Welding procedure tests supervised by the Society for verification of satisfactory operational handling and a trouble-free execution of the procedure, and also adequate quality properties for the welded joints made under production conditions at the user's works are in general required for:

– materials [1] other than "simple-to-weld" hull structural steels A to D and comparable structural steels, forged steels and cast steels and also for composite materials,

– welding processes [2] other than those stated in B.3., which are adequately covered by general experience, welder's qualification tests and approved welding consumables,

– single-side welding on ceramic, flux or similar backings,

– welding in the vertical-down position.

**1.4** For conventional single-wire submerged-arc butt welding processes using solid wire for welding normal-strength hull structural steels A to D, comparable structural steels, forged steels and cast steels from both sides, proof prior to initial use of the reliability and technical suitability of the method by means of trial welds and non-destructive (e.g. radiographic) tests as directed by the Surveyor is sufficient. The welding consumables and auxiliary materials used must have been approved by the Society.

**1.5** The Society 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. The same applies in analogous manner to other joining processes or (surface) finishing operations such as thermal cutting or flame straightening.

**1.6** The information in the preceding and following paragraphs, especially the information on test pieces, specimen shapes, tests and requirements, applies to the normal materials, welding processes and weld shapes in current use in shipbuilding, the behaviour of which under service conditions has been verified by experience and/or test results. In cases of doubt, the Society may call for additional and/or different test pieces, specimen shapes or tests to verify satisfactory suitability for use.

**1.7** In the case of welding processes whose characteristics result in weld shapes other than those verified by experience and/or test results (e.g. those with a considerable notch effect), the influence of the weld shape on the fatigue strength behaviour of the welded joints may be investigated in addition to carrying out the prescribed tests. The same applies in analogous manner to other characteristics of the welded joints, e.g. corrosion resistance.

## 2. Scope of tests, test schedule, limits of application

### 2.1 Test schedule, test details

**2.1.1** The scope of the welding procedure tests (test pieces, specimens, tests) shall be laid down in a test schedule to be submitted for approval in good time prior to testing, in accordance with Chapter 1, Section 4, B.1. Depending on the nature and application of a welding process, the process details stipulated in Chapter 1, Section 4, B.1.1 shall be taken into account in the tests. Where no further details on the welding procedure tests are given in the following paragraphs, the provisions of Chapter 1, Section 4 and the standards of the series EN 288 / ISO 9956 shall apply.

***Note:***

*The following rules relating to the welding procedure tests comply with, borrow from in part or refer to the standards of the series EN 288/ISO 9956. Compared with the previous versions of these Rules for Welding, all the details relating to the welding procedure tests which, from the shipbuilding aspect, have been satisfactorily covered in the standards, are no longer contained in these Rules or only by reference to these standards, especially to EN 288-3/ISO 9956-3 "Welding procedure tests …….. Steels" and EN 288-4/ ISO 9956-4 "Welding procedure tests ……aluminium alloys"*

1 **Materials:**

Normal-strength hull structural steels E and F, higher- strength hull structural steels and comparable grades of forged steels or steel castings, high-strength (quenched and tempered) fine-grained structural steels, steels tough at subzero temperatures, stainless and clad steels, aluminium alloys and other non- ferrous metals.

2) **Welding Processes:**

**Manual welding processes:**

Vertical-down welding, deep penetration welding, single-side welding with backing, etc.

**Semi-mechanized welding processes:**

Gravity arc or auto-contact welding, single-side welding with backing, flux-cored wire metal-arc welding without shielding gas, etc.

**Fully-mechanized welding processes:**

Submerged arc welding, fusarc and flux-cored wire metal-arc welding, multiple-electrode submerged arc welding, single-side welding, fillet and double-fillet welding, electroslag welding with and without fusible wire guide nozzle electrode(s), gas-shielded metal-arc welding, electrogas welding etc.

**Special welding processes or special applications:**

Stud welding, flash butt welding, friction welding, laser-beam welding, build-up welding, orbital welding of circumferential pipe welds, robot welding, etc.

*Details specific to shipbuilding, such as material groupings, single-side welding or the inclusions and exclusions for welding positions (vertical-down welding) requiring special and specific experience and proven manipulation and which are only inadequately covered in the standards are dealt with in the following paragraphs as a departure from the standards. Under the provisions of the regulations applicable to other ranges of application (e.g. for pressure equipment), the Rules issued by the Society for shipbuilding shall be regarded as the predominant codes of practice.*

**2.1.2** Depending on the nature of the base material or the influence of the characteristics of the process, the Society may set out specifications which go beyond or deviate from the stipulations given in these rules or in the standards and call for different or additional tests, stipulate requirements or change the scope of application. The Society also reserves the right to interpret the standards accordingly. Where the standards contain information which is different from or contradicts these rules, these rules shall take precedence.

### 2.2 Base materials, material groups

**2.2.1** The welding procedure test shall in principle be carried out by welding the base materials for which application for approval was made. Except for hull structural steels and austenitic-ferritic duplex steels, the base materials for the welding procedure tests may be grouped into material groups in accordance with the standards of the series EN 288/ISO 9956 and the test performed using representative materials from this groups. The provisions set out in the following paragraphs apply to hull structural steels. Duplex steels are regarded as an independent material group and are **not** covered by the group of austenitic stainless steels

***Note:***

*The provisional standard DIN V 1738, the German language version of the CEN report CR 12187 (shortly to be available in a revised version as European standard CR TR 15608 or as ISO standard) classifies weldable materials (for general use) into categories with comparable, identifying properties. These categories are finely graded to include in addition special properties such as the behaviour of materials during heat treatment.*

*Austenitic stainless steels and austenitic-ferritic stainless steels are therefore classified into different groups. In preference to the rough classification favoured by the standards of the series EN 288/ISO 9956 (the same applies in analogous manner to the welder's qualification tests conforming to EN 287/ISO 9606), it is therefore advisable to use the classification given in CEN report 12187 or the anticipated follow-on standards. The Society may stipulate this.*

**2.2.2** If a welding procedure test is to be carried out for several base materials simultaneously, materials which cover both the various strength categories (...-, ...32, ...36, ...40) and the various degrees of toughness (A/A..., B, D/D..., E/E..., F...) shall be selected for hull structural steels, taking the wall thicknesses into account. The same procedure shall apply in analogous manner to other materials.

**2.2.3** Based on their chemical composition (behaviour during welding) and their mechanical characteristics the various hull structural steels may be classified or, as the case may be, grouped into the following three (strength) categories:

– Normal-strength hull structural steels A, B, D and E (includes comparable, general structural steels, forged steels and cast steels with minimum yield strengths up to 280 N/mm$^2$)

– Higher-strength hull structural steels A 32, D 32, E 32, F 32, A 36, D 36, E 36 and F 36 (includes comparable general-purpose structural steels with minimum yield strengths of over 280 N/mm$^2$ up to and including 355 N/mm$^2$)

– Higher-strength hull structural steels A 40, D 40, E 40, F 40 (includes comparable, general-purpose structural steels with minimum yield strengths of over 355 N/mm$^2$ up to and including 390 N/mm$^2$).

**2.2.4** Unless otherwise specified in a particular case (e.g. for welding processes with a very high heat input, such as electrogas or electroslag welding), the following conditions also apply to the selection of materials:

– Within each of the three strength categories in para. 2.2.3, a satisfactory welding procedure test on a material with a higher degree of toughness also covers one steel with a lower degree of toughness

– Within the same degree of toughness (e.g. A, A 32, A 36, A 40), a satisfactory welding procedure test on a steel of higher strength also covers one steel of lower strength.

**2.2.5** If the range of application of a welding procedure encompasses several steels belonging to one strength category or one group of degrees of toughness, the welding procedure test shall be performed on at least two steels from each strength category or each degree of toughness, as applicable. Of these, one shall represent the lowest category or degree and one the highest category or degree.

**2.2.6** However, the Society may, when testing several base materials at the same time, dispense with testing certain steels if their influence on the quality of the welded joints is adequately covered by the tests of the other steels (in combination with the various test piece thicknesses if necessary). Some examples of material selection (without taking into account specific process characteristics or as-delivered conditions of materials) are shown in Table 1.2.

**2.2.7** Where the characteristics of the process or the base materials have no appreciable influence on the test results due to the shape of the test piece or specimen or the tests performed, the Society may agree to a restriction to a few base materials or only to one. An example of this is the testing of the fillet welding process using cruciform tensile specimens, macrographic specimens and hardness measurements; in this case it is sufficient to perform the test on a steel from the highest strength category intended for the application and with the maximum possible carbon equivalent.

**Table 1.2 Base material categories (hull structural steels, examples)**

| Range of application | Base material |
|---|---|
| Quality grades A and B<br>Quality grades A to D<br>Quality grades A to E | A or B<br>A and D<br>A and E |
| Quality grades A 32 to D 36<br>Quality grades A 32 to E 36<br>Quality grades A 32 to F 36 | A 36 and D 36<br>A 36 and E 36<br>A 36 and F 36 |
| Quality grades A 40 to D 40<br>Quality grades A 40 to E 40<br>Quality grades A 40 to F 40 | A 40 and D 40<br>A 40 and E 40<br>A 40 and F 40 |
| Quality grades A to D<br>and A 32 to D 36 | A, D and D 36<br>or<br>A, A 36 and D 36 |
| Quality grades A to E<br>and A 32 to E 36 | A, D and E 36<br>or<br>A, E and E 36<br>or<br>A, A 36 and E 36 |

## 2.3 Thicknesses of test pieces, range of wall thicknesses

**2.3.1** The thicknesses of the test pieces shall be geared to the range of application and the welding process in such a way as to comply with the conditions specified in Table 1.3. As a general rule, test pieces of at least two different thicknesses shall be welded and tested for each range of application according to Table 1.2 (each base material group). For vertical-down welding, the upper thickness limit for the intended range of application shall be used for the thickness of the test piece.

**2.3.2** In conjunction with the test piece thicknesses stated in para. 2.3.1, (cf. also 3.2), the throat thicknesses "a" of fillet welds shall be established such that the approval range from "0,75a" to "1,5a" covers the desired range of application. The throat thicknesses for the test piece shall therefore be selected so that the "a" dimension roughly equals half the thickness of the test piece (half the thickness of the thinner plate where the thicknesses of the plate are unequal). For (test piece) throat thicknesses of 10 mm or more, a range of application $a \geq 10$ mm applies.

**2.3.3** Where, for subsequent use, relatively thin fillet welds are to be applied to very thick components (cf. G.10.3.3), similar test pieces are to be welded and examined for hot cracking, underbead cracks or hardening cracks. This requirement is specially applicable to higher- and high-strength grades of steel and cast steel.

**2.3.4** For the reduction of the specified fillet weld throat thicknesses where specially deep penetration is proved, see G.10.3.5. With regard to the increase of the "a" dimension when overweldable shop primers which are particularly liable to cause porosity or processes with inadequate root penetration are used, see G.10.3.6.

**2.3.5** Where a fillet welding process is to be applied to plates or sections coated with overweldable shop primer, similarly coated plates are to be used for the fillet weld test pieces required for the welding procedure test. The type and thickness of the coating of shop primer shall be stated in the test report.

**Table 1.3 Test piece thickness**

| Test piece thickness t [1] | Range of application [2, 3] | |
|---|---|---|
| | Single-run welding (single bead) and welding in one run on each side (Two-run technique) | Multi-run technique |
| $t \leq 3$ | 0,8 t to 1,1 t | t to 2 t |
| $3 < t \leq 12$ | 0,8 t to 1,1 t | 3 mm to 2 t |
| $12 < t \leq 100$ | 0,8 t to 1,1 t | 0,5 to 2 t, max. 150 mm |
| $t > 100$ | 0,8 t to 1,1 t | 0,5 t to 1,5 t |

[1] If special cooling conditions have to be complied with or particular weld shapes are prescribed, they shall be taken into account when selecting the test piece thickness; cf. also Chapter 1, Section 4, B.4.

[2] For unequal plate thicknesses the following applies:
For butt welds, the average of the two plate thicknesses in the weld area ≈ weld thickness is the ruling dimension. For fillet weld joints, the lower limit of the range of application of 0,8 times the smaller test piece thickness $t_1$ (e.g. web thickness) and the upper limit of 1,1 times the larger test piece thickness $t_2$ (e.g. flange thickness) is the ruling dimension, but the ratio of plate thicknesses $t_2$ to $t_1$ shall not exceed 3.

[3] For the vertical-down welding, the test piece thickness t is always taken as the upper limit of the range of application.

## 3. Test pieces, dimensions, direction of rolling, welding positions

### 3.1 Shape and size of test pieces, direction of rolling

**3.1.1** Unless other provisions are given in the paragraphs below, the shape and size of test pieces shall be selected in accordance with the series of standards EN 288/ISO 9956. The length of the test pieces shall be appropriate for the welding process and the number of specimens. Where scheduled in the fabrication work for the particular welding process in question, both butt-weld and fillet-weld test pieces shall be made. The direction of rolling of the plates for the test pieces should be parallel to the direction of the weld.

**3.1.2** The length of test pieces (length of weld) for manual and semi-mechanized welding processes (cf. F.1.3 [2] shall not be less than 350 mm and for fully mechanized and/or automatic welding processes the length of the test piece shall be the same as the weld length to be deposited during later fabrication work, subject to a minimum length of 1000 mm.

**3.1.3** For welding in (clamping) jigs, the size of the test piece shall conform to the size of the jig. For single-side welding processes and the fully mechanized and/or automatic double fillet welding (e.g. for stiffeners on platings), the test piece shall be at least 3000 mm long.

**3.1.4** In the case of vertical welding, the length of the test piece (the weld length) shall conform to the size of the jig used in fabrication. For jigs using a fusible wire-guide electrode, the length of the test piece shall conform to the length of the wire-guide electrode or the height of the components to be welded. Any special features affecting the application of these processes (e.g. welding operations performed through the deck) shall be allowed for in the configuration of the test piece.

**3.1.5** 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.

### 3.2 Fillet-weld test pieces (T-joint and/or double T-joint (cruciform) test pieces)

**3.2.1** Fillet-weld test pieces (T-joint and double T-joint (cruciform) test pieces) shall be joined with air gaps not greater than 0,5 mm. Depending on subsequent practice, tacks shall also be included in the test (and overwelded where applicable). The throat thickness of the fillet welds should correspond to those used in subsequent fabrication but should not be greater than 0,5 × plate thickness (cf. 2.3.2 to 2.3.4). For shop primers, cf. 2.3.5.

**3.2.2** Double T-joint test pieces as shown in Fig. 1.1 or Fig. 1.2 (cruciform test pieces) are always required when the welding procedure test relates to vertical-down welding or to the welding of high-strength steels with minimum yield strengths over 460 N/mm², clad plates and non-ferrous metals. The Society may also require cruciform test pieces for other processes and/or materials.

The throat thickness of the fillet weld "a" shall not exceed 0,5 times the plate thickness.

**3.2.3** In order to simplify the process where the test pieces are broken open on alternate sides, welding may be performed on one side only of the double T-joint (cruciform) test pieces on alternate sides in the fracture area, in analogous manner to the stipulations of the codes of practice DVS 1702.

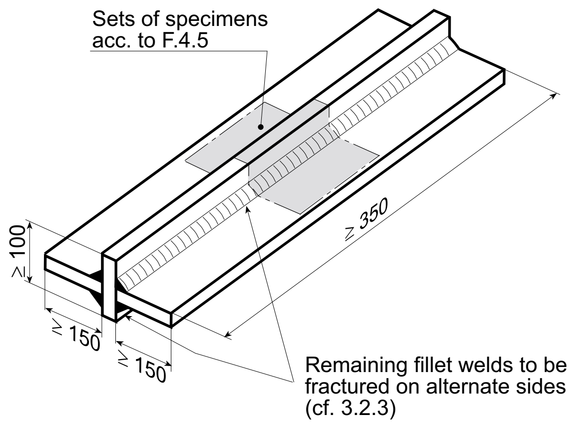



**Fig. 1.1 Double T-joint (cruciform) test piece for manual and semi-mechanized welding processes**

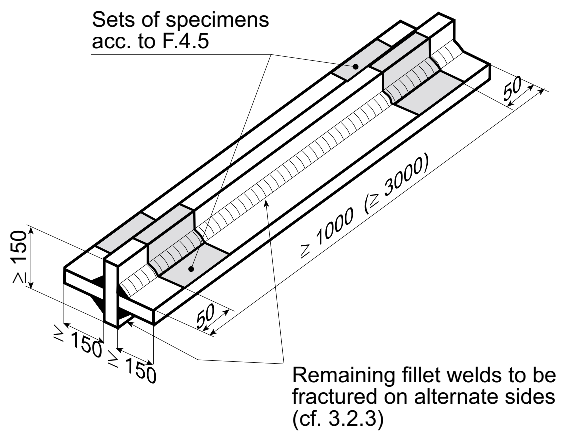



**Fig. 1.2 Double T-joint (cruciform) test piece for fully mechanized welding processes**

### 3.3 Weld shapes, welding positions, heat treatment, non-destructive testing

**3.3.1** Weld forms which may differ in their manner of joining (e.g. butt weld or T-joint) and plate thickness shall be included in the test. Where weld forms, welding parameters and run build-up (e.g. in submerged-arc welding from square butt weld via single-V butt weld to double-V butt weld) are changed during a welding process within the range of application for which application for approval is made, these "shifts" in procedure shall also be allowed for by means of appropriate test pieces.

**3.3.2** T-joints with full penetration welded single-bevel or double-bevel butt joints are normally regarded as butt joints, i.e. they are covered by the butt weld test pieces. For welds with incomplete penetration and for special weld forms (e.g. the deep, acute-angled open single-V butt welds used in branch pieces) the Society may, however, call for additional test pieces to at least verify adequate weld penetration and penetration conditions.

**3.3.3** Test pieces are normally welded in all the conventional welding positions (for which application for approval is made). For single-side welding, a test piece which has been welded in the PC (h-v) position must always be provided. For information on the welding procedure for the test pieces, any post-weld heat treatment or other finishing work which may be required and the non-destructive tests, cf. the corresponding provisions in Chapter 1, Section 4, B.

## 4. Sets of specimens, test specimens, mechanical and technological tests

### 4.1 Set of test specimens for butt welds - general provisions

**4.1.1** For standard manual and semi-mechanized welding, one set of test specimens shall be taken from the butt-welded test pieces in accordance with the above-mentioned standards. For fully-mechanized and/or automatic welding, at least one set each shall be taken from the start and end of the weld, cf. Chapter 1, Section 4, B.8.3. The division of the test pieces into sections (preparation of specimens, marking) and the performance of the mechanical and technological tests, etc. shall be carried out in accordance with the standards or Chapter 2, Section 5 as applicable.

**4.1.2** Unless otherwise agreed in a particular case, one set of butt weld specimens shall comprise the following specimens. The specimen shapes and dimensions shall conform to the provisions of the standards or Chapter 2, Section 5 as applicable:

– **2 transverse tensile test specimens** in accordance with EN 895/ISO 4136 (for larger plate thicknesses a correspondingly greater number of specimens shall be provided to cover the full cross-section),

– **1 round tensile test specimen** by analogy to the provisions of Chapter 1, Section 5, B.2.3 (Fig. 5.1 and 5.2) taken lengthwise from the weld metal if welding consumables and auxiliary materials not approved by the Society are to be used (cf. Chapter 1, Section 4, B.3.2) or if the characteristics of the welding process suggest that the weld metal itself is likely to be considerably affected.

A round tensile test specimen is to be prepared in every case (except for aluminium alloys) where the mechanical properties of the weld metal are inferior to those of the base material (e.g. when welding high-strength steels). The diameter "$d_0$" of the specimen shall be as large as possible (but not more than 10 mm) and the gauge length "$L_0$" shall be $5 \times d_0$. The provisions of Chapter 1, Section 5, B.2. are to be applied in analogous manner.

– **4 transverse bend test specimens**, in accordance with EN 910/(ISO 5173) half to be bent with the final pass in tension (FBB) and half with the root pass in tension (RBB),

or

– **2 transverse bend test specimens** as before and

**2 side bend test specimens** taken at right angles to the butt weld (SBB) in accordance with EN 910/(ISO 5173) in the case of test pieces over 12 mm thick

or:

– **4 side bend test specimens** (SBB) in the case of test pieces 20 mm thick and welding processes liable to give rise to segregations, lack of fusion or similar defects inside the weld (e.g. single-side and vertical-down welding).

**Note:**

*In the case of pairs of materials which differ in strength, it may be advisable to use butt-welded longitudinal bend test specimens (FBB and RBB) in accordance with EN 910/(ISO 5173) with the weld seam in the centre of the specimen instead of butt-welded transverse bend test specimens. See also Chapter 2, Section 5. The details of this test and the requirements (as a rule a qualitative assessment of the bending behaviour) shall be agreed on a case-by-case basis.*

– **3 notched bar impact test specimens each** (Charpy V-notch specimens with the notch perpendicular to the surface of the plate) in accordance with EN 875/ISO 9016, from the centre of the weld (VWT 0/1), from the fusion boundary/transition zone (VHT 0/1) and from the heat-affected zone (VHT 2/1). The notched bar impact test specimens shall be taken from the last side welded, and with larger plate thicknesses they shall be taken from both sides. With very large plate thicknesses and welding processes liable to cause segregation in the central zone, an additional 3 notched bar impact test specimens of each type shall be taken from the same areas in middle of the plate thickness.

The dimension "a" (cf. EN 875/ISO 9016) shall be such that the point of intersection of the centre line of the specimen and the middle of the notch lies in the coarse-grained area of the heat-affected zone. This dimension may be generally taken as 2 mm. Where welding procedure tests are performed on steels tough at subzero temperatures, test specimens with notches located at a = 1 mm, a = 3 mm and a = 5 mm shall be prepared, unless otherwise specified in an individual case.

Depending on the base material and welding process concerned, further notched bar impact test specimens from other areas may be stipulated. Notched bar impact test specimens may be partly or wholly dispensed with where the results of these tests in connection with the use of a particular welding process are of minor significance for certain materials (e.g. austenitic stainless steels or aluminium alloys, except for low-temperature applications).

– **2 macrographic** (if necessary, **micrographic**) specimens for evaluating the grain structure.

– **Hardness tests** (Vickers HV5 or HV10) in accordance with EN 1043-1 (EN 1043-2 in the case of laser welding) shall be carried out where, having regard to the base material and the welding process, the possibility cannot be discounted that preheating and/or the heat flow during welding may affect the hardness values in such a way as to impair the toughness or strength characteristics of the weld. Hardness measurements shall always be performed on higher-strength hull structural steels and on high-strength (quenched and tempered) fine-grained structural steels with minimum yield strengths of more than 355 N/mm².

### 4.2 Set of butt weld test specimens for single-side welding processes

**4.2.1** Sets of test specimens as specified in para. 4.1.1 and 4.1.2, but subject to the differences listed below, shall be taken from butt-weld test pieces for single-side welding processes (e.g. manual or semi-mechanized welding using ceramic backing or submerged-arc welding with flux backing):

– **2 transverse tensile test specimens**, cf. para. 4.1.2.

- **1 round tensile test specimen** taken lengthwise from the weld metal. This is also required when additional welding consumables (e.g. in the form of iron powder and the like) are employed or where the possibility of a metallurgical reaction between the weld metal and the backing material cannot be discounted (cf. 4.1.2)
- **2 transverse bend test specimens** (one FBB and one RBB) and

  **2 side bend test specimens** (SBB), cf. 4.1.2.
- **3 notched bar impact test specimens each** additionally from the root zone: from the centre of the weld seam (VWT 0/t-1), the fusion boundary/transition zone (VHT 0/t-1) and heat-affected zone (VHT 2/t-1). Cf. para. 4.1.2.
- **2 macrographic specimens** at least one of which - for manual and semi-mechanized welding processes - must pass through a starting point of welding (cf. 4.1.2).
- **Hardness tests**, cf. para. 4.1.2

**4.2.2** By analogy with the provisions of para. 4.2.1, the following test specimens shall be taken from butt-welded test pieces prepared by manual or semi-mechanized welding processes already approved by the Society for the range of application concerned (base materials, welding positions) for the sole purpose of extending the said approval to single-side welding with backings:

- **2 transverse bend test specimens** with the root in tension (RBB) and **2 side bend test specimens** (SBB). Cf. 4.1.2
- **3 notched bar impact test specimens each** only from the root zone: from the centre of the weld seam (VWT 0/t-1), the fusion boundary/transition zone (VHT 0/t-1) and heat-affected zone (VHT 2/t-1) where normal-strength, hull structural steel grade E and/or higher-strength hull structural steels are to be welded or where stipulated for other materials (cf. 4.1.2)
- **2 macrographic specimens**, at least one of which must pass through a starting point of welding in the case of manual and semi-mechanized welding processes. (cf. 4.1.2).
- **hardness tests**, cf. para. 4.1.2.

### 4.3 Set of butt weld specimens for vertical welding processes

In accordance with Chapter 1, Section 4, B.8.3, one or more sets of test specimens as described in paras. 4.1.1 and 4.1.2 shall be taken from butt-weld test pieces for vertical welding processes (e.g. electrogas or electroslag welding) as follows:

- **2 transverse tensile test specimens**, cf. para. 4.1.2.
- **1 round tensile test specimen** taken lengthwise from the weld metal. This is also required when additional welding consumables (e.g. in the form of iron powder and the like) are employed (cf. 4.1.2).
- **2 transverse bend test specimens** (one FBB and one RBB) and

  **2 side bend test specimens** (SBB), cf. 4.1.2.
- **3 notched bar impact test specimens** each from the centre of the weld seam (VWT 0/2), the edge of the weld seam (VWT a/2), the fusion boundary/transition zone (VHT 0/2) and heat-affected zone (VHT 2/2). The dimension "a" shall be such that the notch lies in the coarse-grained area of the weld metal (normally about 2 – 3 mm). With very large plate thicknesses and welding processes liable to cause segregation in the central zone, an additional 4 notched bar impact test specimens of each type shall be taken from the same areas in the middle of the plate thickness. Cf. 4.1.2.
- **2 macrographic specimens** at least one of which must pass through a starting point of welding (cf. 4.1.2).
- **Hardness tests**, cf. para. 4.1.2

### 4.4 Set of fillet weld test specimens (set of T-jointed test pieces)

**4.4.1** By analogy with para. 4.1.1, two or more **macrographic specimens**, as applicable depending on the length of the test piece, shall be taken from the simplified (T-jointed) fillet-welded test pieces in accordance with EN 288/ISO 9956 to evaluate the penetration conditions, any irregularities in the test piece and the grain structure. If necessary, **hardness measurements** as described in EN 1043-1 and -2 shall be performed (cf. 4.1.2).

**4.4.2** The remainder of the test pieces is to be divided into convenient portions which, after removal of one of the welds, are to be broken open on alternate sides for **evaluation of the fracture** (cf. EN 1320).

### 4.5 Set of fillet weld specimens (set of double-T jointed (cruciform) test pieces)

**4.5.1** As shown in Figures 1.1 and 1.2, one or more sets of test specimens shall be taken from the (cruciform) fillet-welded test pieces as called for in 4.1.1 depending on the length of the test piece as shown in Fig. 1.3. Preparation of specimens, marking, performance of mechanical and technological tests, etc. shall be carried out in accordance with the provisions of Chapter 2, Section 5.

**4.5.2** A set of (cruciform) fillet weld test specimens as called for in 4.5.1 shall comprise the following specimens. The specimen shapes and dimensions shall conform to the provisions of Chapter 2, Section 5.

– **3 cruciform tensile test specimens** (Z) as shown in Fig. 1.4 for determining the tensile-shear strength of the weld metal

– **2 macrographic specimens** (M) for evaluating the penetration conditions, any irregularities in the specimens and the grain structure. If necessary, **hardness measurements** (cf. 4.1.2) shall be performed in accordance with EN 1043-1 and -2 (cf. 4.1.2).

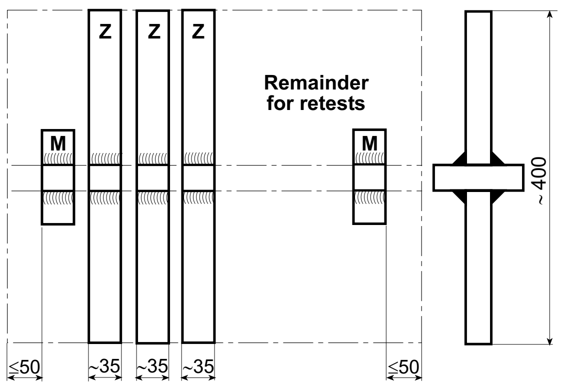
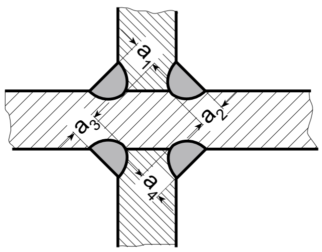



**Fig. 1.3 Set of double-T (cruciform) test specimens**




$a_1 + a_2$ = fracture section $S_{1/2}$
$a_3 + a_4$ = fracture section $S_{3/4}$

$$\text{Tensile-shear strength} = \frac{\text{Breaking load } F}{S_B \cdot \text{width of specimen}} \quad [\text{N/mm}^2]$$

$S_B = S_{1/2}$ or $S_{3/4}$ according to position of fracture

**Fig. 1.4 Cruciform tensile test specimen (weld cross section)**

**4.5.3** The remainder of the test pieces is to be divided into convenient portions which, after removal of one of the welds, are to be broken open on alternate sides for **evaluation of the fracture**, cf. EN 1320.

## 5. Requirements

### 5.1 Hull structural steels

**5.1.1** In welding procedure tests and tests on production specimens relating to hull structural steels, butt weld specimens must meet the minimum requirements shown in Table 1.4. Equivalent structural steels, forged steels and cast steels shall be classified in analogous manner according to their chemical composition and mechanical characteristics.

**5.1.2** The minimum impact energy values shown in Table 1.4 apply to the centre of the weld metal, the transition zone/fusion boundary and the heat-affected zone. The values for manual and semi-mechanized welding apply to all positions except the vertical-up position (PF). The values applicable to the vertical position (PF) are those for fully mechanized welding (34 J or 41 J resp.).

***Note:***

*In the fusion boundary/transition zone and/or the heat affected area of "simple" steels, (for example Grade A steels), difficulties may possibly arise in meeting the required values listed in Table 1.4 which have been derived from the requirements relating to welding consumables. In such cases, the values established during the testing of the base material and during appropriate monitoring checks may be used as reference values. The values established on the welded joint should not fall below these reference values.*

**5.1.3** In special cases (e.g. where the working temperature of the component is below – 10 °C), the test temperatures and impact energy values laid down in the material specifications for the testing of the steels concerned may also be stipulated for welding procedure tests in place of the test temperatures and impact energy values shown in Table 1.4. Unless otherwise agreed, these values shall then apply to all welding positions and notch positions.

**5.1.4** 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 1.4 shall be reduced in accordance with Table 1.5.

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 1.4 Requirements applicable to hull structural steels**

| Grade | Yield strength (weld metal) [N/mm²] | Tensile strength [N/mm²] | Elongation (weld metal. $L_0 = 5\ d_0$) [%] | Impact energy [1] [J] | | | Bending angle (D = 3 t) [2] | Bending elongation gauge length $2\ L_S$ [3] [%] |
|---|---|---|---|---|---|---|---|---|
| | | | | manual and semi-mechanized. | full mechanized | Temp. [°C] | | |
| A/B | 305 | 400 | 22 | 47 | 34 | + 20 | 180° | 22 |
| D | | | | | | ± 0 | | |
| E | | | | | | – 20 | | |
| A 32 | 335 | 440 | 22 | 47 | 34 | + 20 | 180° | 22 |
| D 32 | | | | | | ± 0 | | |
| E 32 | | | | | | – 20 | | |
| F 32 | | | | | | – 40 | | |
| A 36 | 375 | 490 | 22 | 47 | 34 | + 20 | 180° | 22 |
| D 36 | | | | | | ± 0 | | |
| E 36 | | | | | | – 20 | | |
| F 36 | | | | | | – 40 | | |
| A 40 | 400 | 510 | 22 | 47 | 41 | + 20 | 180° | 22 |
| D 40 | | | | | | ± 0 | | |
| E 40 | | | | | | – 20 | | |
| F 40 | | | | | | – 40 | | |

[1] Charpy V-notch specimens, average value of three specimens. For minimum individual values and retests, see Chapter 1, Section 4, C.2.3. With regard to the notch position and the welding positions, see 5.1.2.

[2] The Society may consent to the use of a mandrel with a diameter D equal to $D = 4 \times t$ if this does not adversely affect the reliability of the test results. For bending angles, see 5.1.5.

[3] The gauge length ($L_0$) = the weld width ($L_S$) + half the plate thickness (a/2) on each side adjacent to the weld, cf. EN 910/(ISO 5173).

**Table 1.5 Required impact energy values with specimens of reduced width**

| Specimen section [mm × mm] | Specified impact energy value to be multiplied by: |
|---|---|
| 10 × 7,5 | 5/6 |
| 10 × 5,0 | 2/3 |

**5.1.5** The bending tests are to be performed using a mandrel with a diameter equal to 3 times the thickness (t) of the specimen. The Society may instead consent to the use of a mandrel with a diameter D of $4 \times t$ if this does not impair the reliability of the test results. The required bending angle of 180 ° under the test conditions specified in EN 910 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 must be attained before the first incipient crack appears. Minor pore exposures or the like up to a maximum length of 3 mm may be tolerated. The fracture surfaces of ruptured test specimens shall be evaluated.

**5.1.6** Measured on cruciform tensile test specimens, the minimum tensile (tensile-shear) strength of the weld section (fracture section in accordance with Fig. 1.4) shall meet the requirements stated in Table 1.6.

**Table 1.6 Requirements applicable to cruciform tensile specimens**

| Grades | Tensile-shear strength [N/mm²] |
|---|---|
| A – E | 350 |
| A 32 – F 36 | 430 |
| A 40 – F 40 | 450 |

### 5.2 High-strength (quenched and tempered) fine-grained steels

**5.2.1** For welding procedure tests and tests on production specimens relating to high-strength (quenched and tempered) fine-grained steels, the minimum properties specified in Chapter 1, Section 5, F. for the testing of welding consumables and auxiliary materials must be met for butt-weld specimens. Unless otherwise agreed in an individual case, a bending mandrel diameter of 4 times the specimen thickness shall be used for the bending tests. Test temperatures of – 20 °C or below shall be selected for the notched bar impact test.

**5.2.2** Measured on cruciform tensile test specimens (cf. 3.2.2), the minimum tensile strength (tensile-shear strength) of the weld section (fracture section as shown in Fig. 1.4) shall satisfy the requirements relating to the welded joint stipulated in Chapter 1, Section 5, F.

### 5.3 Austenitic stainless (clad) and austenitic-ferritic (duplex) steels

**5.3.1** For welding procedure tests and tests on production specimens relating to austenitic stainless (clad) and austenitic-ferritic (duplex) steels, the minimum properties specified in Chapter 1, Section 5, I. for the testing of welding consumables and auxiliary materials must be met for butt weld specimens. In the case of joints between different types of steel, the strength values of the base material which has the lower strength shall be used.

**5.3.2** Unless otherwise agreed in an individual case, a bending mandrel diameter of 3 times the specimen thickness may be used for the bending test and a test temperature of + 20 °C for the notched bar impact test performed on austenitic stainless steels. Austenitic-ferritic (duplex) steels shall be tested at a temperature of – 30 °C.

**5.3.3** Measured on cruciform tensile test specimens (cf. 3.2.2), the minimum tensile strength (tensile-shear strength) of the weld section (fracture section as shown in Fig. 1.4) shall satisfy the requirements relating to the welded joint stipulated in Chapter 1, Section 5, I. The throat thickness of the fillet welds on clad plates shall be such (≤ 0,5 × plate thickness) that the fracture always occurs in the weld seam.

### 5.4 Aluminium alloys

**5.4.1** For welding procedure tests and tests on production specimens relating to aluminium alloys, the values specified in Table 1.7 shall be used as guide values for butt weld specimens taken from 5000 and 6000 series alloys as stipulated in the Society's Rules for Materials. The tensile strength of the specimens may not on any account be less than the minimum stipulated value for the base material in its "soft" condition. Different values shall be allowed for where applicable in the design and dimensioning operations. 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 these are specified on a case-by-case basis allowing for the characteristics of the base material and the joint efficiency factors stipulated in EN 288-4/ISO 9956-4.

**Table 1.7 Requirements applicable to aluminium alloys**

| Base material | | Welded joints [1] | | | |
|---|---|---|---|---|---|
| **Alloy no.** | **Material designation** | **0,2 %-proof stress [2] [N/mm²]** | **Tensile strength [N/mm²]** | **Bending angle [3] [degree]** | **Bending elongation [%]** |
| EN AW-5083 | AlMg4,5Mn0,7 | 125 | 275 | 180 | 18 |
| EN AW-5086 | AlMg4 | 100 | 240 | | |
| EN AW-5383 | AlMg4,5Mn0,7mod. | 145 | 290 | | |
| EN AW-5754 | AlMg3 | 80 | 190 | | |
| —— | AlMg5,5Mn0,8ZnZr | 160 | 300 | | |
| EN AW-6005A | AlSiMg(A) | 115 | 165 | | 10 |
| EN AW-6061 | AlMgSilCu | 115 | 155 | | |
| EN AW-6082 | AlSilMgMn | 125 | 185 | | |

[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 to EN 288-4/ISO 9956-4.

**5.4.2** The required bending angle of 180° under the test conditions specified in EN 910 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 must be attained before the first incipient crack appears. Minor pore exposures or the like up to a maximum length of 3 mm may be tolerated. The fracture surfaces of ruptured test specimens shall be evaluated.

**5.4.3** Measured on cruciform tensile test specimens, the minimum tensile-shear strength of the weld section (fracture section in accordance with Fig. 1.4) shall generally not be less than 60 % of the stipulated tensile strength. For the allowances which may be necessary when dimensioning the fillet-welded joints (if this value is not attained), see G.10.3.2.

**5.4.4** 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 dispensed with. The requirements applicable to low temperature applications will be specified separately.

### 5.5 Other materials

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 temperature).

## G. Design, Dimensioning

***Preliminary remark:***

*The contents of this section are largely identical to the provisions of the Rules for Classification and Construction I, Part 1 " Seagoing Ships", Chapter 1 "Hull Structures", Section 19 "Welded Joints". Because of the time separating the reissues of the different rules, some temporary divergences may arise and in such circumstances the more recent rules shall prevail.*

### 1. General

**1.1** The general design principles described in Chapter 2, Section 1 shall be followed.

**1.2** Welded joints shall be designed to ensure that the proposed weld type and quality (e.g. complete root fusion in the case of single- and double-bevel butt welds) can be satisfactorily achieved under the given fabricating conditions. Failing this, provision shall be made for welds which are easier to execute and the (possibly lower) load-bearing capacity of these welds shall be allowed for in the dimensional design.

**1.3** Severely stressed welded joints, which are therefore normally subject to compulsory inspection, shall be designed such that the most appropriate inspection technique for the detection of defects (radiography, ultrasonic or surface crack inspection) can be applied without restriction so that tests offering reliable results can be carried out.

### 2. Characteristics related to materials, corrosion

**2.1** Characteristics related to materials, e.g. the (inferior) strength of rolled products in the thickness direction (cf. para. 7.) or the softening of hardened aluminium alloys when welded, are to be allowed for when designing and dimensioning the components and the welded joints.

**2.2** Clad plates where the efficiency of the bond between the support and the superimposed material is proven may generally be treated as solid plates (up to medium plate thicknesses with mostly fillet welds).

**2.3** In thermally stressed composite structures made of different materials (e.g. hull structural and stainless steels in the case of tank heating systems), due allowance shall be made for the differences in the thermal conductivities and especially the rates of thermal expansion of the different steels.

**2.4** Where pairs of different materials are exposed to seawater or other electrolytes, e.g. the welded joints between unalloyed and stainless steels in the wear linings of rudder nozzles and in build-up welds on rudderstocks, attention is to be paid to the increased tendency towards corrosion, especially at the weld, due to the differences in electrochemical potential.

**2.5** If welded joints of this kind cannot be avoided, they shall whenever possible be located at points where there is less danger of corrosion (e.g. outside tanks) or special corrosion protection shall be provided (e.g. coating or cathodic protection).

### 3. Stress flow, transitions

**3.1** All welded joints on primary supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to expansion (cf. also the Rules for Construction of Seagoing Ships, Chapter 1, Section 3, H.).

**3.2** This applies in analogous manner to the welding of subordinate components onto primary supporting members whose exposed plate or flange edges should, as far as possible, be kept free from notch effects due to welded attachments. Regarding the inadmissibility of weldments to the upper edge of the sheer strake, see the Rules for Construction of Seagoing Ships, Chapter 1, Section 6, C.3.3. This applies in analogous manner to weldments to the upper edge of continuous hatchway sidecoamings.

**3.3** Butt joints in long or continuous external structures, such as bilge keels, fenders, slop coamings, crane rails, hatchway cover running rails, compression bars, etc. attached to primary supporting members are therefore to be welded over their entire cross section. Their ends shall be designed in analogous manner to the ends of the doubling plates (cf. 6.4) with "smooth" transitions into the component underneath.

**3.4** Wherever possible, welded joints (especially site joints) in girders and sections shall not be located in areas of high bending stress. Joints at the buckling points of flanges are to be avoided. Full penetration welds uniting three plates with additional fillet welds applied from the rear side in analogous manner to Fig. 1.18 on buckle stiffeners are generally acceptable.

**3.5** The transition between differing component dimensions shall be smooth and gradual. Where the depth of web of girders or sections differs, the flanges or bulbs are to be bevelled and the web slit and expanded or pressed together to equalize the depth of the members so that the flanges or bulbs, as applicable, may be satisfactorily welded together. The length of the transition should equal at least twice the difference in depth.

**3.6** Where the plate thickness changes at joints running perpendicular to the direction of the main stress, differences in thickness greater than 4 mm (greater than 3 mm where the thickness of the thinner plate is less 10 mm) must be accommodated by bevelling the proud edge in the manner shown in Fig. 1.5 at a ratio of at least 1 : 3 or less according to the notch category (cf. the Rules for Construction of Seagoing Ships, Chapter 1, Section 20, Table 20.3). Differences in thickness up to the values stated above may be accommodated within the weld.

**3.7** For the welding on of plates or other relatively thin-walled elements, steel castings and forgings must be appropriately tapered or provided with integrally cast or forged welding flanges in accordance with Fig. 1.6. Failing this, the Society may approve a correspondingly thicker transition piece welded over its entire cross-section to the steel casting or forging in a manner analogous to that for shaft brackets (cf. Fig. 1.24 and 1.25) or to that for the horizontal rudder coupling flanges (cf. Fig. 1.26)

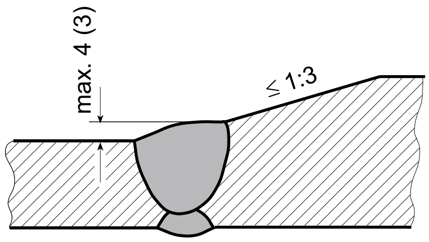



**Fig. 1.5 Accommodation of differences in thickness**

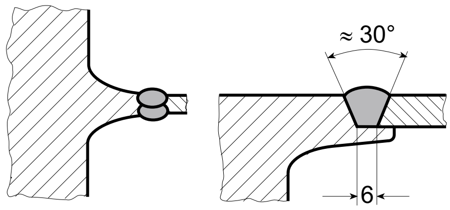



**Fig. 1.6 Welding flange on steel castings and forgings**

**3.8** For the connection of shaft brackets to the hub and the shell plating, see 13. and the Rules for Construction of Seagoing Ships, Chapter 1, Section 13, D.1.; for the connection of horizontal coupling flanges to the rudder body, see 14. For the thickened rudderstock collar required with build-up welds and for the connection of the coupling flange, see 9. and 14. respectively and the Rules for Construction of Seagoing Ships, Chapter 1, Section 14, D.2.4. The connection between the rudderstock and the coupling flange must be welded over the entire cross section.

## 4. Local clustering of welds, minimum spacing, socket weldments

**4.1** Local clustering of welds and short distances between welds are to be avoided. Where account has to be taken of higher residual welding stresses due to thicker plates or welds and corresponding rigidity of the components, the preparation should allow for the fact that adjacent butt welds should be separated from each other by a distance of at least

50 mm + 4 × plate thickenss

Fillet welds should be separated from each other and from butt welds by a distance of at least

30 mm + 2 × plate thickenss

In this case, the applicable dimensions are edge of fillet weld to edge of fillet weld or edge of fillet weld to centre of butt weld. The width of interchangeable sections (strips) of plates should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater. Other dimensions shall be subject to approval by the Society in each individual case as part of the examination of the drawings.

***Note:***

*In special cases, for example where plating bends over its length (e.g. the inner bottom plating in the fore section of the hull or lateral longitudinal bulkheads in the fore and aft sections of the hull), especially in the lower plate thickness range (up to approx. 20 mm) it may be advisable, in order to improve buckle stiffening - or where the weld throat thicknesses are not too large (up to about 5 mm) - to reduce the distances stated above or even position the buckle stiffening section or the like directly on the plate weld causing the buckling.*

*Although the extra fillet welds on the butt joint produce an additional clustering of welds and thus residual welding stresses, this is relatively minor compared with the residual welding stresses which occur in larger plate thicknesses and the correspondingly larger number of passes and may therefore be acceptable as a way of increasing the strength properties of the design. For permitted tolerances, see H.3.*

**4.2** Reinforcing plates, welding flanges, drain unions, mountings and similar components socket-welded into plating should be of the following minimum size:

$$D_{min} = 170 + 3\,(t - 10) \geq 170\ \text{mm}$$

where

D = Diameter of round or length of side of angular socket weldments in [mm]

t = Plating thickness in [mm]

With angular socket weldments, the corner radii should be at least 50 mm or the "longitudinal seams" should be extended beyond the "transverse joints". Socket weldments shall be welded to the surrounding plating over the entire cross-section. For the provisions relating to the increase in stresses due to possible differences in thickness, cf. the Rules for Construction of Seagoing Ships, Chapter 1, Section 20, B.1.3.

## 5. Welding apertures

**5.1** Welding apertures for the (later) execution of butt or fillet welds following the positioning of transverse members should be rounded (minimum radius 25 mm or twice the plate thickness, whichever is the greater) and (especially where the loading is mainly dynamic) should be shaped to provide a gentle transition to the adjoining surface and adequately notch-free welding should be carried out around the end faces as shown in Fig. 1.7.

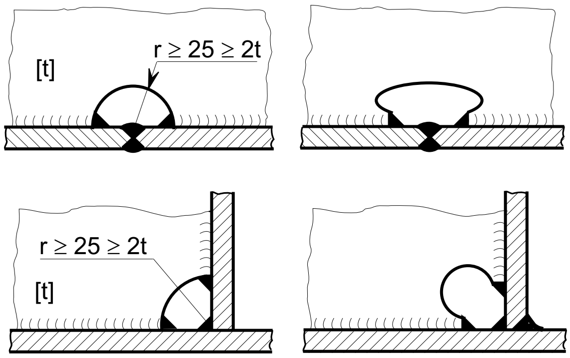



**Fig. 1.7 Welding apertures**

**5.2** Where the welds are completed prior to the positioning of transverse members, no welding apertures are needed. Any weld reinforcements present are to be machined off prior to positioning the transverse member, or the members to be positioned are to be notched accordingly.

## 6. Local reinforcements, plate doublings

**6.1** Where platings (including girder plates and tube walls) are subjected locally to increased stresses, thicker plates should be used wherever possible in preference to plate doublings. Bearing bushes, hubs, etc. shall invariably take the form of thicker sections welded into the plating (cf. 4.2).

**6.2** Where doublings cannot be avoided, the thickness of the doubling plate should not exceed twice the plating thickness. Doubling plates whose width is greater than approximately 30 times their thickness shall be plug-welded to the underlying plating in accordance with 10.5 at intervals not exceeding 30 times the thickness of the doubling plate.

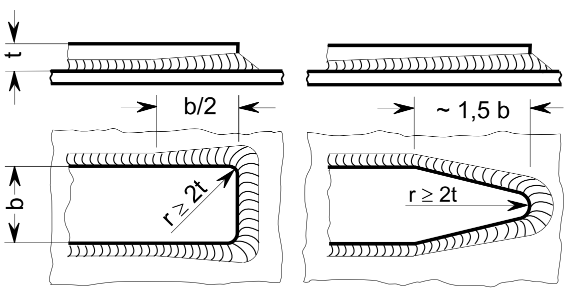



**Fig. 1.8 Weld at the ends of doubling plates**

**6.3** Along their (longitudinal) edges, doubling plates shall be continuously fillet welded with a throat thickness "a" of 0,3 × the doubling plate thickness. At the ends of doubling plates, the throat thickness "a" at the end faces shall equal 0,5 × the doubling plate thickness t, but shall not exceed the plating thickness (see Fig. 1.8).

**6.4** The weld joining the end faces to the plating should make a smooth transition with the latter at an angle of 45° or less.

Where proof of fatigue strength is demanded, (cf. Section 20 of Chapter 1of the Rules for Construction of Seagoing Ships) the ends of the doubling plates must be designed so that they comply with the detail category selected.

**6.5** Doubling plates are not acceptable in tanks for flammable liquids, gases or chemicals.

## 7. Transverse members, stress in the thickness direction

**7.1** Where, in the case of members lying transverse to each other, plates or other rolled products are stressed in the thickness direction by residual stresses due to the welding and/or by applied loads, suitable measures shall be taken in the design and fabrication of the structures to prevent lamellar tearing (stratified fractures) due to the anisotropy of the rolled products.

**7.2** Such measures include the use of suitable weld shapes with a minimum weld volume and an appropriate welding sequence designed to reduce transverse shrinkage. Other measures are the distribution of the stresses over a larger area of the plate surface by using a build-up weld or the "joining together of several layers" of members stressed in the thickness direction, as exemplified by the deck stringer/sheer strake joint shown in Fig. 1.17.

**7.3** Where there are very severe stresses in the thickness direction (due, for example, to the aggregate effect of the shrinkage stresses of bulky single- or double-bevel welds plus high applied loads), plates with guaranteed through thickness strength properties are to be used (higher degree of purity and guaranteed minimum reductions in area of ≥ 20 % of tensile test specimens taken in the thickness direction [3].

**7.4** Sandwiched flat bar steel positioned transversely to the direction of force (e.g. for use as backings for plug welding or to accommodate excessive air gaps) are not permitted where components intersect.

## 8. Welding of cold-formed sections, bending radii

**8.1** In structural steels with a tendency towards strain ageing, welding of the cold-formed sections with more than 5 % permanent elongation [4] and the adjacent areas with 5 × plate thickness should be avoided wherever possible. In case of doubt the Society may demand proof (e.g. in the form of notched bar impact tests) that cold forming and subsequent welding have not caused any unacceptable reduction in toughness characteristics.

**8.2** Welding of the cold-formed sections and adjacent areas of hull structural steels and comparable structural steels (e.g. quality groups S….J…. or S….K…. conforming to EN 10025) may be performed, provided that the minimum bending radii are not less than those specified in Table 1.8.

**Table 1.8 Minimum bending radii for welding of cold-formed sections**

| Plate thickness t | Minimum inner bending radius r |
|---|---|
| 4 mm or less | 1 × t |
| 8 mm or less | 1,5 × t |
| 12 mm or less | 2 × t |
| 24 mm or less | 3 × t |
| over 24 mm | 5 × t |

***Note:***

*The bending capacity of the material may necessitate a larger bending radius.*

**8.3** For other steels and, where applicable, other materials, the necessary minimum bending radius shall, in case of doubt, be established by test. Proof of adequate toughness after welding may be stipulated for steels with minimum yield strengths of more than 355 N/mm² and plate thicknesses of 30 mm and above which have undergone cold forming resulting in 2 % or more permanent elongation.

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3 See the Rules for Materials and Welding, Part, 1, Metallic Materials, Chapter 2, Section 1, I., and also Supply Conditions 096 for Iron and Steel Products, "Plate, strip and universal steel with improved resistance to stress perpendicular to the product surface" issued by the German Iron and Steel Makers' Association.

4 Elongation ε in the outer tensile stressed zone:

$$\varepsilon = \frac{100}{1 + 2\,r\,/\,t} \quad [\%]$$

r = inner bending radius in [mm]
t = plate thickness in [mm]

## 9. Build-up welds on rudderstocks and pintles

**9.1** Wear-resistant and/or corrosion-resistant build-up welds on the bearing surfaces of rudder-stocks, pintles, etc. shall be applied to a thickened collar exceeding by at least 20 mm the diameter of the adjoining part of the shaft.

**9.2** Where a thickened collar is impossible for design reasons, the build-up weld may be applied to the smooth shaft provided that relief-turning in accordance with 9.3 is possible (leaving an adequate residual diameter).

**9.3** After welding, the transition areas between the welded and non-welded portions of the shaft shall be relief-turned with large radii, as shown in Fig. 1.9, to remove any base material whose structure close to the concave groove has been altered by the welding operation and in order to effect the physical separation of geometrical and "metallurgical" notches.

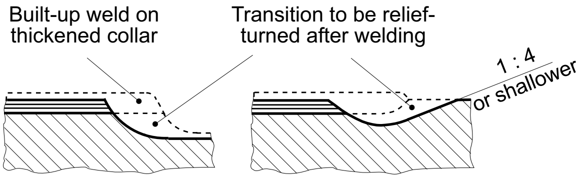



**Fig. 1.9 Build-up welds applied to rudder-stocks and pintles**

**9.4** If, during a repair, a build-up weld is exceptionally to be applied to the smooth shaft without relief turning with the special permission of the Society, this weld shall be made in analogous manner to 9.3 (at an adequate distance beyond the zone of maximum bending stress) as shown in Fig. 1.10 in such a way that at least two passes of weld metal remain in the smooth part of the shaft after machining. The transition between the build-up weld and the shaft must be machined cleanly and free of notches.

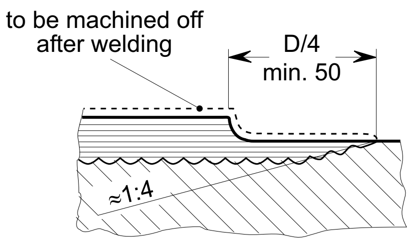



**Fig. 1.10 Repair made by build-up welding**

**9.5** Build-up welding may only be carried out using a fully mechanized process approved by the Society (e.g. 12, submerged-arc welding) in the circumferential direction on a rotating fixture.

## 10. Weld shapes and dimensions

### 10.1 Butt joints

**10.1.1** Depending on the plate thickness, the welding process and the welding position, butt joints shall take the form of square, V or double-V welds (double V butt joints) conforming to the standards (e.g. EN 22553, EN 29629, DIN 8551 Part 4, DIN 8552 or DIN 8553). The weld shapes shall be illustrated in the drawings or in other production documents, together with the standard symbols.

**10.1.2** Where weld shapes are proposed other than those specified in the standards, these are to be specially described in the drawings. Weld shapes for special welding processes (e.g. submerged-arc, single-side welding, electrogas or electroslag welding) must have been tested and approved in the context of a welding procedure test.

**10.1.3** As a matter of principle, the rear sides of butt joints shall be grooved and welded with at least one backing run (capping pass). Exceptions to this rule, as in the case of submerged-arc welding or the welding processes mentioned in para. 10.1.1, require testing and approval in the context of a welding procedure test.

**10.1.4** Where the aforementioned conditions cannot be met (e.g. where the welds are accessible from one side only), the joints shall be executed as lesser bevelled welds with an open root and an attached or an integrally machined or cast permanent weld pool support (backing), as shown in Fig. 1.11.

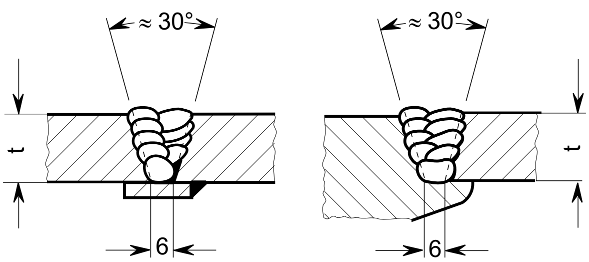



**Fig. 1.11 Single-side welds with permanent weld pool supports (backings)**

**10.1.5** The effective weld thickness is deemed to be the plate thickness or, where the plate thicknesses differ, the lesser plate thickness. Where proof of fatigue strength is required (see para. 15.3), the detail category depends on the workmanship (geometry and quality) of the weld.

**10.1.6** The weld shapes illustrated in Fig. 1.12 shall be used for clad plates. These weld shapes shall be used in analogous manner for corner joints and for joining clad plates to (unalloyed and low-alloy) hull structural steels.

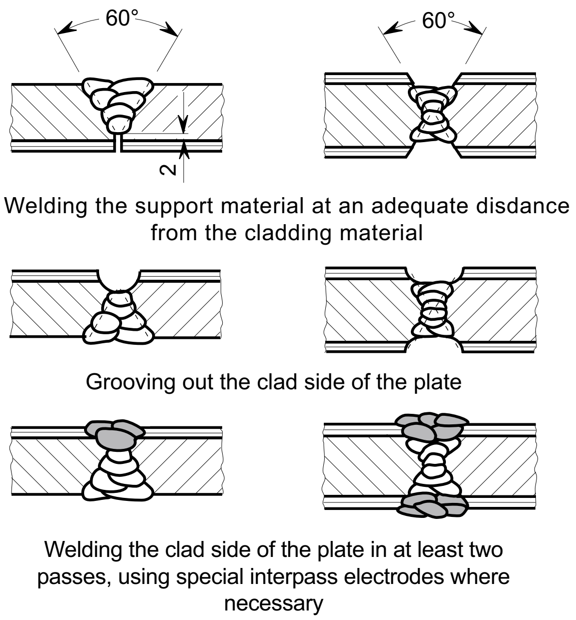



**Fig. 1.12 Weld shapes for welding of clad plates**

### 10.2 Corner, T and double-T (cruciform) joints

**10.2.1** Corner, T and double-T (cruciform) joints with **full root penetration connection** of the abutting plates shall be executed as single- or double-bevel welds with a minimum root face and adequate air gap, as shown in Fig. 1.13, and **with grooving of the root** and capping from the opposite side.

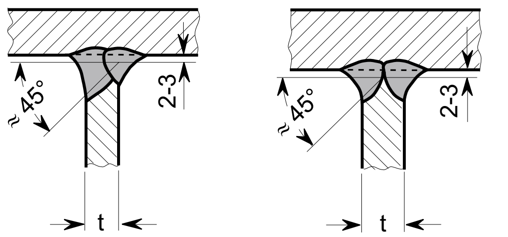



**Fig. 1.13 Single- and double-bevel welds with full root penetration**

The effective weld thickness is deemed to be the thickness of the abutting plate. Where proof of fatigue strength is required (see 15.3), the detail category depends on the workmanship (geometry and quality) of the weld. These welds are to be classified according to type 21 in accordance with Chapter 1, Section 20, Table 20.3 of the Rules for Construction of Seagoing Ships.

**10.2.2** Corner, T and double-T (cruciform) joints with a **defined incomplete root penetration "f",** as shown in Fig. 1.14 shall be executed as single- or double-bevel welds, as described in para. 10.2.1, **with capping from the rear side** but **without grooving of the root.**

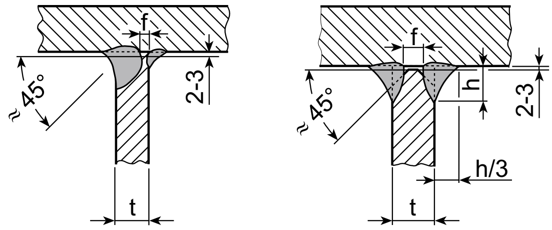



**Fig. 1.14 Single- and double-bevel welds with defined incomplete root penetration**

The effective weld thickness may be deemed to be the thickness t (- f) of the abutting plate, the assumed incomplete root penetration f = 0,2 t, max. 3 mm, being compensated for by means of additional fillet welds of at least equal size applied to each side. As a practical dimension, a leg length of z = h/3 at the root of the weld may be prescribed where h is the depth of the weld as shown in the figure. If proof of fatigue strength is required (see para. 15.3), these welds may also be placed in detail category no. 21 in accordance with the Rules for Construction of Seagoing Ships, Chapter 1, Section 20, Table 20.3.

**10.2.3** Corner, T and double-T (cruciform) joints with an unwelded root face "c" and an incomplete root penetration "f" which is also to be allowed for shall be executed in accordance with Fig. 1.15.

The effective weld thickness is deemed to be the thickness of the abutting plate t – (c + f), where f is to be assigned a value of 0,2 t subject to a maximum of 3 mm. Where proof of fatigue strength is required (see para. 15.3), and depending on the plate thickness to weld thickness ratio, these welds are to be classified according to type 22 or 23 in accordance with the Rules for Construction of Seagoing Ships, Chapter 1, Section 20, Table 20.3.

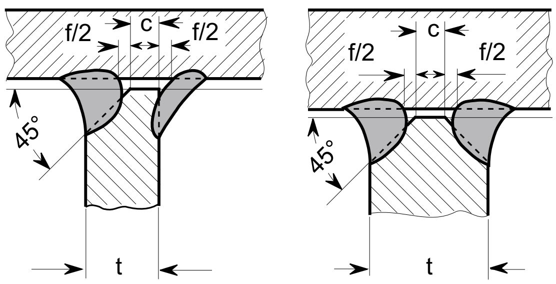



**Fig. 1.15 Single- and double-bevel welds with unwelded root face and defined incomplete root penetration**

**10.2.4** Corner, T and double-T (cruciform) joints which are accessible from one side only may be executed in accordance with Fig. 1.16 in a manner analogous to the butt joints referred to in para. 10.1.4 using a weld pool support (backing) or as single-side single-bevel welds laid down in a manner similar to that prescribed in para. 10.2.2.

The effective weld thickness shall be determined by analogy with para. 10.1.5 or 10.2.2, as appropriate. Wherever possible, these joints should not be used where proof of fatigue strength is required (see para. 15.3).

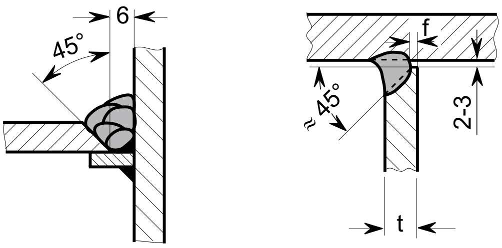



**Fig. 1.16 Single-side welded T-joints**

**10.2.5** Where corner joints are flush, i.e. with neither of the plates standing proud, the weld shapes shall be as shown in Fig. 1.17 with bevelling of the perpendicularly juxtaposed plates to avoid the danger of lamellar tearing (stratified fracture, cf. 7.). A similar procedure is to be followed in the case of fitted T-joints (uniting three plates) where the perpendicular plate illustrated is to be socketed (between two horizontal plates).

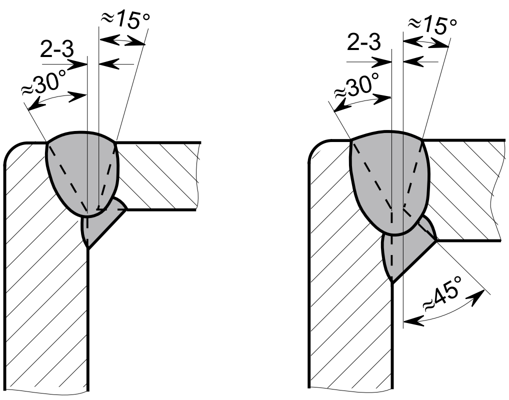



**Fig. 1.17 Flush fitted corner joints**

**10.2.6** Where, in the case of T-joints (uniting three plates), the direction of the main stress lies in the plane of the horizontal plates (e.g. the plating) shown in Fig. 1.18 and the connection of the perpendicular (web) plates is of secondary importance, welds uniting three plates may be made in accordance with Fig. 1.18 (with the exception of those subjected mainly to dynamic loads).

The effective thickness of the weld uniting the horizontal plates shall be determined by analogy with 10.1.5. The requisite "a" dimension is determined by the joint uniting the vertical (web) plates and shall, where necessary, be determined in accordance with the Rules of Construction of Seagoing Ships, Chapter 1, Section 19, Table 19.3 or by calculation as for fillet welds.

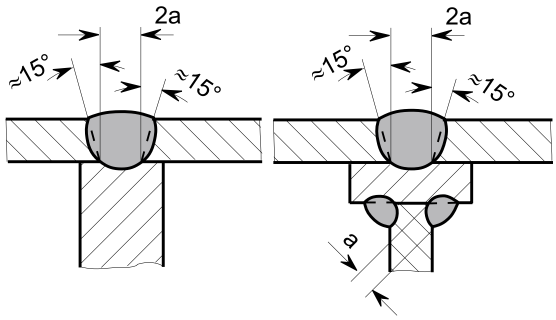



**Fig. 1.18 Welding together three plates**

## 10.3 Fillet weld joints

**10.3.1** Fillet welds shall normally be made on both sides, and exceptions to this rule (as in the case of closed box girders and predominant shear stresses parallel to the weld) are subject to approval in each individual case. The throat thickness "a" of the weld (the height of the inscribed isosceles triangle) shall be determined in accordance with the Rules for Construction of Seagoing Ships, Chapter 1, Section 19, Table 19.3 or by calculation in accordance with 15. The leg length "z" of a fillet weld is to be not less than 1,4 × the throat thickness "a". For fillet welds at doubling plates, see 6.3; for the welding of deck stringers to sheer strakes, see the Rules for Construction of Seagoing Ships, Chapter 1, Section 7, A.2.1, and for bracket plate connections, see Section 19, C.2.7.

**10.3.2** The relative fillet weld throat thicknesses specified in the above-mentioned Table 19.3 relate to normal- and higher-strength hull structural steels and comparable structural steels. They may also be applied to high-strength structural steels and non-ferrous metals provided that the tensile-shear strength of the weld metal used is at least equal to the tensile strength of the base material. Failing this, the "a" dimension shall be increased accordingly and the necessary increment shall be established during the welding procedure test. Alternatively, proof by calculation taking account of the properties of the weld metal may be presented.

***Note:***

*In the case of higher-strength aluminium alloys (e.g. AlMg 4,5 Mn), such an increment may be necessary for cruciform joints subject to tensile stresses, as experience shows that in the welding procedure tests the tensile-shear strength of fillet welds (made with matching filler metal) often fails to attain the tensile strength of the base material. Cf. F.5.4.3.*

**10.3.3** The throat thickness of fillet welds shall not exceed 0,7 times the lesser thickness of the parts to be welded (the web thickness, for instance). The minimum weld thickness is defined by the expression:

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \text{ [mm]},$$

but not less than 3 mm

where

$t_1$ = lesser (e.g. the web) plate thickness in [mm]

$t_2$ = greater (e.g. the flange) plate thickness in [mm]

Cf. Chapter 2, Section 1, E.2.

**10.3.4** It is desirable that the fillet weld section should be flat faced with smooth transitions to the base material. Where proof of fatigue strength is required (see para. 15.3), machining of the weld (grinding to remove notches) may be required depending on the detail category. The weld should penetrate at least close to the theoretical root point (cf. Fig. 1.19).

**10.3.5** Where mechanized welding processes are used which ensure deeper penetration extending well beyond the theoretical root point and where such penetration is uniformly and dependably maintained under production conditions, approval may be given for this deeper penetration to be allowed for in determining the throat thickness. The effective dimension

$$a_{deep} = a + \frac{2 \text{ min e}}{3} \text{ [mm]}$$

shall be ascertained in accordance with Fig. 1.19 and by applying the term "min e", which is to be established for each welding process by a welding procedure test. The throat thickness shall not be less than the minimum throat thickness related to the theoretical root point.

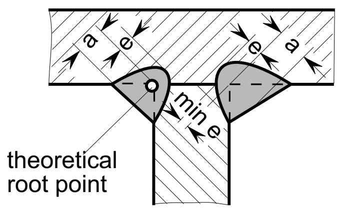



**Fig. 1.19 Fillet welds with increased penetration**

***Note:***

*In the case of welding processes where there is a particularly deep, narrow penetration, as occurs for example in laser welding without welding consumable in which no significant fillet weld is produced but the entire welded joint is virtually shifted "inwards", the above requirement for a specific minimum fillet weld thickness may be difficult or impossible to meet. In such cases the extent of the effect of the weld shape (if any) on the characteristics of the welded joint (e.g. resistance to cracking, strength) shall be assessed and/or verified in the welding procedure test, taking into consideration any fatigue strength requirements which may be stipulated. The details of this shall be agreed with the Society on a case-by-case basis.*

**10.3.6** When welding on top of shop primers which are particularly liable to cause porosity, an increase of the "a" dimension by up to 1 mm may be stipulated depending on the welding process used. This is especially applicable where minimum fillet weld throat thicknesses are employed. The size of the increase shall be decided on a case-by-case basis allowing for the nature and the severity of the loading according to the results of the examination of the shop primer in accordance with Chapter 1, Section 6 or of the welding procedure tests or production tests, as applicable. This applies in analogous manner to welding processes where provision has to be made for inadequate root penetration.

**10.3.7** Strengthened fillet welds continuous on both sides are to be used in areas subjected to severe dynamic loads (e.g. for joining the longitudinal and transverse girders of the engine base to top plates close to foundation bolts, cf. the Rules for Construction of Seagoing Ships, Chapter 1, Section 8, C.3.2.5 and Section 19, Table 19.3) unless single- or double- bevel welds are stipulated in these locations. In these areas the fillet weld throat thickness "a" shall equal 0,7 times the lesser thickness of the parts to be welded.

**10.3.8** Intermittent fillet welds may be located opposite each other (chain intermittent welds, possibly with scallops) or may be offset (staggered welding), in accordance with the Rules for Construction of Seaoging Ships, Chapter 1, Table 19.3 (cf. Fig. 1.20). The use of different scallop shapes and dimensions may be agreed on for very small sections.

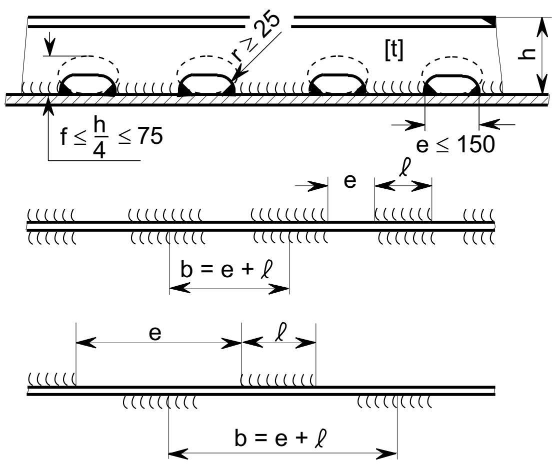



**Fig. 1.20 Scallop, chain and staggered welds**

In water and cargo tanks, in the bottoms of fuel tanks and of rooms where pools of condensation or spray water may collect, and in hollow components (e.g. rudders) threatened by corrosion, only continuous fillet welds or intermittent welds with scallops shall be used. The same applies in analogous manner to areas, components or compartments which are exposed to extreme weather conditions or to a corrosive cargo.

There shall be no scallops in areas where the plating is subjected to severe stresses (e.g. in the bottom section of the fore ship) and continuous welds are to be preferred where the loading is chiefly dynamic.

**10.3.9** The throat thickness $a_u$ of intermittent fillet welds is to be determined according to the selected pitch ratio b/ℓ by applying the following formula:

$$a_u = a \cdot \frac{b}{\ell} \cdot 1{,}1 \quad [\text{mm}]$$

where

a = necessary fillet weld throat thickness for a continuous weld conforming to the Rules for Construction of Seaoging Ships, Chapter 1, Table 19.3, or determined by calculation in [mm]

b = pitch = e + ℓ in [mm]

e = interval between the welds in [mm]

ℓ = length of fillet weld in [mm]

The pitch ratio b/ℓ may not be greater than 5. The maximum unwelded length (b – ℓ with scallop and chain welds or b/2 – ℓ with staggered welds) shall not exceed 25 times the lesser thickness of the parts to be welded. However, the length of the scallops shall not exceed 150 mm.

### 10.4 Lapped joints

**10.4.1** Lapped joints running transversely to the main direction of load should be avoided wherever possible and may not be used for heavily loaded components. Lapped welds may be accepted for components subject to low loads (excluding, however, tanks for chemicals, combustible liquids or gases) provided that wherever possible, they are orientated parallel to the direction of the main stress.

**10.4.2** The width of the lap shall be 1,5 t + 15 mm (t = thickness of the thinner plate). Except where another value is determined by calculation, the fillet weld throat thickness "a" shall equal 0,4 times the thickness of the thinner plate, subject to the requirement that it shall not be less than the minimum throat thickness prescribed in para. 10.3.3. The fillet weld must be continuous on both sides and must meet at the ends.

### 10.5 Plug welding

**10.5.1** In the case of plug welding, the plugs should, wherever possible, take the form of elongated holes lying in the direction of the main stress. The distance between the holes and the length of the holes may be determined by analogy with the pitch "b" and the fillet weld length "ℓ" in the intermittent welds covered by para. 10.3. The fillet weld throat thickness "$a_u$" may be established in accordance with 10.3.9.

**10.5.2** The width of the holes shall be equal to at least twice the thickness of the plate and shall not be less than 15 mm. The ends of the holes shall be semi-circular.

**10.5.3** Plates or sections placed underneath should at least equal the perforated plate in thickness and should project on both sides to a distance of 1,5 × the plate thickness subject to a maximum of 20 mm. Wherever possible, only the necessary fillet welds shall be made, while the remaining void is packed with a suitable filler.

**10.5.4** Lug-joint welding is not permitted.

## 11. Welding at the ends of girders and stiffeners

**11.1** As shown in Fig. 1.21, the web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance at least equal to the depth "h" of the girder or stiffener subject to a maximum of 300 mm. Regarding the strengthening of the welds at the ends, normally extending over 0,15 of the span, see the Rules of Construction for Seagoing Ships Chapter 1, Section 19, Table 19.3.

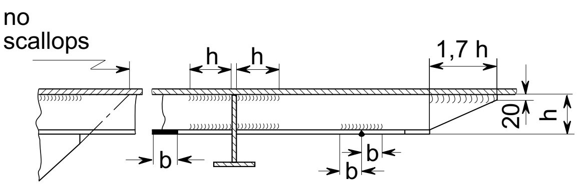



**Fig. 1.21 Welds at the ends of girders and stiffeners**

**11.2** The areas of bracket plates should be continuously welded over a distance at least equal to the length of the bracket plate. Scallops shall be located only beyond a line imagined as an extension of the free edge of the bracket plate.

**11.3** Wherever possible, the free ends of stiffeners shall abut against the transverse plating or the webs of sections and girders so as to avoid stress concentrations in the plating. Failing this, the ends of the stiffeners shall be cut off obliquely and shall be continuously welded in accordance with Fig. 1.21 over a distance of at least 1,7 h, subject to a maximum of 300 mm. Different dimensions may be agreed for very small sections.

**11.4** Where butt joints occur in flange plates, the flange shall be continuously welded to the web on both sides of the joint over a distance "b" at least equal to the width of the flange.

**11.5** In the case of girders lying transversely to each other, e.g. as shown in Fig. 1.21, and section passages, a continuous weld shall also be made, by analogy with 11.1, on the girder depicted in section in the figure on both sides of the point where the girders cross.

## 12. Joints between section ends and plates

**12.1** Welded joints uniting section ends and plates (e.g. at lower ends of frames) may be made in the same plane or lapped. Where no design calculations have been carried out or stipulated for the welded connections, the joints may be made analogously to those shown in Fig. 1.22.

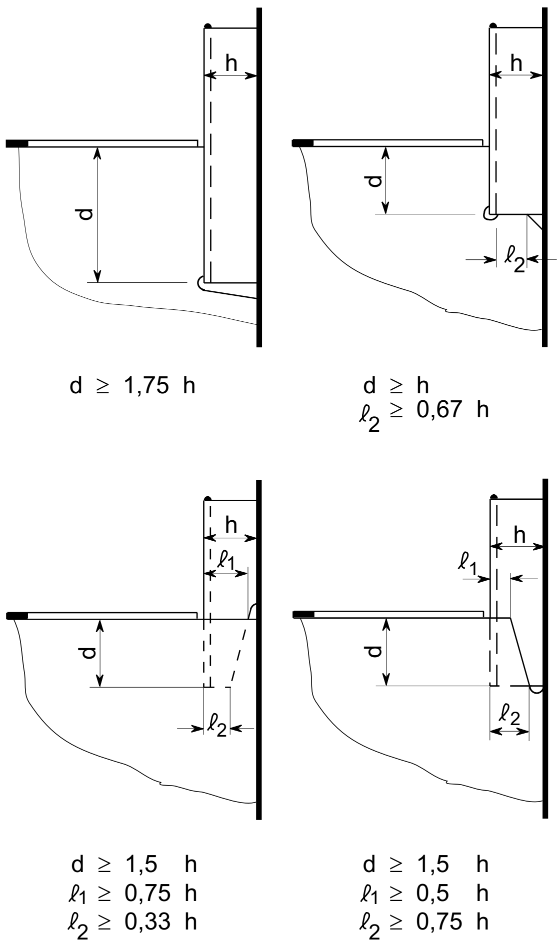



**Fig. 1.22 Joints uniting section ends and plates**

**12.2** Where the joint lies in the plane of the plate, it may conveniently take the form of a single-bevel butt weld with fillet. Where the joint between the plate and the section end overlaps, the fillet weld must be continuous on both sides and must meet at the ends. The necessary "a" dimension is to be calculated in accordance with the Rules of Construction for Seagoing Ships, Chapter 1, Section 19, C.2.6. The fillet weld throat thickness shall not be less than the minimum specified in 10.3.3.

## 13. Welded shaft bracket joints

**13.1** Unless cast in one piece or provided with integrally cast welding flanges analogous to those prescribed in 3.7 (see Fig. 1.23), strut barrel and struts are to be joined to each other and to the shell plating in the manner shown in Fig. 1.24.

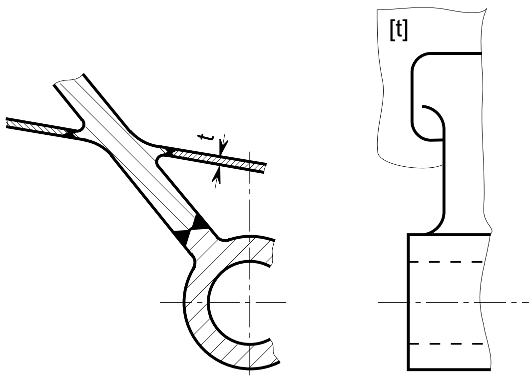
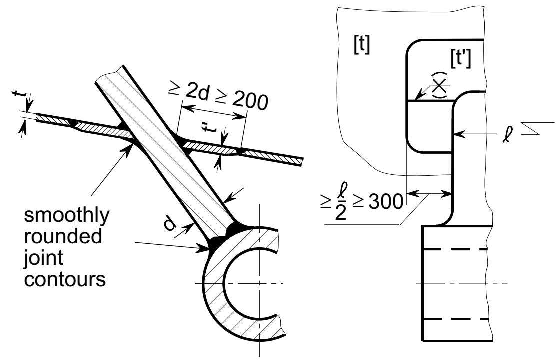



**Fig. 1.23 Shaft bracket with integrally cast welding flanges**




t = plating thickness in accorordance with the Rules for Construction of Seagoing Ships, Chapter 1, Section 6, F in [mm]

$t' = \frac{2/3 d_{max}}{3} + 5$ [mm] for $d < 50$ mm

$t' = 3\sqrt{d}$ [mm] for $d \geq 50$ mm

**Fig. 1.24 Shaft bracket without integrally cast welding flanges**

**13.2** In the case of single-strut shaft brackets, no welding may be performed on the arm at or close to the position of constraint. Such components must be provided with integrally forged or cast welding flanges. Alternatively, a design in accordance with Fig. 1.25 may be used, subject to the consent of the Society in each individual case. If so, it is essential to keep the concave groove free from welds or other notches.

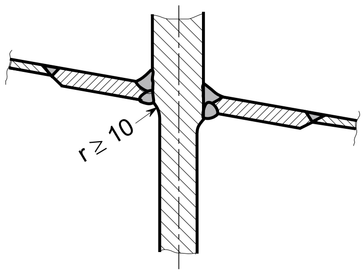
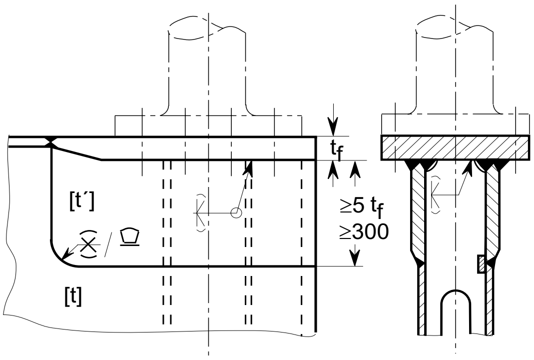



**Fig. 1.25 Single-strut shaft bracket**

## 14. Rudder coupling flanges

**14.1** Unless forged or cast steel flanges with integrally forged or cast welding flanges in conformity with 3.7 are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single- or double-bevel welds as prescribed in 10.2.1 (see Fig. 1.26). Cf. also the Rules for Construction of Seagoing Ships, Chapter 1, Section 14, D.1.4 and 2.4.




t = plating thickness in accordance with the Rules for Construction of Seagoing Ships, Chapter 1, Section 14, E.3.1 in [mm].

$t_f$ = actual flange thickness

$t' = \frac{t_f}{3} + 5$ [mm] for $t_f < 50$ mm

$t' = 3\sqrt{t_f}$ [mm] for $t_f \geq 50$ mm

**Fig. 1.26 Horizontal rudder coupling flanges**

**14.2** Allowance shall be made for the reduced strength of the coupling flange in the thickness direction (cf. 2.1 and 7.). In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

**14.3** The use of horizontal couplings for spade rudders is permitted only if the specified thickness of the coupling flanges is less than 50 mm. If this is not the case, taper couplings shall be used. Taper couplings are the only type permitted for high-performance spade rudders. Cf. also Rules for Construction of Seagoing Ships, Chapter 1, Section 14, D.1.4 and 2.4.

**14.4** The welded joint between the rudder shaft (with thickened collar, cf. para. 3.8) and the flange shall be made in accordance with Fig. 1.27 in such a way that the concave groove at the transition to the thickened collar remains absolutely free of welds. Where necessary, the transition shall be machined to remove notches. For larger flange thicknesses, it is advisable to carry out a single-U weld preparation instead of a double- bevel butt weld.

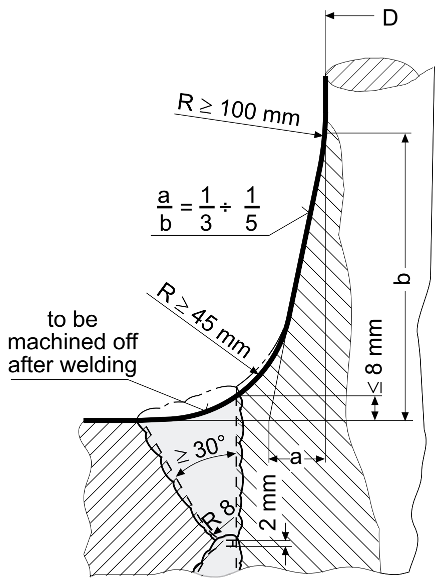



**Fig. 1.27 Welded joint between rudder shaft and coupling flange**

## 15. Design calculations applied to welded joints

**15.1** Any calculation relating to welded joints which is stipulated in the Rules or prescribed as an alternative to the rules governing dimensions shall be performed in accordance with the Rules for Construction of Seagoing Ships, Chapter 1, Section 19, C. Calculations conforming to other rules, standards or codes (e.g. DIN 15018, DIN 18800 or DIN EN V 1993 (Eurocode 3)) are subject to the prior consent of the Society.

**15.2** Proof by calculation of adequate dimensioning with mainly static loading (a general stress analysis) is required where the thickness of butt welds, T-joints or double-T (cruciform) joints cannot be regarded as equal to the plate thickness (cf. 10.1.5, 10.2.1 to 10.2.4, 10.2.6 and elsewhere) or the throat thicknesses of fillet welds do not conform to the tables (cf. the Rules for Construction of Seagoing Ships, Chapter 1, Section 19, Table 19.3).

**15.3** For welded joints subjected to mainly dynamic loads, the permissible loading shall be determined by reference to the number of load alternations, the global loading conditions, the mean stress and the notch category (proof of fatigue strength). The notch category is a function of the geometrical configuration of the welded joint. It is also associated with (graduated degrees of) proof of the absence of serious internal and external notches (welding defects). Cf. the notch category catalogue in the Rules for Construction of Seagoing Ships, Chapter 1, Section 20.

## H. Execution of Welds

### 1. General

**1.1** The general rules prescribed and the instructions given in Chapter 2, Section 2 for the execution of welds shall be complied with.

**1.2** For the necessary approvals, inspections and tests of welding shops, welders, welding procedures, welding consumables and auxiliary materials, overweldable shop primers, etc., see the relevant sections and also A. to F. of this section.

### 2. Welders and supervisors

**2.1** Welding work on components governed by these Rules may only be performed by qualified welders who have been approved by the Society and hold valid qualification certificates. Welders and operators (cf.2.3 and 2.4) shall be adequately experienced in the practice of the craft.

**2.2** Welders for manual and semi-mechanized welding of normal-strength hull structural steels must be qualified for the relevant welding process and welding positions on both butt welds and fillet welds in accordance with Chapter 1, Section 3. Welders for vertical-down welding must also be qualified for this position.

**2.3** Welders working with higher-strength hull structural steels, special structural steels, stainless steels or aluminium alloys must be qualified for welding these materials in analogous manner to the provisions of Chapter 1, Section 3.

**2.4** Operators for fully mechanized and automatic welding equipment must have received instruction and training in the use of the equipment and must be qualified in accordance with the provisions of Chapter 1, Section 3, A.1.3. The Society may demand that the operators' qualifications be verified in the course of the welding procedure test (cf. Chapter 1, Section 4) or by means of production tests during fabrication.

**2.5** Every workshop which performs welding work must have a welding supervisor who is an employee of the workshop, proof of whose technical qualifications shall be furnished (cf. Chapter 1, Section 2). The Society is to be automatically informed of any changes to the welding supervisors.

**2.6** The welding supervisor shall supervise the preparation and performance of the welding work in a responsible manner (cf. C.). Wherever these differ from the preceding and following conditions, requirements, etc., he shall take steps to ensure that the quality of the welded joints is consistent and adequate in consultation with the Society.

### 3. Weld preparation and assembly

#### 3.1 Overweldable shop primers

**3.1.1** Only those overweldable shop primers may be used for which the Society has issued a confirmation of acceptability based on a porosity test. See also Chapter 1, Section 6 and the list of welding consumables and auxiliary materials approved by the Society, VI, 9, 3, Part II.

**3.1.2** By means of suitable checks carried out in the course of production (e.g. measurements of coat thickness, production tests), workshops using shop primers shall ensure that the conditions of use on which the confirmation of acceptability was based are adhered to and that, in fillet welding, no excessive pore formation occurs which adversely affects the application. See also Chapter 1, Section 6 (notes).

#### 3.2 Weld shapes, root openings (air gaps)

**3.2.1** When preparing and assembling components, care shall be taken to ensure compliance with the weld shapes and root openings (air gaps) specified in the manufacturing documents. With single- and double-bevel welds especially, attention shall be paid to an adequate root opening in order to achieve sufficient root penetration (cf. G.10.2.1 and G.10.2.2).

**3.2.2** The root opening shall not exceed twice the specified gap. If the size of the gap permitted by this rule is exceeded locally over a limited area, the gap may be reduced by build-up welding of the side walls, subject to the prior consent of the Surveyor. With fillet welds, the "a" dimension shall be increased accordingly, or a single- or double-bevel weld shall be used if the air gap is large. See also the note to 3.3.2.

**3.2.3** With the Surveyor's agreement, large gaps may be closed by means of a strip of plate with a width of at least ten times the plate thickness or 300 mm, whichever is the greater (cf. G.4.).

### 3.3 Alignment of components, edge misalignment

**3.3.1** Components which are to be united by butt joints shall be aligned as accurately as possible. Sections etc. welded to plating shall be left unfastened at the ends for this purpose. Special attention shall be paid to the alignment of (abutting) girders etc. which are interrupted by transverse members. If necessary, such alignment shall be facilitated by drilling check holes in the transverse member which are later seal-welded.

**3.3.2** The permissible edge misalignment depends on the importance and loading of the component concerned (weld quality, cf. I.6.1). With heavily loaded seams (weld quality grade 1) running transversely to the main direction of loading, the edge misalignment of butt welds shall not exceed 10 % of the thickness of the plate or section, subject to a maximum of 3 mm.

***Note:***

*A serviceable guide to permissible fabricating tolerances is provided in the standards EN 25817/ISO 5817 (Annex A of Chapter 2) relating to steel and EN 30042/ISO 10042 (Annex B of Chapter 2) relating to aluminium and also in the IACS “Shipbuilding and Repair Quality Standard” and the "Fertigungsstandard des Deutschen Schiffbaus" (Manufacturing Standard of the German Shipbuilding Industry). In the case of the standards, the assessment category or the individual evaluative criteria to be applied to components or welded joints have to be determined by reference to their loading (cf. Table 1.9). The range of assessment categories, particularly for dynamic loading, is given in code of practice DVS 0705.*

*GL has agreed to the "Manufacturing Standard" subject to the reservation that in particular instances, e.g. where important, highly stressed components are concerned or where there is an accumulation of deviations from nominal dimensions, it may also impose decisions which differ from the Standard and may call for improvements to be carried out. Where the Society raises no objection, the provisions of the Manufacturing Standard may therefore be considered to represent the maximum permissible upper limit for deviations from the stipulated dimensions.*

### 3.4 Tack welds, auxiliary fixtures

**3.4.1** Tack welds should be used as sparingly as possible and should be made by trained operators. Where their quality does not meet the requirements applicable to the subsequent welded joint, they are to be carefully removed before the permanent weld is made. Cracked tack welds may under no circumstances be welded over.

**3.4.2** Clamping plates, temporary ties, aligning pins, etc. must be made of (hull structural) steel of good weldability and should not be used more than necessary. When the components have been permanently welded, they are to be carefully removed to prevent damage to the surfaces of the components.

**3.4.3** Clamping plates, temporary ties, aligning pins, etc. may not be welded to components subject to particularly high stresses (e.g. hatchway corners), nor shall they be welded to the edges of flange plates or, especially, to the upper edges of sheer strakes and continuous hatchway sidecoamings. The same applies to the welding of handling lugs and other auxiliary fixtures.

**3.4.4** Particularly with mechanized welding processes, and invariably when end craters and defects at the start and end of the weld have to be avoided, run-in and run-off plates of adequate section shall be attached to components and cleanly removed on completion of the weld.

## 4. Weather protection, welding at low temperatures

**4.1** The area in which welding work is performed - particularly outside - is to be sheltered from wind, damp and cold. Where gas-shielded arc welding is carried out, special attention is to be paid to ensuring adequate protection against draughts. When working in the open in unfavourable weather conditions, it is advisable always to dry welding edges by heating.

**4.2** At low temperatures (below 5 °C), suitable measures shall be taken to ensure the satisfactory quality of the welds. Such measures include the shielding of components, extensive preliminary heating and preheating, especially when welding with a relatively low heat input, e.g. when laying down thin fillet welds or welding thick-walled components. Wherever possible, welding work should be suspended if the temperature falls below – 10 °C.

## 5. Preheating

**5.1** The need for and the degree of preheating necessary for welding (cf. Chapter 2, Section 3, D.) are governed by a series of factors. These factors differ in their effect in the manner indicated in Chapter 2, Section 3, D.2.5 (Table 3.4), i.e. they raise or lower the necessary preheating temperature. For information on the measurement of the preheating temperature and the interpass temperatures to be maintained, see also Chapter 2, Section 3, D.

**5.2** Apart from the measures prescribed in para. 4.1 and 4.2, normal-strength hull structural steels do not normally require preheating. However, with large cross sections (e.g. steel castings or forgings) and where difficult conditions with regard to design or welding practice apply (e.g. severe distortion of components), it is advisable to carry out uniform preliminary heating of the areas surrounding the welded joints. Cf. 4.1 and 4.2.

**5.3** Higher-strength hull structural steels shall generally 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, paying due regard to the other factors described in Chapter 2, Section 3, D.2.5 (Table 3.4). For an average carbon equivalent and an average heat input (energy applied per unit length of weld), the threshold wall thicknesses "t" and preheating temperatures "T" shown in Fig. 1.28 may be used as an initial guide. These values, however, are governed by the influencing factors shown in the above-mentioned Table 3.4 and have to be adjusted in line with the prevailing conditions. Where necessary, the need for and degree of preheating shall be determined in accordance with Chapter 2, Section 3, D. or by means of tests (e.g. during the welding procedure tests).

**5.4** Tack and auxiliary welds shall be executed to a length of at least 50 mm and require preheating whenever it has to be carried out for the other welds. Exceptions to this are tack and auxiliary welds whose heat-affected zone is reliably and completely remelted during subsequent welding, e.g. tack welds for submerged-arc welding.

**5.5** Preheating shall be applied uniformly throughout the thickness of the plate or component and to a distance of 4 times the plate thickness, but not more than 100 mm, on both sides of the weld. Localized overheating is to be avoided. Preheating with gas burners should be performed with a gentle, though not sooty, flame. The preheating temperature shall be kept constant throughout the duration of the welding work.

## 6. Welding positions, vertical-down welding

**6.1** Welding should be performed in the optimum welding position, and positional welding (e.g. in the PE or PD (overhead) positions) shall be limited to the indispensable minimum.

**6.2** For similar and repetitive welding operations, it is advisable to use a (rotating) fixture enabling all welds to be made as far as possible in "simple" positions, such as the flat (PA) or horizontal vertical (PB) position.

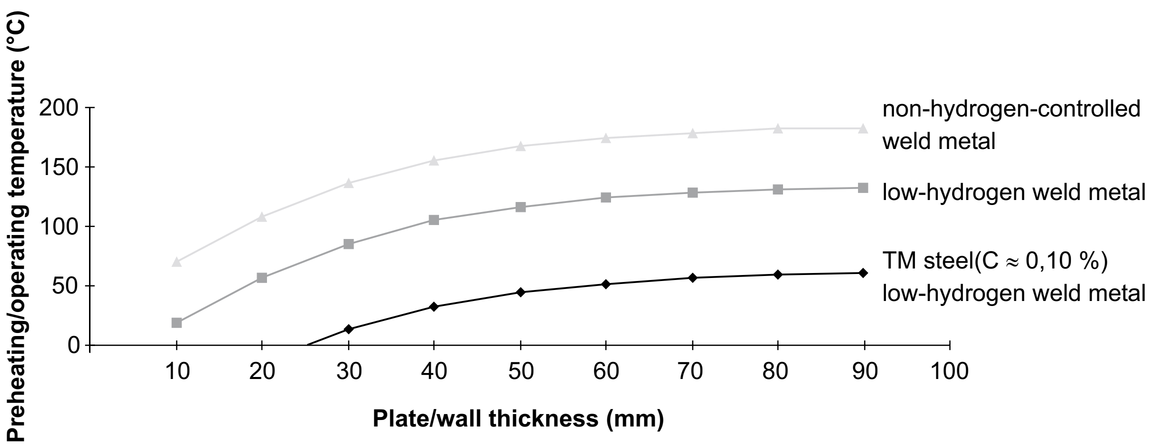



**Fig. 1.28** **Threshold wall thicknesses and preheating temperatures for higher-strength hull structural steels (guide values)**

**6.3** Even after a satisfactory welding procedure test and approval of the process (cf. F.1.), vertical-down fillet welding may not be used:

- for joining together continuous primary supporting members interrupted by transverse members (e.g. the longitudinal members of the upper and lower girder); the same applies where transverse loads predominate,
- for mainly dynamically loaded welded joints (e.g. in the area of engine baseplates, shaft brackets and rudders),
- on crane components and other lifting gear including their substructures (e.g. crane pillars),
- at intersections of main girders and in the area of the supports or stoppers of hatchway covers.

***Note:***

*Vertical-down welding may be used for joining secondary components (e.g. stiffeners) to primary supporting members, for fillet-welding floor plates to continuous bottom longitudinal girders, for fillet-welding transverse bulkheads to the shell plating, and for between-decks, interior partitions, etc. which do not affect the longitudinal or local strength of the vessel. In case of doubt, the extent of the vertical-down welding shall be agreed with the Society.*

**6.4** The Society may permit exceptions to the provisions of 6.3 and increase the extent of vertical-down welding if the welding shop takes special measures to ensure a satisfactory standard of workmanship (particularly the accurate assembly of components without any significant air gaps, adequate root penetration and prevention of lack of fusion defects) even under normal conditions of fabrication. Such measures include:

- choosing a suitable welding process and appropriate welding consumables and auxiliary materials which guarantee especially good penetration (cf. F.1.1, note),
- special training and careful selection of welders for vertical-down welding (see also 2.2),
- conscientious monitoring of the weld preparation, the welding parameters and the welding work (e.g. electrode control) while welding is in progress,
- production tests at random (fillet weld fracture specimens) during the course of fabrication.

The Society may demand proof that special measures of this kind have been taken. In addition, the Society may require more extensive monitoring or inspections of the vertical-down welds.

## 7. Welding sequence

**7.1** The assembly and welding sequence shall be chosen to allow shrinkage to take place as freely as possible and to minimize shrinkage stresses in the component. Butt joints in areas of plating shall invariably be fully welded, at least on one side, prior to the fastening of girders, stiffeners, etc.

**7.2** Where individual plates are later welded into position in areas of plating (as in the case of erection holes in the deck or shell plating), the longitudinal seams shall be left unwelded, or shall be opened up, to a distance of approx. 300 mm beyond the transverse joints. The transverse joints shall be welded first, followed by the longitudinal seams.

**7.3** The welding of patches (cf. G.4.2) may be performed in analogous manner, unless angular patches with rounded corners or round patches are used.

**7.4** In special cases (e.g. when welding together particularly rigid components) and for similar, repetitive welding operations (e.g. for the welding of masts into ships), it is advisable to set down the assembly procedure or welding sequence in a welding sequence schedule.

**7.5** Where welded and riveted joints meet (the same also applies analogously to other mechanical methods of assembly), the welds shall invariably be completed first, then the riveting adjoining the weld shall be carried out.

## 8. Performance of work

**8.1** The areas of the components to be welded must be clean and dry. Scale, rust, cutting slag, grease, paint and dirt shall be carefully removed prior to welding (with regard to overweldable shop primers, see 3.1).

**8.2** Components shall not be subjected to any appreciable movements or vibrations during welding. Parts to be assembled while floating or suspended from cranes shall be clamped prior to the tacking of the joint in such a way that no further movement of the parts is possible. Components which have not been fully welded and are to be handled or turned must have welded joints of adequate strength.

**8.3** Cracked tack welds may not be welded over, but are to be machined out. In multi-pass welding, the slag of the previous run shall be completely removed before the next pass. Pores, visible slag inclusions and other welding defects and cracks may not be welded over, but are to be machined out and repaired.

**8.4** The welding shop shall ensure that the specified welding parameters are adhered to and that the welding work is expertly performed by competent personnel (cf. 2.5 and 2.6).

**8.5** Welds must have sufficient penetration and must display a clean, regular surface with "gentle" transitions to the base material. Excessive weld reinforcements and undercuts (cf. note to 3.3.2) together with notches affecting the edges of plates and cutouts are to be avoided.

**8.6** Butt-welded joints must display full fusion over the entire cross section, unless a deviation from this is authorized in a particular case. For this purpose, the root shall normally be grooved and capped.

Following a successful welding procedure test confirmed by the Society, single-side welds, e.g. using ceramic backings, may be regarded as equivalent to butt welds executed from both sides.

Other joints welded on one side only, e.g. using permanent backings, are subject to approval by the Society when scrutinizing the relevant drawings. For the evaluation of such welded joints see G.10.3.

**8.7** Single- and double-bevel welds are to be made according to the design specification either with grooved roots as full-penetration welded joints or with a permitted incomplete penetration at the root or a defined, unwelded root face subject to the appropriate reduction factors (cf. G.10.2). The type of weld is to be specified in the drawings in each case and must have received the Society's approval when the drawings were scrutinized.

**8.8** With fillet welds, particular attention shall be given to good root penetration. The penetration must extend at least to the immediate vicinity of the theoretical root point (cf. G.10.3.4 to 10.3.6). The ideal fillet weld section is that of an equal-sided flat-faced weld with smooth (notch-free) transitions to the base material. At the ends of web plates, at cutouts and at welding apertures, the fillet welds shall meet to form a continuous seam around the root face.

**8.9** Major cases of faulty workmanship or defects in the material may only be repaired with the Surveyor's agreement. Minor surface defects shall be removed by shallow grinding. Defects which penetrate more deeply into the material (e.g. cracks, or tears left by the removal of welded-on erection aids) shall be cleanly machined, ground and repair-welded with an adequate heat input.

## 9. Welding of higher-strength hull structural steels and high-strength (quenched and tempered) fine-grained structural steels

***Preliminary remark:***

*The following provisions apply in analogous manner to the welding of low-alloy steels tough at subzero temperatures used for structural members in shipbuilding, e.g. for cargo tank supports on gas tankers. The tanks themselves are subject to the Rules for Construction of Seagoing Ships, Chapter 6 "Liquefied Gas Tankers". See also Section 3 “Welding of Pressure Vessels”.*

**9.1** The steelmaker's instructions and recommendations [5] and any conditions arising from the welding procedure test shall be implemented when welding higher-strength hull structural steels and high-strength (quenched and tempered) fine-grained structural steels. For the use and working of thermo-mechanically rolled (TM) steels, see the appropriate Society rules [6].

**9.2** The welding process, welding consumables, weld build-up and thermal practice (preheating, heat input and interpass temperature) etc. shall be suited to the base material being welded and shall be maintained within the appropriate limits during welding. These parameters must match those used during the welding procedure test. Any appreciable deviations require the Society's consent and are normally contingent on additional tests. Wherever possible, multi-pass welding shall be used (particularly for high-strength (quenched and tempered) fine-grained structural steels), the final pass being laid down as a "temper bead" run some 2 mm away from the base material.

**9.3** When welding high-strength fine-grained structural steels it may be necessary to verify not only the preheating but also the heat input during welding [7] and the interpass temperatures. These checks shall invariably be carried out and recorded when welding high-strength quenched and tempered fine-grained structural steels. The values must correspond to the energy per unit length of weld established during the welding procedure tests and to be laid down in the welding schedule.

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5 See Stahl-Eisen-Werkstoffblatt 088 "Weldable fine-grained structural steels: instructions for use with special attention to welding" issued by the German Iron and Steel Association.

6 Regulations for the use and working of thermo-mechanically rolled (TM) steels issued by Germanischer Lloyd.

7 Determination of heat input (energy applied per unit length of weld) "E":

$$E = \frac{U\,[\text{volts}] \cdot I\,[\text{amps}] \cdot \text{welding time}\,[\text{min}] \cdot 6}{\text{length of weld}\,[\text{mm}] \cdot 100} \left[\frac{\text{kJ}}{\text{mm}}\right]$$

**9.4** Special attention is to be paid to the generally more sensitive hardening properties and the increased notch sensitivity of higher-strength steels, and especially of high-strength fine-grained structural steels. Unnecessary arc strikes on the surface of the plate, scarring of exposed edges, etc. are to be avoided at all costs. Where necessary, such blemishes shall be cleanly ground out and inspected for incipient cracks. The same applies analogously to auxiliary welds.

**9.5** Additional thermal treatments involving a high heat input (e.g. flame gouging and flame straightening) shall not impair the properties of the materials and welded joints and shall, if necessary, be avoided completely. In doubtful cases, proof of the satisfactory performance of thermal treatments may be demanded.

***Note:***

*Standard flame straightening carried out on higher-strength hull structural steels up to and including E 36 may generally be regarded as acceptable provided that the straightening temperature does not exceed 700 °C and that localized overheating or heating of the whole area over a longer period of time (e.g. using heating blocks) and abrupt cooling (e.g. with water) are avoided. The same applies in analogous manner to the flame straightening of thermo-mechanically rolled (TM) steels. Prior to flame straightening of high-strength (quenched and tempered) fine-grained structural steels, special agreement with the steel manufacturer is required. Cf. also SEW 088* [5].

## 10. Welding of stainless and clad steels

**10.1** During the entire construction period, suitable measures shall be taken in transport, storage and fabrication to keep the surface of stainless steels free from impurities and extraneous metallic inclusions (due to abrasion from other components or auxiliary erection supports).

**10.2** Welding processes and welding consumables shall be selected with due regard to strength and corrosion aspects, taking into account the recommendations of the makers of the steel and the welding consumables. Unalloyed welding consumables may not be used for welding stainless steels.

**10.3** Edges are to be prepared mechanically by cutting or planing. Where a thermal cutting technique such as plasma cutting has to be employed, the edges shall subsequently be machined clean.

**10.4** Clad plates shall invariably be tack-welded on the "black" side of the support material. Back-up plates are to be used sparingly and must be made of the material to which they are to be welded.

**10.5** On the side of the cladding and at the corner joints of clad plates (as in the case of drain wells), at least two layers of stainless weld metal are to be laid down over the support material (cf. G.10.1.6). Where necessary, different welding consumables shall be used for the intermediate and final runs depending on the base material.

**10.6** Fused weld spatter is to be avoided for reasons of corrosion. Such fusion can be prevented by applying suitable media (e.g. milk of lime) to the surface of the plate on both sides of the weld. Where necessary, weld spatter is to be machined off and the area ground smooth.

**10.7** To achieve corrosion-resistant seams, post-weld treatment (pickling or passivation) shall be carried out in accordance with the instructions issued by the steelmaker or the manufacturer of the welding consumables.

## 11. Welding of steel castings and forgings

**11.1** With steel castings and forgings of large section, difficult welding or structural conditions, heavily distorted members and low workpiece temperatures, a sufficient area surrounding the welded joint shall be uniformly preheated throughout the section.

**11.2** Welding operations on steel castings and forgings shall be performed continuously and without interruption, if possible in a single heating cycle. Cooling shall take place gradually and appropriate measures shall be taken to prevent over-rapid cooling (screening, wind protection).

**11.3** Repair welds (production welds) on steel castings and forgings may only be undertaken with the Surveyor's consent. Where the work concerned is relatively extensive, sketches and a description of the repair shall be submitted to the Society's head office for approval, together with details of the welding process, welding consumables and auxiliary materials, heat treatment and composition of the base material.

**11.4** The Society may stipulate stress relief heat treatment or, in special cases, normalizing heat treatment of the components after welding (e.g. for rudderstocks). The preliminary remark to Chapter 1, Section 5, B. applies in analogous manner to the necessary proof of the properties of the welded joint in heat-treated condition.

**11.5** Welds uniting hull structural steels or comparable forged or cast steels on the one hand to austenitic stainless steels on the other may not be heat-treated. The same applies in analogous manner to build-up welds made with austenitic stainless welding consumables (e.g. on rudderstocks, pintles, etc.). Any post-weld heat treatment which may be required for build-up welds made with other (e.g. heat-treatable) welding consumables shall be specified on a case-by-case basis.

## 12. Welding of aluminium alloys

**12.1** The foregoing provisions relating to the welding of steels apply in analogous manner to the welding of aluminium alloys above and beyond the provisions stipulated in the following paragraphs. Special attention is to be paid to cleanliness, thorough degreasing and the avoidance of extraneous metallic impurities. For the use of various types of steel-aluminium welding transition joints (especially the thermosensitivity of the boundary layer between the steel and aluminium), see Society's working sheets.

**12.2** As a rule, welding grooves are to be thoroughly cleaned (e.g. with solvents and/or brushes) immediately before welding. Tools and equipment shall not be used for working on other materials and shall not themselves leave behind extraneous metallic residues. Welding grooves, welding consumables and auxiliary materials must at all costs be dry before welding begins.

**12.3** Welded joints on aluminium alloy structural components used in shipbuilding shall, wherever possible, be made by inert gas welding (MIG welding, or, possibly, TIG welding for small components) performed in welding bays protected from the weather. The weld pool must be safely shielded by an adequate supply of inert gas. Winds and draughts are to be avoided. Care shall be taken to achieve the optimum welding speed and to minimize the effect of the heat on the base material (softening).

**12.4** To avoid end-crater cracking, especially when making intermittent fillet-welded joints, it is advisable (unless welding equipment with crater-filling devices is used) to retract the bead somewhat prior to withdrawal of the electrode or torch so that the end crater is moved back from the end of the seam to a point on the weld and to fill the crater.

**12.5** Extensive preheating of the faces to 100 °C – 200 °C is recommended when welding thick aluminium alloy plates and sections. The welds are to be executed in a suitable sequence, smoothly and speedily and, if possible, without a break.

**12.6** Cold straightening operations should be performed only by pressing, not by hammering. Hot straightening may only be carried out on alloys suitable for that purpose in accordance with the aluminium producer's instructions. Heating and straightening are to be performed speedily. Temperatures are to be carefully monitored so as to prevent fusion of the material.

## 13. Underwater welding

**13.1** Under certain conditions, the Society may approve the welding (normally fillet welds) of components made of normal-strength hull structural steels which have water behind them. The temperature of the water or component should not be less than 5 °C. The welding point must be dry and clean. At least two passes must be laid down, the last of which shall be run as a "temper bead" over the first pass which has been deposited on the "cooled" component such that it performs a "post-weld heat treatment" function. Welds executed in this manner shall be subjected to a crack test.

**13.2** As a general principle for underwater welding, only those welding processes and/or welding consumables that guarantee a low hydrogen content in the weld metal shall be used. Welding should be performed in a dry environment (chamber pressurized to 1 bar or high-pressure chamber). The above applies in analogous manner to the temperature of the component, the welding point and the crack test. For the required welding procedure tests, see F.

**13.3** Underwater arc welding in which the arc burns in the water or in a small gas vessel and where allowance has to be made for a large amount of hydrogen entering the weld metal may only be used with the explicit authorization of the Society in each individual case (even if welding procedure approval has been granted) and then only for temporary repairs (e.g. sealing welds) to components which are subjected to relatively low loads. Welds executed in this manner shall be replaced by normal welds at the next available opportunity and until such a replacement is made the Society may prescribe restrictions in the operation of the vessel (e.g. in the operating area).

# I. Inspection of Welded Joints

## 1. General

**1.1** In addition to the following provisions, the inspection of welded joints in shipbuilding is governed by the provisions of Chapter 2, Section 4 concerning the preparation and performance of non-destructive weld tests.

**1.2** As stipulated in Chapter 2, Section 4, D., an inspection schedule shall be submitted to the Society for approval before commencing the tests. The Society reserves the right to modify this schedule even after it has been approved, and in particular to extend the scope of the tests and/or change the individual testing positions if necessitated by fabrication operations and/or test results.

**2. Workshop inspections, visual examination**

**2.1** Workshop inspections are to be carefully performed by trained personnel (e.g. welding supervisors, cf. C. and H.2.) to ensure the professionally competent and satisfactory execution (appearance and dimensional accuracy) and the integrity of the welds.

**2.2** After welding operations have been completed and subjected to workshop inspection, the work shall be presented to the Surveyor for checking at suitable stages of fabrication. For this purpose, welds shall be readily accessible and shall normally be uncoated. Wherever possible, the results of non-destructive tests shall be presented at this juncture.

**2.3** Where the previous inspection has been inadequate, the Surveyor may reject components and require that they be presented again after satisfactory workshop inspection and any necessary repair work has been performed.

**3. Non-destructive tests**

**3.1** The necessary weld quality as stipulated in Table 1.9 shall be attested by non-destructive tests, the scope of which shall be at least that specified in 6. Should these tests reveal defects of any considerable extent, the scope of the tests shall be increased. Unless otherwise agreed, tests shall then be performed on two further sections of weld of the same length for every weld section tested and found to be in need of repair. Where it is not certain that a defect is confined to the section of weld under test, the adjoining weld sections shall be additionally tested.

**3.2** The Society may stipulate further tests, especially in the event of doubts as to the professionally competent and satisfactory execution of the welds. For the purpose of monitoring and, where necessary, giving instruction to welders, it is recommended that from time to time radiographic inspections should also be carried out on components which are not subject to regular testing.

**3.3** The method of inspection to be applied in each instance shall be selected with due consideration for the test conditions (shape and dimensions of the weld, nature and location of possible defects, accessibility) so that any defects may be reliably detected. The method of inspection requires the Society's agreement. The Society may stipulate that two or more inspection techniques be used in conjunction.

**3.4** Subject to the provisions of Chapter 2, Section 4, the testing appliances and equipment used shall conform to modern technical practice and the relevant standards. The tests are to be performed by properly qualified and experienced testers. For details of the prescribed proof of qualification of ultrasonic testers see Chapter 2, Section 4, C.1.).

**4. Production specimens**

**4.1** Production specimens, i.e. test pieces welded simultaneously at specified intervals during fabrication, may be called for where the base material, the welding process and/or the loading conditions require proof to be provided that the mechanical or other characteristics of the welded joints made under fabrication conditions are adequate.

**4.2** Production specimens shall be welded and tested in a manner analogous to that prescribed in Chapter 1, Section 4 and in F., as applicable, in connection with welding procedure tests. The scope of the tests and the requirements to be met shall be determined on a case-by-case basis. For production specimens in connection with shop primers, see Chapter 1, Section 6, C.

**5. Leakage tests**

**5.1** Where required, leakage tests on welded seams are normally to be carried out in accordance with the Rules for Classification and Construction, Part 1, Chapter 1 (e.g. Section 8, B.9.; 12, H.24; A.15., or the Rules for Construction of floating docks) prior to the application of any paint or cement.

**5.2** In special cases, and with the approval of the Society, the hydrostatic tests stipulated for the leakage tests may be replaced by other methods (e.g. testing under compressed air or vacuum, gas detection method). The Society may call for such methods as an alternative or in addition to that stipulated.

**6. Weld quality grades, scope of tests, test methods, requirements**

**6.1** According to the nature and severity of the applied loads and their role in ensuring the soundness of the overall structure, welded joints are to be classified by reference to the influencing factors, their materials, design and service environment (e.g. operating temperature) into one of the three weld quality grades shown in Table 1.9 and shall be identified in the inspection schedule.

**6.2** The individual welded joints are to be classified into quality grades according to their position in the component concerned, i.e. their position in relation to the direction of the main stress, as illustrated by the examples cited in Table 1.9. Components and welded joints not mentioned in the Table or in para. 6.5 shall be classified in an analogous manner.

**6.3** The scope of the non-destructive tests to be applied to welded joints with quality grade 1 (radiographic and ultrasonic inspection) shall be determined by the following formula according to the type and construction of the ship. The number "A" of test positions to be determined refers in the first place to radiographs with a (film) length of 480 mm. Where, in accordance with para. 6.10 or 6.11, ultrasonic tests are performed instead of radiographic inspection, 1 metre of weld is to be tested in each case in place of the 480 mm length of film.

$$A = 0{,}8\,A_L \cdot c_P \left(A_B \cdot c_B + A_H \cdot c_H\right)$$

where

$A_L = \dfrac{\mathbf{L}}{16 \cdot a_0}$

**L** = length of ship in [m]

$a_0$ = $\mathbf{L} : 500 + 0{,}48 \le 1{,}0$ in [m]

$c_p$ = 1,5 with transverse frame construction

$c_p$ = 2,0 with mixed transverse and longitudinal frame construction (in the area of the upper and lower girder)

$c_p$ = 2,3 with longitudinal frame construction

$A_B = \dfrac{\mathbf{B}}{2{,}5}$

**B** = breadth of ship in[m]

$c_B$ = 1,0 for single-hull tankers and comparable main frame cross sections

$c_B$ = 1,3 for dry-cargo freighters and bulk carriers

$c_B$ = 1,5 for container ships and double-hull (chemical) tankers

$A_H = \dfrac{\mathbf{H}}{2{,}5}$

**H** = depth of ship in[m]

$c_H$ = 0,5 for dry-cargo freighters

$c_H$ = 1,3 for tankers, container ships and bulk carriers

$c_H$ = 1,5 for double-hull tankers with additional longitudinal bulkheads

**6.4** The number "A" of test positions determined in accordance with para. 6.3 shall be distributed in such a way that roughly two-thirds of the number "A" established are positioned on the welded joints with quality grade 1 described in Table 1.9 and roughly the remaining third on those joints with quality grade 2. Appropriate consideration shall be given to the individual components specified in para. 6.5. Depending on the loading conditions, a different inspection density (a different distribution of the total number of test positions) for the various weld quality grades or components may be expedient or may be demanded by the Society.

**6.5** The welded joints of the particular components listed below are to be classified and tested as follows:

– Deck stringer/sheer strake joint within 0.5 **L** of midship: weld quality grade 1, 100 % ultrasonic inspection if full-penetration welding is required in accordance with G.10.2.1.

– Deck stringer/sheer strake joint outside of 0.5 **L** of midship: weld quality grade 2, 10 % ultrasonic inspection if full-penetration welding is required in accordance with G.10.2.1.

– Joints between horizontal rudder coupling plate and rudder body (cf. Fig. 1.26): weld quality grade 1, 100 % ultrasonic inspection and 100 % surface crack inspection.

– Joints between rudderstock and horizontal coupling plate (cf. Fig. 1.27): weld quality grade 1, 100 % ultrasonic inspection and 100 % surface crack inspection.

– Full-penetration single- and double-bevel T-joints (cf. Fig. 1.13): weld quality grade 1 or 2 depending on position of weld, 100 % or 10 % ultrasonic inspection respectively.

– Restarting points in electroslag or electrogas welds: weld quality grade 1 or 2 depending on position of weld, 100 % radiography or ultrasonic inspection, the latter with the test sensitivity increased by 12 dB (see also Chapter 2, Section 4, L.2.5).

– Welds for which proof of fatigue strength is required: weld quality grade and inspection depend on detail category (cf. catalogue of notch categories, Rules for Construction of Seagoing Ships, Chapter 1, Section 20, A.3. and Table 20.3).

**6.6** In the case of ships for which no special proof of (longitudinal) strength has to be submitted (generally ships less than 65 m long; cf. the Rules for Construction of Seagoing Ships, Chapter 1, Section 5), the number "A" (of test positions) may be reduced to 70 %

of the figure prescribed in para. 6.3 and 6.4. The reduction shall be agreed with the Society in every case and is to be specially indicated in the inspection schedule.

**6.7** Where the conditions of fabrication remain unchanged, i.e. where to a large extent the same welders are employed in welding the same or similar components (e.g. in repetition shipbuilding) by means of the same welding processes, welding consumables and auxiliary materials, the Society's head office may consent to a reduction of the scope of inspection specified in para. 6.3 and 6.4. This is conditional on proof being supplied of uniformly good results and a relatively low incidence of repairs, as attested by the results of all initial inspections performed on welded joints prior to any repairs.

**6.8** Where radiographic inspections are performed randomly, they are to be carried out chiefly at the intersections of longitudinal seams and transverse joints, at sectional joints and at joints presenting difficulty or requiring to be welded in a fixed position. Joints in girders and stiffeners are to be classified similarly to those in plating and are to be included in the inspection.

**6.9** Ultrasonic tests may be performed in place of a proportion (to be specified in every case) of the number of radiographs prescribed in paras. 6.3 and 6.4. For wall and plate thicknesses of 30 mm and over, ultrasonic testing is to be preferred to radiography as a method of inspection.

**6.10** In special cases, ultrasonic tests may be stipulated as an alternative, or additionally, to radiographic inspection, e.g. where certain defects, owing to their nature and location or to the configuration of the weld, cannot be sufficiently reliably detected or assessed by radiography.

**6.11** Surface crack inspections shall generally be carried out following the welding of large sections, particularly those of steel castings and forgings as well as in the case of welds made under stress or at low temperatures, large-volume single- or double-bevel welds (plate thicknesses of about 30 mm and over) and thick fillet welds, e.g. on stern posts, after welding-in of masts and welds on bulkhead stools.

**6.12** For the inspection of particular components and their welded joints, see 6.5. The Society may, in addition, call for further tests in conjunction with the approval of drawings.

**6.13** Welded joints and components not covered by the foregoing provisions shall undergo non-destructive tests whose scope shall be specified in each individual case. Where certain components (e.g. the masts of cargo handling gear, liquefied gas tanks and the pressure hulls of underwater vehicles) are governed by special rules or codes of practice, the provisions contained in these shall be implemented.

**Table 1.8 Weld quality grades, scope of inspection, requirements**

| **Weld quality grade** | **1** | **2** | **3** |
|---|---|---|---|
| Loading, importance | Welded joints which are subjected to severe static or mainly dynamic stresses and/or which are essential to the soundness of the overall structure. | Welded joints which are subjected to medium stresses and/or whose failure entails the loss of function of individual components without endangering the structure as a whole. | Welded joints which are subjected to minor stresses and/or whose failure does not entail the loss of function of important components. |
| Components, position of welded joints (for individual details relating to particular components and welded joints, see para. 6.5) | Transverse joints in the area of the upper and lower flange plate [1] within 0,5 **L** of midship [2], e.g. in the outer bottom incl. bilge strake, longitudinal girders, longitudinal frames, strength deck incl. sheer strake. Longitudinal girders and beams, longitudinal bulkheads incl. longitudinal stiffeners, hatchway side coamings incl. longitudinal stiffeners.<br>Joints in shell plating and strength deck in the immediate vicinity of fittings and fixtures (traversing the plate), e.g. rudder heels, masts including the welds uniting them to the first-named items. Joints in the flanges and webs of main girders, e.g. in hatchway covers, hatch or cantilever girders and in cantilever masts. Joints in tank bulkheads and the bottom structures of bulk carriers including the bulkhead stools.<br>Joints in or on components subjected mainly to dynamic loads, e.g. shaft struts, rudder heels, rudder couplings, (connecting them to the rudder body) and the main girders of engine beds. | Longitudinal bulkheads [3] in the area of the upper and lower hull flange plate, transverse joints in the area outside 0,5 **L** of midship [2], and joints in the rest of the shell plating and in the double bottom.<br>Joints in watertight transverse bulkheads of dry-cargo freighters and in web frames.<br>Joints in hatchway covers, end bulkheads of super-structures and deckhouses, and joints in transverse girders. | Joints in subordinate components such as decks, partitions and their stiffeners not included in the main strength structure, decks of super-structures and deckhouses, joints in bulwarks, etc. |

**Table 1.9 Weld quality grades, scope of inspection, requirements *(continuous)***

| **Weld quality grade** | **1** | **2** | **3** |
|---|---|---|---|
| Scope and method of inspection | Visual inspection and random dimensional checks.<br>Non-destructive tests in accordance with 6. (random checks with greater intensity of inspection).<br>Leakage and other tests, where required. | Visual inspection, random dimensional checks in cases of doubt.<br>Non-destructive tests in accordance with 6. (random checks with lesser intensity of inspection).<br>Leakage and other tests, where required. | Visual inspection<br>In cases of doubt, non-destructive tests in accordance with 6.<br>Leakage and other tests, where required. |
| Requirements, weld quality [4] | Welded seams to be free from cracks, lack of fusion and root defects, slag lines, coarse pore clusters and slag inclusions, prominent undercuts, etc. in conformity with assessment category B in accordance with EN 25871/ISO 5817 relating to steel (Annex A of Chapter 2) and EN 30042/ ISO 10042 relating to aluminium (Annex B of Chapter 2), as applicable.) [5] | Welded seams to be free from cracks, major lack of fusion and root defects, long slag lines, coarse slag inclusions, uninterrupted pores, coarse pore clusters, major undercuts, etc. in conformity with assessment category C in accordance with EN 25817/ISO 5817 relating to steel (Annex A of Chapter 2) and EN 30042/ISO 10042 relating to aluminium (Annex B of Chapter 2), as applicable.[5] | Welded seams to be free from cracks, major root defects and slag inclusions, uninterrupted pores, severe undercutting, etc. in conformity with assessment category D in accordance with EN 25817/ISO 5817 relating to steel (Annex A of Chapter 2) and EN 30042/ISO 10042 relating to aluminium (Annex B of Chapter 2), as applicable.[5] |

[1] In accordance with the Rules for Construction of Seagoing Ships, Chapter 1, Section 3, B., this is the area extending to at least 0.1 **H** and 0.1 **H'** above and below respectively. The inspection shall, however, invariably cover the entire sheer strake and bilge strake area together with continuous longitudinal members (e.g. hatchway side coamings and crane rails) above the strength deck. Where partial use is made of higher-strength steel, the inspection shall embrace the whole area of this steel in terms of height, and in the case of container ships and similar vessels it shall cover the entire area of the upper box girders.

[2] In ships with large deck openings, i.e. ships with large hatches (such as container ships), the transverse joints in the upper hull girder flange fore and aft of 0.5 **L** (generally the entire hatchway area) shall also be assigned to weld quality grade 1 where necessary (e.g. because of the torsional stresses imposed).

[3] At weld intersections the adjoining 300 mm of longitudinal seam are to be classified identically with the relevant transverse joints.

[4] See also the note to H.3.3.2. Comparable provisions contained in other standards, etc., may also be used for assessment purposes, subject to the Society's consent.

Where components or welded joints have been dimensioned according to fatigue strength criteria on the basis of a specific detail category $\Delta\sigma_R$ (see Rules for Construction of Seagoing Ships, Chapter 1, Section 20, Table 20.3), the quality grade must also meet the requirements of this detail category. Code of practice 0705 issued by the Deutscher Verband für Schweißtechnik e.V. [German Welding Society] contains instructions for the classification of individual irregularities in correlation to the assessment groups in conformity with EN 25817/ISO 5817 relating to steel.

[5] With regard to the requirements for ultrasonic testing, see Chapter 2, Section 4, L.5 (Table 4.4).