# Requirements concerning MATERIALS AND WELDING

# CONTENTS

# W1 Material and welding for gas tankers

(1975)
(Rev. 1 1984)
(Rev.2 May 2004)

## W1.1 General

W1.1.1 The present texts give the general principles which are applied by Classification Societies for approval and survey of the relevant items of liquefied gas tankers for classification purposes. They do not intend to cover full details of such approval and survey procedures which are to be found in the individual Rules of Classification Societies.

W1.1.2 Where appropriate, these Rules refer to the basic tank types which are defined under G1 & 2 differing from these definitions will be the subject of special consideration.

W1.1.3 Consideration of future technical advances may warrant modifications to the principles and details set forth in the text. IACS will accordingly review continuously these requirements.

W1.1.4 When reference is made in these Rules to "Classification Society," only members or associates of IACS are considered.

## W1.2 Scope

W1.2.1 This document gives the requirements for plates, sections, pipes, forgings, castings and weldments used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping and secondary barriers. This document also gives the requirement for plates and sections of hull structural steels which are subject to reduced temperature due to the cargo and which are not forming part of secondary barrier. (See G1 para. G1.9.1 and G1.9.4).

The requirements for rolled products, forgings and castings are given in Tables 1-5. The requirements for weldments are given in W1.4.

W1.2.2 The manufacture, testing, inspection and documentation are to be in accordance with the general practice of the Classification Society and the specific requirement given in this document.

W1.2.3 Acceptance tests are to include Charpy V-notch toughness tests unless otherwise approved. The specified Charpy V-notch requirements are minimum average energy values for three full size (10mm x 10mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens are to be in accordance with the requirements of W2. The testing of sub-size specimens is to be in accordance with UR W2.

In all cases, the largest size Charpy specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface. (See Fig. 1 for weld test specimens).

**W1** cont'd

The re-testing of Charpy specimens is to be in accordance with UR W2.

At the discretion of the Classification society, other types of toughness tests, e.g., drop weight test, may be used. These may be either in addition to or in lieu of the Charpy V-notch test.

W1.2.4 Tensile strength, yield stress and elongation are to be approved by the Classification Society.

For carbon-manganese steel and other materials with definitive yield points, consideration is to be given to the limitation of the yield to tensile ratio.

W1.2.5 The bend test may be omitted as a material acceptance test, but is required for weld tests.

W1.2.6 Materials with alternative chemical composition or mechanical properties may be accepted by special agreement with the Classification Society.

W1.2.7 Where postweld heat treatment is specified or required the properties of the base materials are to be determined in the heat treated condition in accordance with the applicable table and the weld properties are to be determined in the heat treated condition in accordance with W1.4. In cases where a postweld heat treatment is applied the test requirements may be modified at the discretion of the Classification Society.

W1.2.8 Where reference is made to hull structural steels, the requirements of W11 for appropriate grades apply.

### W1.3 Material requirements

**Table 1 Plates, pipes (seamless and welded), (1) sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.**

| | | |
|---|---|---|
| CHEMICAL COMPOSITION AND HEAT TREATMENT | | |
| CARBON-MANGANESE STEEL | | Fully killed |
| Fine grain steel where thickness exceeds 20 mm. | | |
| Small additions of alloying elements by agreement with the Classification Society. | | |
| Composition limits to be approved by the Classification Society. | | |
| Normalized, or quenched and tempered.(2) | | |
| TENSILE AND (IMPACT) TEST REQUIREMENTS | | |
| PLATES | Each "piece" to be tested. | |
| SECTIONS AND FORGINGS | Batch test. | |
| TENSILE PROPERTIES | Specified minimum yield stress not to exceed 410 $N/mm^2$(3) | |
| CHARPY V-NOTCH TEST | Transverse test pieces. Minimum average energy | |
| PLATES | value E, 27J | |
| SECTIONS AND FORGINGS | Longitudinal test pieces. Minimum average energy value E, 41J | |
| TEST TEMPERATURE | Thickness t (mm) | Test temperature (°C) |
| | $t \leq 20$ | 0 |
| | $20 < t \leq 40$ | -20 |

NOTES
1. For seamless pipes and fittings normal Classification Society practice applies. The use of longitudinally or spirally welded pipes should be specially approved by the Classification Society.
2. A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by the Classification Society.
3. Materials with specified minimum yield stress exceeding 410 $N/mm^2$ may be specially approved by the Classification Society. For these materials, particular attention is to be given to the hardness of the weld and heat affected zone.

**W1**
cont'd

**Table 2 Plates, sections and forgings[1] for cargo tanks, secondary barriers[5] and process pressure vessels for design temperatures below 0°C and down to -55°C. Maximum thickness 25mm[2]**

CHEMICAL COMPOSITION AND HEAT TREATMENT

CARBON-MANGANESE STEEL Fully killed Aluminium treated fine grain steel

Chemical composition (ladle analysis)

| C | Mn | Si | S | P |
|---|---|---|---|---|
| 0.16% max.[3] | 0.70-1.60% | 0.10-0.50% | 0.035% max. | 0.035 % max. |

Optional additions: Alloys and grain refining elements may be generally in accordance with the following.

| Ni | Cr | Mo | Cu | Nb | V |
|---|---|---|---|---|---|
| 0.80% max. | 0.25% max. | 0.08% max. | 0.35% max. | 0.05% max. | 0.10% max. |

Normalized or quenched and tempered[4]

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

| | |
|---|---|
| PLATES | Each "piece" to be tested. |
| SECTIONS | Batch test. |
| CHARPY V-NOTCH TEST | Test temperatures 5°C below the design temperature or -20°C whichever is lower. |
| PLATES | Transverse test pieces. Minimum average energy value E,27J |
| SECTIONS AND FORGINGS[1] | Longitudinal test pieces. Minimum average energy value E,41J |

NOTES:

1. The Charpy V-notch and chemistry requirements for forgings may be specially considered.

2. For material more than 25mm thick, Charpy V-notch tests are to be conducted as follows:

| Material Thickness | Test Temp. |
|---|---|
| $25 < t \leq 30$ mm | 10°C below design temp. or -20°C whichever is lower |
| $30 < t \leq 35$ mm | 15°C below design temp. or -20°C whichever is lower |
| $35 < t \leq 40$ mm | 20°C below design temp. |

The impact energy value shall be in accordance with the table for applicable type of test specimen. For material more than 40mm thick, the Charpy V-notch values should be specially considered.

Material for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C whichever is lower.

3. By special agreement with the Classification Society the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40°C.

4. A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by the Classification Society.

5. Where the secondary barrier is formed by the deck or shell side platings, the material grade required by Table 2 should be carried into the adjacent deck or side shell platings, where applicable, to a suitable extent.

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**W1**
cont'd

Guidance:
For materials exceeding 25mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steel or steels in accordance with Table 3 may be necessary.

**Table 3 Plates, sections and forgings [(1)] for cargo tanks, secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C.[(2)] Maximum thickness 25mm.[(3)]**

| Minimum design temperature (°C) | Chemical composition[(4)] and heat treatment | Impact test temperature (°C) |
|---|---|---|
| -60 | 1.5% nickel steel - normalized | -65 |
| -65 | 2.25% nickel steel - normalized or normalized and tempered[(5)] | -70 |
| -90 | 3.5% nickel steel - normalized or normalized and tempered[(5)] | -95 |
| -105 | 5% nickel steel - normalized or normalized and tempered[(5), (6)] | -110 |
| -165 | 9% nickel steel - double normalized and tempered or quenched and tempered | -196 |
| -165 | Austenitic steels (e.g. types 304, 304L, 316, 316L, 321, and 347) Solution treated [(7)] | -196 |
| -165 | Aluminium alloys; e.g. type 5083 annealed | Not required |
| -165 | Austenitic Fe-Ni alloy. (36% nickel) Heat treatment as agreed | Not required |

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

| | |
|---|---|
| PLATES | Each "piece" to be tested. |
| SECTIONS | Batch test. |
| CHARPY V-NOTCH TEST | |
| PLATES | Transverse test pieces. Minimum average energy value E,27J |
| SECTIONS AND FORGINGS | Longitudinal test pieces. Minimum average energy value E,41J |

NOTES:
1. The impact test required for forgings used in critical applications should be subject to special consideration.

2. The requirements for design temperatures below -165°C are to be specially agreed.

3. For materials 1.5% Ni, 2.25% NI, 3.5% Ni, and 5% Ni, with thickness greater than 25 mm, the impact tests shall be conducted as follows:

| Material Thickness | Test Temp* |
|---|---|
| $25 < t \leq 30$ mm | 10°C below design temp. |
| $30 < t \leq 35$ mm | 15°C below design temp. |
| $35 < t \leq 40$ mm | 20°C below design temp. |

* In no case shall the test temperature be above that indicated in the table.

▶

**W1**
cont'd

The energy value shall be in accordance with the table for the applicable type of test specimen. For material more than 40mm thick, the Charpy V-notch values should be specially considered.

For 9% Ni, austenitic stainless steels, and aluminium alloys, thicknesses greater than 25mm may be used at the discretion of the Classification Society.

4. The chemical composition limits should be approved by the Classification Society.

5. A lower minimum design temperature for quenched and tempered steels may be specially agreed.

6. A specially heat treated, e.g, triple heat treated 5% nickel steel may be used down to -165°C upon special agreement with the Classification Society, provided that the impact tests are carried out at –196°C.
7. The impact test may be omitted subject to agreement with the Classification Society.

**Table 4 Pipes (seamless and welded),[1] forgings[2] and castings[2] for cargo and process piping for design temperatures below 0°C and down to -165°C.[3] Maximum thickness 25mm**

| Minimum design temperature (°C) | Chemical composition[5] and heat treatment | Impact test<br>Test temperature (°C) | Minimum average energy E (J) |
|---|---|---|---|
| -55 | Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed[6] | See Note 4 | 27 |
| -65 | 2.25% nickel steel. Normalized or normalized and tempered[6] | -70 | 34 |
| -90 | 3.5% nickel steel. Normalized or normalized and tempered[6] | -95 | 34 |
| -165 | 9% nickel steel.[7] Double normalized and tempered or quenched and tempered | -196 | 41 |
| | Austenitic steels, e.g. types 304, 304L, 316, 316L, 321, and 347. Solution treated.[8] | -196 | 41 |
| | Aluminium alloys, e.g. type 5083 annealed | | Not required |
| TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS<br>Each batch tested<br>IMPACT TEST - Longitudinal test pieces | | | |

NOTES:
1. The use of longitudinally or spirally welded pipes should be specially approved by the Classification Society
2. The requirements for forgings and castings may be subject to special consideration.
3. The requirements for design temperatures below -165°C should be specially agreed.
4. The test temperature should be 5°C below the design temperature or -20°C whichever is lower.
5. The composition limits should be approved by the Classification Society.
6. A lower minimum design temperature may be specially agreed for quenched and tempered materials.
7. This chemical composition is not suitable for castings.
8. Impact tests may be omitted subject to agreement with the Classification Society.

**W1** cont'd

**Table 5 Plates and sections for hull structures required by G1.9.1 and G1.9.4**

| Minimum design temperature of hull structure (°C) | Maximum thickness (mm) for steel grades in accordance with W1.2.8 | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | D | E | AH | DH | EH |
| 0 and above (1)<br>-5 and above (2) | Normal practice | | | | | | |
| down to -5 | 15 | 25 | 30 | 50 | 25 | 45 | 50 |
| down to -10 | X | 20 | 25 | 50 | 20 | 40 | 50 |
| down to -20 | X | X | 20 | 50 | X | 30 | 50 |
| down to -30 | X | X | X | 40 | X | 20 | 40 |
| Below -30 | In accordance with Table 2 except that the thickness limitation given in Table 2 and the supplementary requirements for thicker material given in footnote 2 of that Table do not apply. | | | | | | |

NOTES:
"x" means steel grade not to be used.
(1) For the purpose of G1.9.4
(2) For the purpose of G1.9.1

### W1.4 Welding and nondestructive testing

W1.4.1 General

The requirements listed herein are those generally employed for carbon, carbon-manganese, nickel alloy and stainless steels, and may form the basis for acceptance testing of other material. At the discretion of the Classification Society, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

W1.4.2 Welding consumables

Welding consumables intended for welding of liquefied gas tanks are to be approved by the Classification Society, unless otherwise agreed.

Deposited weld metal tests and butt weld tests are required for all welding consumables, unless specially agreed otherwise. The results obtained from tensile and Charpy V-notch impact tests are to be approved by the Classification Society. The chemical composition of the deposited weld metal is to be reported for information and approval.

W1.4.3 Welding procedure tests for cargo tanks and process pressure vessels and secondary barriers

(a) Number and orientation of test assemblies

Procedure tests are required for all butt welds and are to be representative of the following:

(i) Each base material
(ii) Each type of consumable and welding process
(iii) Each welding position

For butt welds in plates, the test assemblies are to be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test is to be approved by the Classification Society. Radiographic or ultrasonic examination may be performed at the option of the fabricator or the Classification Society. Fillet welding procedure tests are to be in accordance with the Classification Society practice. In such cases consumables should be selected which exhibit satisfactory impact properties.

**W1** cont'd

(b) Required tests

The following tests are required from each test assembly:

(i) Cross-weld tensile tests
(ii) Transverse bend tests: they may be face, root or side bends at the discretion of the Classification Society. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.
(iii) One set of three Charpy V-notch impacts are to be made generally at each of the following indications (see Fig. 1):

(1) Centre line of the welds
(2) Fusion line (F.L.)
(3) 1mm from the F.L.
(4) 3mm from the F.L.
(5) 5mm from the F.L.

(iv) Macrosection. Microsection and hardness survey may also be required at the discretion of the Classification Society.

W1.4.4 Test requirements

(a) Tensile tests

Generally tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. It may also be accepted subject to agreement with the Classification Society that the transverse weld tensile strength is not to be less than the specified minimum tensile strength for the weld metal, where the weld metal has lower tensile strength than that of the parent metal. In any case, the position of fracture is to be reported for information.

(b) Bend tests

No fracture after 180° bend over a former diameter of 4t where t is the thickness of the test pieces, unless otherwise specially required or agreed.

(c) Charpy V-notch impact tests

Charpy tests are to be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy E, are to be no less than 27J. The weld metal requirements for subsize specimens and single energy values are to be in accordance with W1.2.3. The results of fusion line and heat affected zone impact tests, minimum average energy E, are to be generally in accordance with the transverse or longitudinal requirements of the base material whichever is applicable and requirements for subsize specimens, minimum average energy E, are to be generally in accordance with W1.2.3. When the material thickness does not permit machining either full size or standard subsize specimens, the testing procedure and acceptance standards are to be approved by the Classification Society.

W1.4.5 Welding procedure tests for piping

Welding procedure tests for piping are required and are to be similar to those detailed for cargo tanks provided in W1.4.3. Unless specially agreed otherwise the test requirements are to be in accordance with W1.4.4.

W1.4.6 Production weld tests

For all cargo tanks and process pressure vessels except for integral and membrane tanks, production tests are generally to be performed for approximately each 50 m of butt weld joints and are to be representative of each welding position. For secondary barriers, the same type production tests as required for cargo tanks are to be performed except that the number of tests may be reduced subject to the agreement with the Classification Society. Tests, other than those specified, may be required for cargo tanks or secondary barriers at the discretion of the Classification Society. ▶

**W1**
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(a) Independent type A and type B and semimembrane tanks

The production tests for independent tanks type A and type B and semimembrane tanks are to include the following tests:

Bend tests and, where required for procedure tests, one set of three Charpy V-notch tests should be made for each 50m of weld.

The Charpy V-notch tests are to be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches should be in the centre of the weld.

The test requirements are the same as the applicable test requirements listed in W1.4.4 except that impact tests that do not meet the prescribed energy requirements (see W1.2.3) may still be accepted, upon special consideration by the Classification Society, by passing a drop weight test. In such cases, two drop weight specimens are to be tested for each set of Charpy specimens that failed and both must show "no break" performance at the temperature at which the Charpy tests were conducted.

(b) Independent type C tanks and process pressure vessels

In addition to those tests listed in (a), for independent type C tanks and process pressure vessels, transverse weld tensile tests are also required.

The test requirements are the same as the applicable test requirements listed in W1.4.4 except that impact tests that do not meet the prescribed energy requirements (see W1.2.3) may still be accepted, upon special consideration by the Classification Society, by passing a drop weight test. In such cases, two drop weight specimens are to be tested for each set of Charpy specimens that failed and both must show "no break" performance at the temperature at which the Charpy tests were conducted.

(c) Integral and membrane tanks

Production tests for integral and membrane tanks are to be in accordance with the requirements of the Classification Society.

W1.4.7 Nondestructive testing

(a) Independent type A and B tanks and semimembrane tanks

(i) For independent type A tanks and semimembrane tanks where the design temperature is equal to or lower than -20°C, and for independent type B tanks regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks are to be 100 percent inspected by radiographic testing.

(ii) For independent type A tanks and semimembrane tanks where the design temperature is higher than -20°C, all full penetration butt welds in way of intersections and at least 10% of the remaining full penetration butt welds of tank structures are to be inspected by radiographic testing.

(iii) In each case, the remaining tank structure, including the welding of stiffeners and other fittings and attachments, is to be examined by nondestructive test methods as considered necessary by the Classification Society.

(iv) All testing procedures and acceptance standards are to be approved by the Classification Society. At the discretion of the Classification Society, an approved ultrasonic testing procedure may be used in lieu or in addition to radiographic testing.

(b) Independent type C tanks and process pressure vessels

Inspection of independent type C tanks and precess pressure vessels is to be carried out in accordance with G 2.8.2(i) or (ii).

(c) Integral and membrane tanks

Special weld inspection procedures and acceptable standards are to be submitted by the designers of integral and membrane tanks for approval by the Classification Society.

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**W1**
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(d) Piping

Inspection of piping is to be carried out in accordance with G3.

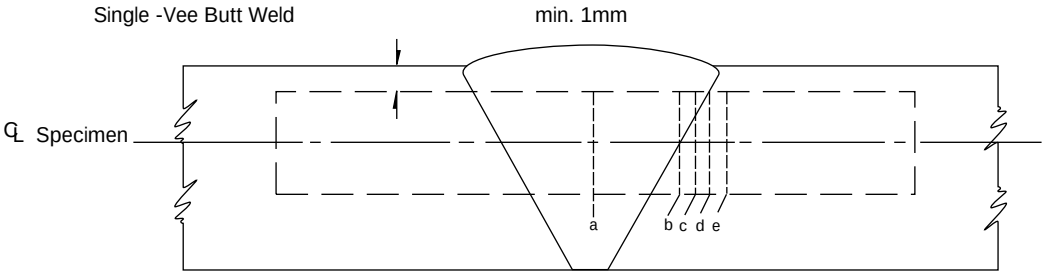
(e) Secondary barriers

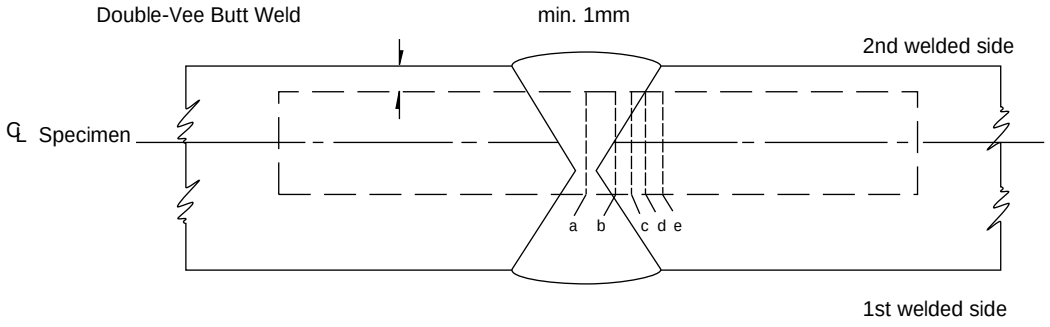
The secondary barrier is to be radiographed as considered necessary. When the outer shell of the hull is part of the secondary barrier, all sheerstrake butts and the intersections of all butts and seams in the side shell are to be examined by radiography.

FIGURE 1

Location of Weld Test Specimen

The largest size Charpy specimens possible for the material thickness are to be machined with the centre of the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. For double-vee butt welds, specimens are to be machined closer to the surface of the second welded side.




Notch location
a Centre of weld
b On fusion line
c In HAZ, 1mm from fusion line
d In HAZ, 3mm from fusion line
e In HAZ, 5mm from fusion line

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# W2 Test specimens and mechanical testing procedures for materials

W2 ( Rev 1 1995) (Rev.2 July 2003)

## W2.1 Scope

W2.1.1 This document gives the requirements for test specimens when testing ferrous and non-ferrous metals.

W2.1.2 The corresponding testing procedures generally are to follow established practice as laid down in international and national standards. Some testing procedures are given in this document.

W2.1.3 Alternative specimens, such as those complying with recognized national standards, may be accepted subject to special approval by the Classification Society. The same applies to the given testing procedures.

## W2.2 General

W2.2.1 Test samples from which test specimens are cut are to have undergone the same treatment as the material from which they have been taken (e.g. heat treatment).

W2.2.2 If test samples are cut from material by flame cutting or shearing, a reasonable margin is required to enable sufficient material to be removed from the cut edges during final machining.

W2.2.3 The preparation of test specimens is to be done in such a manner that test specimens are not subjected to any significants straining or heating.

W2.2.4 Any of the test specimens referred to as 'alternative' may be used except as otherwise stated or agreed.

## W2.3 Testing machines

W 2.3.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be traced to a nationally recognised authority and is to be to the satisfaction of the Classification Society.

Impact testing machines are to be calibrated in accordance with ISO 148-2 or other recognised standard.

The accuracy of tensile test machines is to be within ± one per cent.

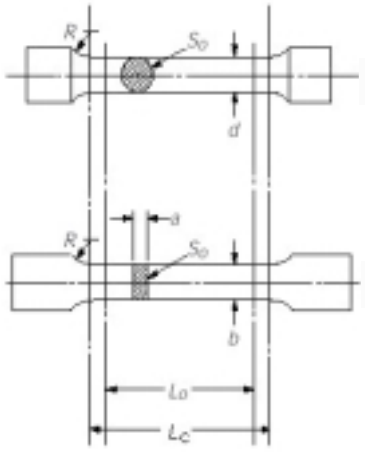
Tension/compression testing machines are to be calibrated in accordance with ISO 7500-1 or other recognised standard.

## W2.4 Tensile test specimens

W2.4.1 Designations

The following designations are used:

$d$ = diameter
$a$ = thicknes
$b$ = width
$L_0$ = original gauge length
$L_c$ = parallel length
$S_0$ = original cross sectional area
$R$ = transition radius
$D$ = external tube diameter
$t$ = plate thickness

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**W2**
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**W2.4.2 Dimensions**

**W2.4.2.1 General**

Proportional test specimens with a gauge length $Lo = 5,65\sqrt{S_0}$

or = 5 d should preferably be used as the minimum percentage elongation values specified in the W Unified Requirements refer to this gauge length, $L_0$ should preferably be greater than 20mm. The gauge length may be rounded off to the nearest 5 mm provided that the difference between this length and Lo is less than 10% of Lo.

**W 2.4.2.2 Plates, strips and sections**

Flat specimens are usually to be used with dimensions as specified below

a) **Proportional flat specimen**

a = t
b = 25 mm
$Lo = 5,65\sqrt{S_0}$
$Lc = Lo + 2\sqrt{S_0}$
R = 25 mm

b) **Non-proportional flat specimen**

a = t
b = 25 mm
Lo = 200 mm
Lc ≥ 212.5 mm
R = 25 mm

When the capacity of the available testing machine is insufficient to allow the use of test specimen of full thickness, this may be reduced by machining one of the rolled surfaces.
Alternatively, for materials over about 40 mm thick, proportional round test specimens with dimensions as specified below, may be used.

c) **Round specimen**

d ≥ 10 mm to 20 mm, preferably 14 mm
*Lo = 5d*
$Lc \geq Lo + \frac{d}{2}$
R = 10 mm (for nodular cast iron and materials with a specified elongation less than 10%, R ≥ 1,5 d)

The axes of the round test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.

**W2.4.2.3 Aluminium Alloys**

Flat tensile test specimens shall be used for specified thicknesses up to and including 12.5mm. The tensile test specimen shall be prepared so that both rolled surfaces are maintained. For thicknesses exceeding 12.5mm, round tensile test specimens will be used. For thicknesses up to and including 40mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from the surface equal to half of the thickness. For thicknesses over 40mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from one of the surfaces equal to one quarter of the thickness.

**W2.4.2.4Forgings, castings (excluding grey cast iron)**

Proportional round test specimens with dimensions as specified above in W2.4.2.2.c) are usually to be used.
For small size bars and similar products the test specimens may consist of a suitable length of bar or other product tested in the full cross-section. ▶

**W2**
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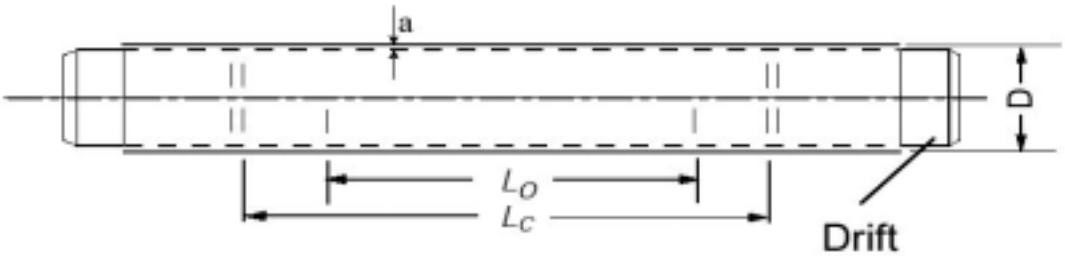
**W2.4.2.5 Tubes**

The test specimen shall conform with the following :

a) full cross-section specimen with plugged ends :

$$Lo = 5,65\sqrt{S_0}$$

$Lc \geq 5,65\sqrt{S_o} + \frac{D}{2}$ where Lc is the distance between the grips or the plugs, whichever is the smallest.

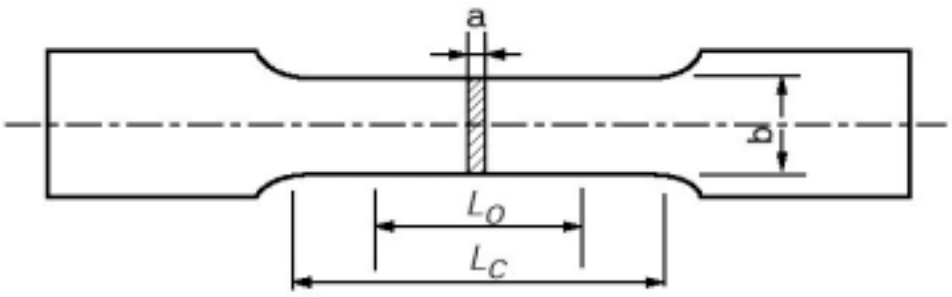



b) Strips cut longitudinally
a = t
b ≥ 12 mm

$$Lo = 5,65\sqrt{S_0}$$

*Lc = Lo + 2b*

The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.




Round test specimens may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions given in W.2.4.2.2.c), with their axes located at the mid-wall thickness.

W2
cont'd

**W2.4.2.6 Wires**

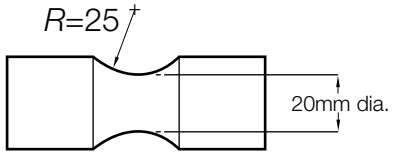
Full cross-section test specimen with the following dimension is to be used:

Lo = 200 mm

Lc = Lo + 50 mm

**W2.4.2.7 Grey cast iron**

Round non-cylindrical machined test specimen as shown below is to be used.




**W2.4.2.8 Weldments**

a) Deposited metal tensile test

Round specimen with the following dimensions is to be used :

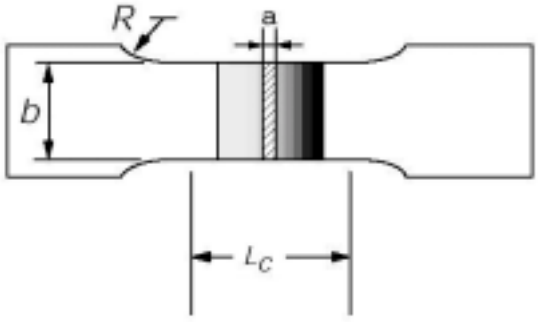
d = 10 mm
Lo = 50 mm
Lc ≥ 55 mm
R ≥ 10 mm

For specially small or large dimensions other specimens may be used after agreement with the Classification Society, provided they conform with the geometrical relationship given in W2.4.2.2.c).

b) Butt weld tensile test

Flat specimen, the weld to be machined (or ground) flush with the surface of the plate, with the following dimensions is to be used :

a = t
b = 12 for t≤2
b = 25 for t>2
Lc = width of weld + 60 mm
R > 25 mm



W2
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**W2.4.2.9 Through thickness tensile test specimen**

Round test specimens including built-up type by welding are to be prepared in accordance with a recognised standard.

**W2.4.2.10 Tolerances**

The tolerances on specimen dimensions are to be in accordance with ISO 6892-98 or other recognised standards as appropriate.

**W 2.4.3 Retest Procedure**

When the tensile test fails to meet the requirements, two further tests may be made from the same piece. If both of these additional tests are satisfactory the item and/or batch (as applicable) is acceptable. If one or both of these tests fail the item and/or batch is to be rejected.

The additional tests detailed above are to be taken, preferably from material taken adjacent to the original tests, but alternatively from another test position or sample representative of the item/batch.

W2
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## W2.5 Tensile properties at ambient temperature

### W2.5.1 Yield stress (yield point)

The value of stress measured at the commencement of plastic deformation at yield, or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield. The test is to be carried out with an elastic stress within the following limits:

| Modulus of Elasticity of the material (E) N/mm$^2$ | Rate of stressing N/mm$^2$s$^{-1}$ | |
|---|---|---|
| | Min. | Max. |
| < 150 000 | 2 | 20 |
| ≥ 150 000 | 6 | 60 |

### W2.5.2 Proof stress (yield strength)

When no well defined yield phenomenon exists, the 0.2% proof stress (*Rp0.2*) is to be determined according to the applicable specification. For austenitic and duplex stainless steel products, the 1% proof stress (*Rp1*) may be determined in addition to *Rp 0.2*.
The rate of loading shall be as stated in W2.5.1 above.

### W2.5.3 Tensile strength ($R_m$)

After reaching the yield or proof load, for ductile material the machine speed during the tensile test is not to exceed that corresponding to a strain rate of 0.008s$^{-1}$. For brittle materials, such as cast iron, the elastic stress rate is not to exceed 10 N/mm$^2$ per second.

### W2.5.4 Fracture elongation (*A*)

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one third of the original gauge length. However the result is valid irrespective of the location of the fracture if the percentage elongation after fracture is equal to or greater than the expected value.

The elongation generally means elongation $A_5$ determined on a proportional gauge length $5.65\sqrt{So} = 5d$ but may also be given for other specified gauge lengths.

If the material is a ferritic steel of low or medium strength and not cold worked and the elongation as measured on a non-proportional gauge length, the required elongation $A_0$ on that gauge length $L_0$ may after agreement be calculated from the following formula:

$$A_0 = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0,40}$$

For tables and graphs see ISO/DIS 2566.

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**W2**
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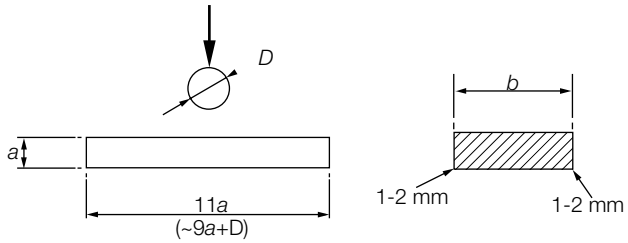
## W2.6 Bend test specimen

W2.6.1 Flat bend test specimen, as given in the following, is to be used. Edges on tension side to be rounded to a radius of 1 to 2 mm.




W2.6.2 Forgings, castings and semi-finished products

a = 20 mm
b = 25 mm

W2.6.3 Plates, structural sections, sheets:
*a* = *t*
*b* = 30 mm

W2.6.4 Butt welds, transverse specimen

a) face and root bend
*a* = *t*
*b* = 30 mm

If the as rolled thickness *t* is greater than 25 mm, it may be reduced to 25mm by machining on the compression side of the bend specimen.

The surfaces of the weld are to be machined (ground) flush with the surface of the plate.

b) side bend

*a* = 10 mm
*b* = *t*

If $t \geq 40$ mm , the side-bend specimen may be subdivided, each part being at least 20 mm wide.

W2.6.5 Butt weld, longitudinal specimens

The test specimens, for longitudinal face and root test, are to be in accordance with an appropriate recognised standard.

W2
cont'd

## W2.7 Toughness testing

### W2.7.1 Charpy V-notch impact specimens

The test specimens shall comply with the following dimensions:

| Dimensions | Nominal | Tolerances |
|---|---|---|
| Length | 55 mm | ± 0,60 mm |
| Width -standard specimen | 10 mm | ±0,11 mm |
| -subsize specimen | 7,5 mm | ±0,11 mm |
| -subsize specimen | 5 mm | ±0,06 mm |
| Angle of notch | 45° | ±2° |
| Thickness | 10 mm | ±0,06 mm |
| Depth below notch | 8 mm | ±0,06 mm |
| Root radius | 0,25 mm | ±0,025 mm |
| Distance of notch from end of test specimen | 27,5 mm | ±0,42 mm |
| Angle between plane of symmetry of notch and longitudinal axis of test specimen | 90° | ±2° |

### W2.7.2 Sub size Charpy requirements

The testing and requirements for smaller than 5,0mm size specimens are to be in accordance with the general practice of the Classification Society. Minimum average values for subsized specimens are as follows:

| Charpy V-notch specimen size | Minimum energy, average of 3 specimens |
|---|---|
| 10 mm x 10 mm | E |
| 10 mm x 7,5 mm | 5E/6 |
| 10 mm x 5,0 mm | 2E/3 |

E = the values of energy specified for full thickness 10 mm x 10 mm specimens

All other dimensions and tolerances are to be as specified in W2.7.1.

Only one individual value may be below the specified average value provided it is not less than 70% of that value.

In all cases, the largest size Charpy specimens possible for the material thickness shall be machined.

### W2.7.3 Testing machines and temperature control in Charpy V-notch impact testing

All impact tests are to be carried out on Charpy machines complying with the requirements of ISO 148 or other national and international recognised standards, and having a striking energy of not less than 150 J.

Where the test temperature is other than ambient the temperature of the test specimen at the moment of breaking shall be the specified temperature within ±2°C.

### W2.7.4 Charpy re-test procedure

Where specified the following Charpy re-test procedure will apply:

When the average value of the three initial Charpy V-notch impact specimens fails to meet the stated requirement, or the value for more than one specimen is below the required average value, or when the value of any one specimen is below 70% of the specified average value, three additional specimens from the same material may be tested and the results added to those previously obtained to form a new average. If this new average complies with the requirements and if not more than two individual results are lower than the required average and of these, not more than one result is below 70% of the specified average value the piece or batch (as specified for each product) may be accepted.

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W2
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### W2.7.5 Dropweight specimens

Dropweight specimens for determination of no–break performance according to ASTM specification (E-208) are to comply with this ASTM standard and have one of the following dimensions (mm):

| | |
|---|---|
| Type P-1: | 25 by 90 by 360 |
| Type P-2 | 19 by 50 by 130 |
| Type P-3 | 16 by 50 by 130 |

The following is to be noted if not otherwise specified:
the specimen sides shall be saw-cut or machined (minimum 25 mm to flame-cut surface)
the machining of the plate to prescribed specimen thickness shall be on one side only
the specimens may be of any orientation, but the orientation shall be the same for all specimens.

## W2.8 Ductility tests for pipes and tubes

### W2.8.1 Flattening test specimens

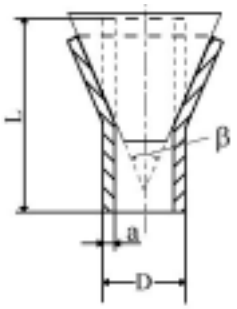
Length is to be from 10mm to 100mm. Plain and smoothed ends cut perpendicular to the tube axis. Reference is made to ISO 8492.

### W2.8.2 Drift expanding test

The lengths *L* of the drift expanding test specimens are to be as follows.
Reference is made to ISO 8493.

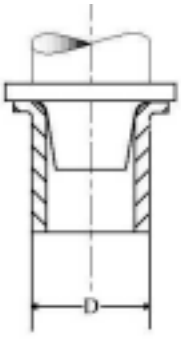
*Metallic tubes*: *L* equal to twice the external diameter *D* of the tube if the angle of the drift $\beta$ is 30°, and *L* equal to 1.5*D* if the angle of the drift is 45° or 60°. The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5D.

The rate of penetration of the mandrel shall not exceed 50mm/min.




### W2.8.3 Flanging test

The flanging test specimen is to be of length *L* equal to approximately 1.5D. The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0,5*D*.
The rate of penetration of the forming tool shall not exceed 50mm/min.
Reference is made to ISO 8494.

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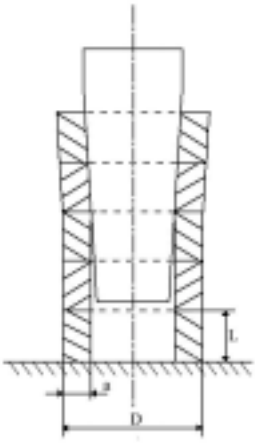
### W2.8.4 Ring expanding test

The test piece consists of a ring having a length of between 10 and 16 mm. The rate of penetration of the mandrel shall not exceed 30mm/s. Reference is made to ISO 8495.




### W2.8.5 Ring tensile test

The ring shall have a length of about 15mm with plain and smoothed ends cut perpendicular to the tube axis.
The ring is to be drawn to fracture by means of two mandrels placed inside the ring and pulled in tensile testing machine. The rate shall not exceed 5mm/s.
Reference is made to ISO 8496.

# W3 Deleted

- due to being superseded by a new UR W2 (Rev. 1, 1995) “Test specimens and mechanical testing procedures for materials”. ◀◀

# W4 Deleted

◀◀

# W5 Deleted

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# W6 Deleted

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# W7 Hull and machinery steel forgings

(1978) (Rev.1 1980) (Rev.2 July 2002) (Rev.3 May 2004)

**W7.1 Scope**

W7.1.1 These requirements are applicable to steel forgings intended for hull and machinery applications such as rudder stocks, pintles, propeller shafts, crankshafts, connecting rods, piston rods, gearing, etc. Where relevant, these requirements are also applicable to material for forging stock and to rolled bars intended to be machined into components of simple shape.

W7.1.2 These requirements are applicable only to steel forgings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary especially when the forgings are intended for service at low or elevated temperatures.

W7.1.3 Alternatively, forgings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or are otherwise specially approved or required by the Classification Society.

W7.1.4 (void)

**W7.2 Manufacture**

W7.2.1 Forgings are to be made at a manufacturer approved by the Classification Society.

W7.2.2 The steel used in the manufacture of forgings is to be made by a process approved by the Classification Society.

W7.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

W7.2.4 The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation. Unless otherwise approved the total reduction ratio is to be at least:

- for forgings made from ingots or from forged blooms or billets, 3:1 where $L>D$ and 1.5:1 where $L\leq D$
- for forgings made from rolled products, 4:1 where $L>D$ and 2:1 where $L\leq D$
- for forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting
- for rolled bars, 6:1.

L and D are the length and diameter respectively of the part of the forging under consideration.

W7.2.5 (void)

W7.2.6 (void)

W7.2.7 For crankshafts, where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by the Classification Society. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

W7.2.8 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel.
For certain components, subsequent machining of all flame cut surfaces may be required.

W7.2.9 When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval. Welding procedure qualification tests may be required.

**W7.3 Quality of forgings**

W7.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their ▶

**W7**
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proper application in service.

**W7.4 Chemical composition**

W7.4.1 All forgings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

W7.4.2 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

W7.4.3 The chemical composition is to comply with the overall limits given in Tables 1 and 2 or, where applicable, the requirements of the approved specification.

W7.4.4 (void)

W7.4.5 At the option of the manufacturer, suitable grain refining elements such as aluminium, niobium or vanadium may be added. The content of such elements is to be reported.

W7.4.6 Elements designated as residual elements in the individual specifications are not to be intentionally added to the steel. The content of such elements is to be reported.

**Table 1** Chemical composition limits [1] for hull steel forgings [6]

| Steel type | C | Si | Mn | P | S | Cr | Mo | Ni | Cu [4] | Total residuals |
|---|---|---|---|---|---|---|---|---|---|---|
| C, C-Mn | 0.23 [2, 3] | 0.45 | 0.30-1.50 | 0.035 | 0.035 | 0.30 [4] | 0.15 [4] | 0.40 [4] | 0.30 | 0.85 |
| Alloy | [5] | 0.45 | [5] | 0.035 | 0.035 | [5] | [5] | [5] | 0.30 | - |

[1] Composition in percentage mass by mass maximum unless shown as a range.
[2] The carbon content may be increased above this level provided that the carbon equivalent (Ceq) is not more than 0.41%, calculated using the following formula:

$$Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (\%)$$

[3] The carbon content of C and C-Mn steel forgings not intended for welded construction may be 0.65 maximum.
[4] Elements are considered as residual elements.
[5] Specification is to be submitted for approval.
[6] Rudder stocks and pintles should be of weldable quality.

**Table 2** Chemical composition limits [1] for machinery steel forgings

| Steel type | C | Si | Mn | P | S | Cr | Mo | Ni | Cu [3] | Total residuals |
|---|---|---|---|---|---|---|---|---|---|---|
| C, C-Mn | 0.65 [2] | 0.45 | 0.30-1.50 | 0.035 | 0.035 | 0.30 [3] | 0.15 [3] | 0.40 [3] | 0.30 | 0.85 |
| Alloy [4] | 0.45 | 0.45 | 0.30-1.00 | 0.035 | 0.035 | Min 0.40 [5] | Min 0.15 [5] | Min 0.40 [5] | 0.30 | - |

[1] Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
[2] The carbon content of C and C-Mn steel forgings intended for welded construction is to be 0.23 maximum. The carbon content may be increased above this level provided that the carbon equivalent (Ceq) is not more than 0.41%.
[3] Elements are considered as residual elements unless shown as a minimum.
[4] Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by the Classification Society.
[5] One or more of the elements is to comply with the minimum content.

W7
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**W7.5 Heat treatment (including surface hardening and straightening)**

W7.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties.

W7.5.2 Except as provided in W7.5.7 and W7.5.8 forgings are to be supplied in one of the following conditions:

(a) Carbon and carbon-manganese steels
Fully annealed
Normalized
Normalized and tempered
Quenched and tempered

(b) Alloy steels
Quenched and tempered

For all types of steel the tempering temperature is to be not less than 550°C. Where forgings for gearing are not intended for surface hardening, lower tempering temperature may be allowed.

W7.5.3 Alternatively, alloy steel forgings may be supplied in the normalized and tempered condition, in which case the specified mechanical properties are to be agreed with the Classification Society.

W7.5.4 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings alternative methods of heat treatment will be specially considered by the Classification Society.

Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

W7.5.5 If for any reasons a forging is subsequently heated for further hot working the forging is to be reheat treated.

W7.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for the approval of the Classification Society. For the purposes of this approval, the manufacture may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

W7.5.7 Where induction hardening or nitriding is to be carried out, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

W7.5.8 Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.

W7.5.9 If a forging is locally reheated or any straightening operation is performed after the final heat treatment consideration is to be given to a subsequent stress relieving heat treatment.

W7.5.10 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the surveyor on request.

**W7.6 Mechanical tests**

W7.6.1 Test material, sufficient for the required tests and for possible retest purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging except as provided in W7.6.7 and W7.6.10. Where batch testing is permitted according to W7.6.10, the test material may alternatively be a production part or separately forged. Separately forged test material is to have a reduction ratio similar to that used for the forgings represented.

**W7**
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W7.6.2 For the purpose of these requirements a set of tests is to consist of one tensile test specimen and, when required, three Charpy V-notch impact test specimens.

W7.6.3 Test specimens are normally to be cut with their axes either mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

W7.6.4 Unless otherwise agreed, the longitudinal axis of test specimens is to be positioned as follows:

a) for thickness or diameter up to maximum 50mm, the axis is to be at the mid-thickness or the center of the cross section.

b) for thickness or diameter greater than 50mm, the axis is to be at one quarter thickness (mid-radius) or 80mm, whichever is less, below any heat treated surface.

W7.6.5 Except as provided in W7.6.10 the number and direction of tests is to be as follows.

(*a*) *Hull components such as rudder stocks, pintles etc. General machinery components such as shafting, connecting rods, etc.*
One set of tests is to be taken from the end of each forging in a longitudinal direction except that, at the discretion of the manufacture, the alternative directions or positions as shown in Fig. 1, 2 and 3 may be used. Where a forging exceeds both 4 tonnes in mass and 3m in length, one set of tests is to be taken from each end. These limits refer to the 'as forged' mass and length but excluding the test material.

(*b*) *Pinions*
Where the finished machined diameter of the toothed portion exceeds 200mm one set of tests is to be taken from each forging in a tangential direction adjacent to the toothed portion (test position B in Fig. 4). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 4). If however, the journal diameter is 200mm or less the tests are to be taken in a longitudinal direction (test position A in Fig. 4). Where the finished length of the toothed portion exceed 1.25m, one set of tests is to be taken from each end.

(*c*) *Small pinions*
Where the finished diameter of the toothed portion is 200mm or less one set of tests is to be taken in a longitudinal direction (test position A in Fig. 4).

(*d*) *Gear wheels*
One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 5).

(*e*) *Gear wheel rims (made by expanding)*
One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 6). Where the finished diameter exceeds 2.5m or the mass (as heat treated excluding test material) exceeds 3 tonnes, two sets of tests are to be taken from diametrically opposite positions (test positions A and B in Fig. 6). The mechanical properties for longitudinal test are to be applied.

(*f*) *Pinion sleeves*
One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 7). Where the finished length exceeds 1.25m one set of tests is to be taken from each end.

(*g*) *Crankwebs*
One set of tests is to be taken from each forging in a tangential direction.

(*h*) *Solid open die forged crankshafts*
One set of tests is to be taken in a longitudinal direction from the driving shaft end of each forging (test position A in Fig. 8).
Where the mass (as heat treated but excluding test material) exceeds 3 tonnes tests in a longitudinal direction are to be taken from each end (test positions A and B in Fig. 8). Where, however, the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the driving shaft end (test position C in Fig. 8).

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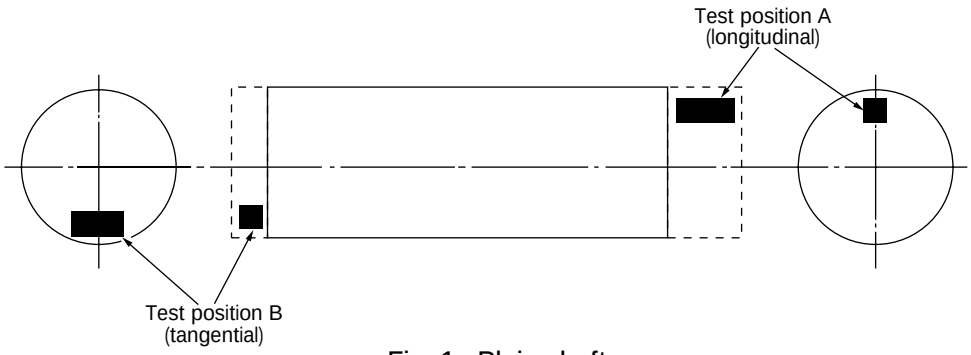


Fig. 1 Plain shaft

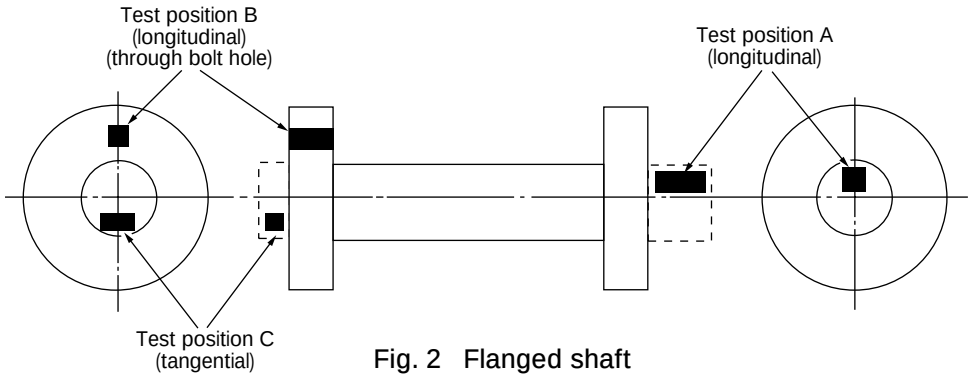


Fig. 2 Flanged shaft

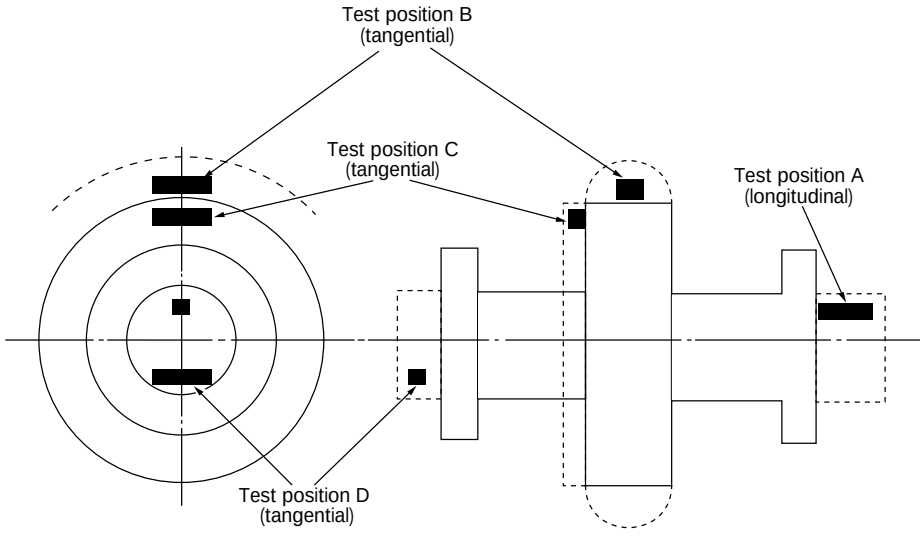


Fig. 3 Flanged shaft with collar

W7.6.6 For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with W7.2.7, the number and position of test specimens is to be agreed with the Classification Society having regard to the method of manufacture employed.

W7.6.7 When a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging.

W7.6.8 Except for components which are to be carburized or for hollow forgings where the ends are to be subsequently closed, test material is not to be cut from a forging until all heat treatment has been completed.

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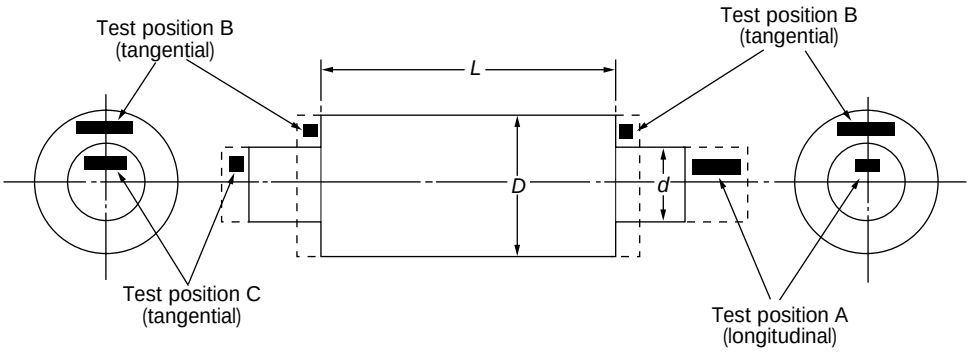


L = length of toothed portion
D = diameter of toothed portion
*d* = journal diameter

Fig. 4 Pinion

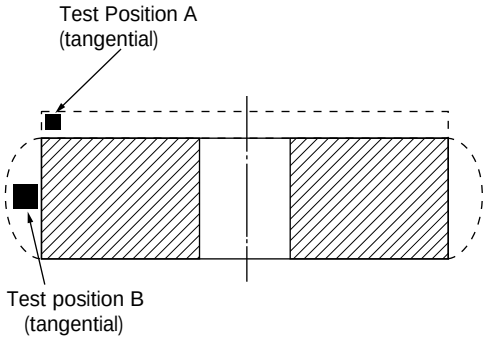


Fig. 5 Gear wheel

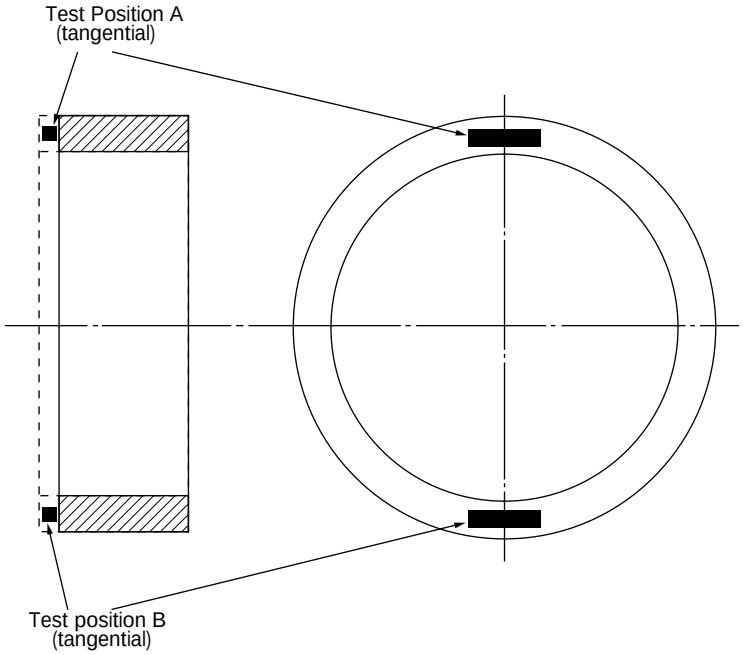


Fig. 6 Gear rim (made by expanding)

**W7**
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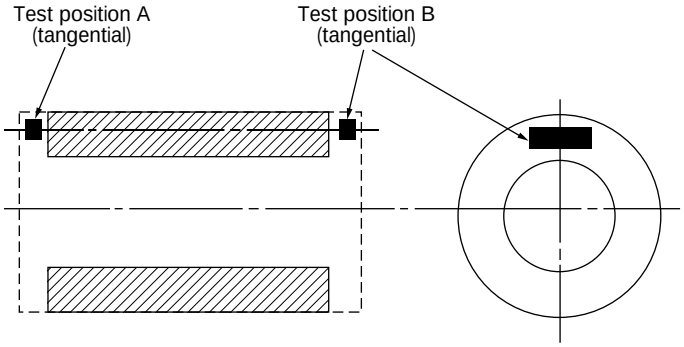


Fig. 7 Pinion sleeve

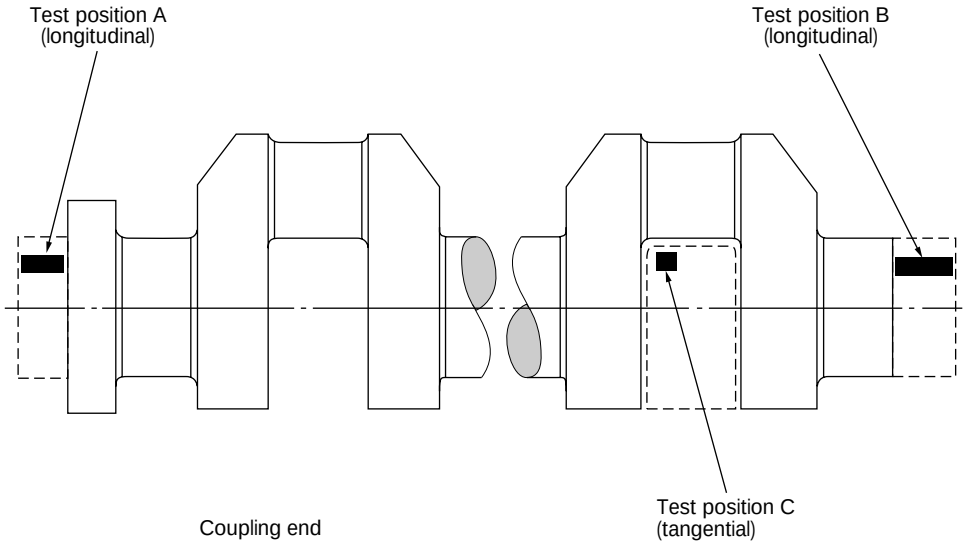


Fig. 8 Solid forged crankshaft

W7.6.9 When forgings are to be carburized, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing.
For this purpose duplicate sets of test material are to be taken from positions as detailed in W7.6.5, except that irrespective of the dimensions or mass of the forging, tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction.
This test material is to be machined to a diameter of $D/4$ or 60mm, whichever is less, where $D$ is the finished diameter of the toothed portion.
For preliminary tests at the forge one set of test material is to be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging.
For final acceptance tests, the second set of test material is to be blank carburized and heat treated along with the forgings which they represent.
At the discretion of the forgemaster or gear manufacture test samples of larger cross section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.
Alternative procedures for testing of forgings which are to be carburized may be specially agreed with the Classification Society.

W7
cont'd

W7.6.10 Normalized forgings with mass up to 1000kg each and quenched and tempered forgings with mass up to 500kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings, respectively.

W7.6.11 A batch testing procedure may also be used for hot rolled bars. A batch is to consist of either:

(i) material from the same rolled ingot or bloom provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge, or

(ii) bars of the same diameter and heat, heat treated in the same furnace charge and with a total mass not exceeding 2.5 tonnes.

W7.6.12 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of W2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyor.

W7.6.13 (void)

### W7.7 Mechanical properties

W7.7.1 Tables 3 and 4 give the minimum requirements for yield stress, elongation, reduction of area and impact test energy values corresponding to different strength levels but it is not intended that these should necessarily be regarded as specific grades. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.

W7.7.2 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 3 or 4 but subject to any additional requirements of the relevant construction Rules.

W7.7.3 The mechanical properties are to comply with the requirements of Tables 3 or 4 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

W7.7.4 (void)

W7.7.5 (void)

W7.7.6 At the discretion of individual Classification Societies hardness tests may be required on the following:

(i) Gear forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2.5m, the above number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1.25m, the hardness is to be determined at eight positions at each end of the forging.

(ii) Small crankshaft and gear forgings which have been batch tested. In such cases at least one hardness test is to be carried out on each forging.

The results of hardness tests are to be reported and, for information purposes, typical Brinell hardness values are given in Table 4.

W7.7.7 (void)

W7.7.8 Hardness tests may also be required on forgings which have been induction hardened, nitrided or carburized. For gear forgings these tests are to be carried out on the teeth after, where applicable, they have been ground to the finished profile. The results of such tests are to comply with the approved specifications (see W7.5.6).

W7.7.9 Re-test requirements for tensile tests are to be in accordance with UR W2.

W7.7.10 Re-test requirements for Charpy impact tests are to be in accordance with UR W2.

**W7** cont'd

W7.7.11 The additional tests detailed in W7.7.9 and W7.7.10 are to be taken, preferably from material adjacent to the original tests, but alternatively from another test position or sample representative of the forging or batch of forgings.

W7.7.12 At the option of the manufacturer, when a forging or a batch of forgings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

**Table** 3 Mechanical properties for hull steel forgings

| Steel type | Tensile strength [1] $R_m$ min. N/mm$^2$ | Yield stress $R_e$ min. N/mm$^2$ | Elongation $A_5$ min. % | | Reduction of area Z min. % | |
|---|---|---|---|---|---|---|
| | | | Long. | Tang. | Long. | Tang. |
| C and C-Mn | 400 | 200 | 26 | 19 | 50 | 35 |
| | 440 | 220 | 24 | 18 | 50 | 35 |
| | 480 | 240 | 22 | 16 | 45 | 30 |
| | 520 | 260 | 21 | 15 | 45 | 30 |
| | 560 | 280 | 20 | 14 | 40 | 27 |
| | 600 | 300 | 18 | 13 | 40 | 27 |
| Alloy | 550 | 350 | 20 | 14 | 50 | 35 |
| | 600 | 400 | 18 | 13 | 50 | 35 |
| | 650 | 450 | 17 | 12 | 50 | 35 |

1) The following ranges for tensile strength may be additionally specified:

| | | |
|---|---|---|
| specified minimum tensile strength: | < 600 N/mm$^2$ | ≥ 600 N/mm$^2$ |
| tensile strength range: | 120 N/mm$^2$ | 150 N/mm$^2$ |

**Table 4** Mechanical properties for machinery steel forgings [2]

| Steel type | Tensile strength [1] $R_m$ min. N/mm$^2$ | Yield stress $R_e$ min. N/mm$^2$ | Elongation $A_5$ min. % | | Reduction of area Z min. % | | Hardness[3] (Brinell) |
|---|---|---|---|---|---|---|---|
| | | | Long. | Tang. | Long. | Tang. | |
| C and C-Mn | 400 | 200 | 26 | 19 | 50 | 35 | 110-150 |
| | 440 | 220 | 24 | 18 | 50 | 35 | 125-160 |
| | 480 | 240 | 22 | 16 | 45 | 30 | 135-175 |
| | 520 | 260 | 21 | 15 | 45 | 30 | 150-185 |
| | 560 | 280 | 20 | 14 | 40 | 27 | 160-200 |
| | 600 | 300 | 18 | 13 | 40 | 27 | 175-215 |
| | 640 | 320 | 17 | 12 | 40 | 27 | 185-230 |
| | 680 | 340 | 16 | 12 | 35 | 24 | 200-240 |
| | 720 | 360 | 15 | 11 | 35 | 24 | 210-250 |
| | 760 | 380 | 14 | 10 | 35 | 24 | 225-265 |
| Alloy | 600 | 360 | 18 | 14 | 50 | 35 | 175-215 |
| | 700 | 420 | 16 | 12 | 45 | 30 | 205-245 |
| | 800 | 480 | 14 | 10 | 40 | 27 | 235-275 |
| | 900 | 630 | 13 | 9 | 40 | 27 | 260-320 |
| | 1000 | 700 | 12 | 8 | 35 | 24 | 290-365 |
| | 1100 | 770 | 11 | 7 | 35 | 24 | 320-385 |

[1] The following ranges for tensile strength may be additionally specified:

| | | |
|---|---|---|
| specified minimum tensile strength: | < 900 N/mm$^2$ | ≥ 900 N/mm$^2$ |
| tensile strength range: | 150 N/mm$^2$ | 200 N/mm$^2$ |

[2] For propeller shafts intended for ships with ice class notation except the lowest one, Charpy V-notch impact testing is to be carried out for all steel types at –10°C and the average energy value is to be minimum 27 J (longitudinal test). One individual value may be less than the required average value provided that it is not less than 70% of this average value.

[3] The hardness values are typical and are given for information purposes only.

**W7**
cont'd

### W7.8 Inspection

W7.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores. Unless otherwise agreed the verification of dimensions is the responsibility of the manufacturer.

W7.8.2 When required by the relevant construction Rules, or by the approved procedure for welded composite components (see W7.2.9) appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer.

The extent of testing and acceptance criteria are to be agreed with the Classification Society. IACS Recommendation No. 68 is regarded as an example of an acceptable standard.

W7.8.3 (void)

W7.8.4 (void)

W7.8.5 When required by the conditions of approval for surface hardened forgings (W7.5.6 refers) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

W7.8.6 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

### W7.9 Rectification of defective forgings

W7.9.1 Defects may be removed by grinding or chipping and grinding provided the component dimensions are acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing.

W7.9.2 Repair welding of forgings except crankshaft forgings may be permitted subject to prior approval of the Classification Society. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for the approval.

W7.9.3 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging repaired. The records are to be presented to the surveyor on request.

### W7.10 Identification of forgings

W7.10.1 The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for so tracing the forgings when required.

W7.10.2 Before acceptance, all forgings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of individual Classification Societies any of the following particulars may be required:

(i) Steel quality.
(ii) Identification number, cast number or other marking which will enable the full history of the forging to be traced.
(iii) Manufacturer's name or trade mark.
(iv) The Classification Society's name, initials or symbol.
(v) Abbreviated name of the Classification Society's local office.
(vi) Personal stamp of Surveyor responsible for inspection.

W7.10.3 Where small forgings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Classification Society.

**W7**
cont'd

### W7.11 Certification

W7.11.1 The manufacturer is to provide the required type of inspection certificate giving the following particulars for each forging or batch of forgings which has been accepted:

(i) Purchaser's name and order number.
(ii) Description of forgings and steel quality.
(iii) Identification number.
(iv) Steelmaking process, cast number and chemical analysis of ladle sample.
(v) Results of mechanical tests.
(vi) Results of non-destructive tests, where applicable.
(vii) Details of heat treatment, including temperature and holding times.

# W8 Hull and machinery steel castings

(1978) (Rev.1 July 2002) (Rev.2 May 2004)

## W8.1 Scope

W8.1.1 These requirements are applicable to steel castings intended for hull and machinery applications such as stern frames, rudder frames, crankshafts, turbine casings, bedplates, etc.

W8.1.2 These requirements are applicable only to steel castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.

W8.1.3 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or are otherwise specially approved or required by the Classification Society.

W8.1.4 Specific requirements are not given for alloy steel castings and where the use of such materials is proposed full details of the chemical composition, heat treatment, mechanical properties, testing, inspections and rectification are to be submitted for approval of the Classification Society.

W8.1.5 (void)

## W8.2 Manufacture

W8.2.1 Castings are to be made at a manufacturer approved by the Classification Society.

W8.2.2 The steel is to be manufactured by a process approved by the Classification Society.

W8.2.3 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

W8.2.4 For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by the Classification Society.

W8.2.5 (void)

W8.2.6 When two or more castings are joined by welding to form a composite component, the proposed welding procedure is to be submitted for approval. Welding procedure qualification tests may be required.

## W8.3 Quality of castings

W8.3.1 All castings are to be free from surface or internal defects, which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

## W8.4 Chemical composition

W8.4.1 All castings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel and the mechanical properties specified for the castings.

W8.4.1 ***bis*** The chemical composition of each heat is to be determined by the manufacturer on a sample ▶

**W8** cont'd

taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

W8.4.2 For carbon and carbon-manganese steel castings the chemical composition is to comply with the overall limits given in Table 1 or, where applicable, the requirements of the approved specification.

**Table 1** Chemical composition limits for hull and machinery steel castings (%)

| Steel type | Applications | C (max.) | Si (max.) | Mn | S (max.) | P (max.) | Residual elements (max.) | | | | Total residuals (max.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Cu | Cr | Ni | Mo | |
| C, C-Mn | Castings for non-welded construction | 0.40 | 0.60 | 0.50 - 1.60 | 0.040 | 0.040 | 0.30 | 0.30 | 0.40 | 0.15 | 0.80 |
| | Castings for welded construction | 0.23 | 0.60 | 1.60 max. | 0.040 | 0.040 | 0.30 | 0.30 | 0.40 | 0.15 | 0.80 |

W8.4.3 (void)

W8.4.4 Unless otherwise required suitable grain refining elements such as aluminium may be used at the discretion of the manufacturer. The content of such elements is to be reported.

W8.4.5 (void)

### W8.5 Heat treatment (including straightening)

W8.5.1 Castings are to be supplied in one of the following conditions:

Fully annealed
Normalized
Normalized and tempered
Quenched and tempered.

The tempering temperature is to be not less than 550°C.

W8.5.2 Castings for components such as crankshafts and engine bedplates, where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be carried out at a temperature of not less than 550°C followed by furnace cooling to 300°C or lower.

W8.5.3 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole casting to be uniformly heated to the necessary temperature. In the case of very large castings alternative methods for heat treatment will be specially considered by the Classification Society. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

W8.5.4 If a casting is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

W8.5.5 The foundry is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

W8
cont'd

### W8.6 Mechanical tests

W8.6.1 Test material, sufficient for the required tests and for possible retest purposes is to be provided for each casting or batch of castings.

W8.6.2 At least one test sample is to be provided for each casting. Unless otherwise agreed these test samples are to be either integrally cast or gated to the castings and are to have a thickness of not less than 30mm.

W8.6.3 Where the casting is of complex design or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test samples are to be provided corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

W8.6.4 For castings where the method of manufacture has been specially approved by the Classification Society in accordance with W8.2.4, the number and position of test samples is to be agreed with the Classification Society having regard to the method of manufacture employed.

W8.6.5 As an alternative to W8.6.2, where a number of small castings of about the same size, each of which is under 1000kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one test sample is to be provided for each batch of castings.

W8.6.6 (void)

W8.6.7 The test samples are not to be detached from the casting until the specified heat treatment has been completed and they have been properly identified.

W8.6.8 One tensile test specimen is to be taken from each test sample.

W8.6.9 (void)

W8.6.10 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of W2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

### W8.7 Mechanical properties

W8.7.1 Table 2 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.

W8.7.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 2 but subject to any additional requirements of the relevant construction Rules.

W8.7.3 The mechanical properties are to comply with the requirements of Table 2 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

W8.7.4 (void)

W8.7.5 Re-test requirements for tensile tests are to be in accordance with UR W2.

W8.7.6 (void)

W8.7.7 The additional tests detailed in W8.7.5 are to be taken, preferably from the same, but alternatively from another, test sample representative of the casting or batch of castings.

W8.7.8 At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

**W8**
cont'd

**Table 2.** Mechanical properties for hull and machinery steel castings

| Specified minimum tensile strength[(1)] ($N/mm^2$) | Yield stress ($N/mm^2$) min. | Elongation on 5,65 $\sqrt{So}$ (%) min. | Reduction of area (%) min. |
|---|---|---|---|
| 400 | 200 | 25 | 40 |
| 440 | 220 | 22 | 30 |
| 480 | 240 | 20 | 27 |
| 520 | 260 | 18 | 25 |
| 560 | 300 | 15 | 20 |
| 600 | 320 | 13 | 20 |

NOTE
**(1)** A tensile strength range of 150 $N/mm^2$ may additionally be specified.

### W8.8 Inspection

W8.8.1 All castings are to be cleaned and adequately prepared for examination; suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

W8.8.2 Before acceptance all castings are to be presented to the Surveyors for visual examination. Where applicable, this is to include the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

W8.8.3 When required by the relevant construction Rules, or by the approved procedure for welded composite components (see W8.2.6.), appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with the Classification Society. IACS Recommendation No. 69 is regarded as an example of an acceptable standard.

W8.8.4 (void)

W8.8.5 (void)

W8.8.6 (void)

W8.8.7 When required by the relevant construction Rules castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence of the Surveyor and are to be to their satisfaction.

W8.8.8 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

### W8.9 Rectification of defective castings

W8 cont'd

#### W8.9.1 General

(i) The approval of the Classification Society is to be obtained where steel castings from which defects were removed are to be used with or without weld repair.

(ii) Procedure of removal of defect and weld repair is to be in accordance with IACS Recommendation No. 69.

(iii) Where the defective area is to be repaired by welding, the excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT.

(iv) Shallow grooves or depressions resulting from the removal of defects may be accepted provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT. Small surface irregularities sealed by welding are to be treated as weld repairs.

(v) The manufacturer is to maintain full records detailing the extent and location of repairs made to each casting and details of weld procedures and heat treatments applied for repairs. These records are to be available to the Surveyor and copies provided on request.

#### 8.9.2 Weld Repairs

When it has been agreed that a casting can be repaired by welding, the following requirements apply:

(i) Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatement and subsequent inspection procedures are to be submitted for approval.

(ii) All castings in alloy steels and all castings for crankshafts are to be suitably pre-heated prior to welding. Castings in carbon or carbon-manganese steel may also require to be pre-heated depending on their chemical composition and the dimensions and position of the weld repairs.

(iii) Welding is to be done under cover in positions free from draughts and adverse weather conditions by qualified welders with adequate supervision. As far as possible, all welding is to be carried out in the downhand (flat) position.

(iv) The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in W8.5.1.

(v) After welding has been completed the castings are to be given either a suitable heat treatment in accordance with the requirements of W8.5.1 or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs .

(vi) Subject to the prior agreement of Classification Society, special consideration may be given to the omission of postweld heat treatment or to the acceptance of local stress-relieving heat treatment where the repaired area is small and machining of the casting has reached an advanced stage.

(vii) On completion of heat treatment the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of non-destructive testing used.

### W8.10 Identification of castings

W8.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyors are to be given full facilities for so tracing the castings when required.

**W8**
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W8.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of individual Classification Societies any of the following particulars may be required:

(i) Steel quality.
(ii) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(iii) Manufacturer's name or trade mark.
(iv) The Classification Society's name, initials or symbol.
(v) Abbreviated name of the Classification Society's local office.
(vi) Personal stamp of Surveyors responsible for inspection.
(vii) Where applicable, test pressure.

W8.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Classification Society.

### W8.11 Certification

W8.11.1 The manufacturer is to provide the required type of inspection certificate giving the following particulars for each casting or batch of castings which has been accepted:

(i) Purchaser's name and order number.
(ii) Description of castings and steel quality.
(iii) Identification number.
(iv) Steel making process, cast number and chemical analysis of ladle samples.
(v) Results of mechanical tests.
(vi) Results of non-destructive tests, where applicable.
(vii) Details of heat treatment, including temperatures and holding times.
(viii) Where applicable, test pressure.

# W9 Grey iron castings

(1978)
(Rev. 1 1995)
(Rev.2 May 2004)

**W9.1 Scope**
**(1978)**

W9.1.1 All major grey iron castings, as defined in the relevant construction Rules, are as be manufactured and tested in accordance with the requirements of the following paragraphs.

W9.1.2 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by the Classification Society.

W9.1.3 Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of the Classification Society.

**W9.2 Manufacture**
**(1978)**

W9.2.1 All major castings are to be made at foundries where the manufacturer has demonstrated to the satisfaction of the Classification Society that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A programme of approval tests may be required in accordance with the procedures of individual Classification Societies.

W9.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

W9.2.3 Where castings of the same type are regularly produced in quantity, the manufacturer is to make any tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

**W9.3 Quality of castings**
**(1978)**

W9.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

**W9.4 Chemical composition**
**(1978)**

W9.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings. When required by individual Classification Societies the chemical composition of ladle samples is to be reported.

**W9.5 Heat treatment**
**(1978)**

W9.5.1 Except as required by W9.5.2 castings may be supplied in either the as cast or heat treated condition.

W9.5.2 For some applications, such as high temperature service or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment.

**W9.6 Mechanical tests**
**(Rev.2 May 2004)**

W9.6.1 Test material sufficient for the required tests and for possible re-tests is to be provided for each casting or batch of castings.

W9.6.2 Separately cast test samples are to be used unless otherwise agreed between the manufacturer and purchaser and generally are to be in the form of bars 30 mm in diamter and of a sutiable length. They are to be cast from the same ladle as the castings in moulds of the same type of material as the moulds for the castings and are not to be stripped from the moulds until the metal temperature is below 500°C. When two or more test samples are cast simultaneously in a single mould, the bars are to be at ▶

W9
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least 50 mm apart as given in Fig. 1.

W9.6.3 Integrally cast samples may be used when a casting is mor ethan 20 mm thick and its mass exceeds 200 Kg, subject to agreement between the manufacturer and the purchaser. The type and location of the sample are to be selected to provide approximately the same cooling conditions as for the casting it represents and also subject to agreement.

W9.6.4 With the exception of 9.6.7, at least one test sample is to be cast with each batch.

W9.6.5 With the exception of 9.6.6, a batch consists of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions. A batch should not normally exceed two tonnes of fettled castings and a single casting will constitute a batch is its mass is 2 tonnes or more.

W9.6.6 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be increased to the output of 2 hours of pouring.

W9.6.7 If one grade of cast iron is melted in large quantities and if production is carefully monitored by systematic checking of the melting process, such as chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals.

W9.6.8 All test samples are to be suitably marked to identify them with the castings which they represent.

W9.6.9 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples the sample shall not be cut off from the casting until after the heat treatment.

W9.6.10 One tensile test specimen is to be prepared from each test sample and for 30mm diameter samples is to be machined to the dimensions given inW.2.4. Where test samples of other dimensions are specially required the tensile test specimens are to be machined to agreed dimensions.

W9.6.11 All tensile tests are to be carried out using test procedures in accordance with W2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

**9.7 Mechanical Properties**
**(Rev.2 May 2004)**

W9.7.1 Only the tensile strength is to be determined and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. The value selected for the specified minimum tensile strength is to be not less than 200 $N/mm^2$ but subject to any additional requirements of the relevant construction Rules. The fractured surfaces of all tensile test specimens are to be granular and grey in appearance.

W9.7.2 Re-test requirements for tensile tests are to be in accordance with UR W2.

**9.8 Inspection**
**(1978)**

W9.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

W9.8.2 Before acceptance, all castings are to be visually examined including, where applicable, the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

W9.8.3 Supplementary examination of castings by suitable nondestructive testing procedures is generally not required except in circumstances where there is reason to suspect the soundness of the casting.

W9.8.4 When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

W9.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

**W9.9 Rectification of defective castings**
**(1978)**

W9.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

W9.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

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**W9**
cont'd

W9.9.3 Repairs by welding are generally not permitted.

**W9.10 Identification of castings**
**(Rev. 1995)**

W9.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original ladle of metal. The Surveyor is to be given full facilities for so tracing the castings when required.

W9.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of individual Classification Societies any of the following particulars may be required:
(i) Quality of cast iron.
(ii) Identification number or other marking which will enable the full history of the casting to be traced.
(iii) Manufacturer's name or trade mark.
(iv) The Classification Society's name, initials or symbol.
(v) Abbreviated name of the Classification Society's local office.
(vi) Personal stamp of Surveyor responsible for inspection.
(vii) Where applicable, test pressure.
(viii) Date of final inspection

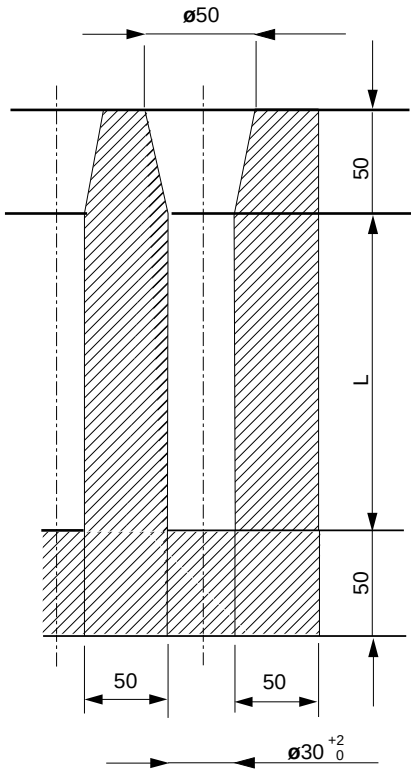
W9.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Classification Society.

**W9.11 Certification**
**(1978)**

W9.11.1 The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:
(i) Purchaser's name and order number.
(ii) Description of castings and quality of cast iron.
(iii) Identification number.
(iv) Results of mechanical tests.
(v) Where applicable, general details of heat treatment.
(vi) When specially required, the chemical analysis of ladle samples.
(vii) Where applicable, test pressure.

**Fig.1**
**Test Sample for grey cast iron**

Dimensions in millimeters



# W10 Spheroidal or nodular graphite iron castings

(1978)
(Rev. 1 1995)
(Rev.2 May 2004)

## W10.1 Scope (1978)

W10.1.1 All important spheroidal or nodular graphite iron castings, as defined in the relevant construction Rules, are to be manufactured and tested in accordance with the requirements of the following paragraphs.

W10.1.2 These requirements are applicable only to castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.

W10.1.3 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by the Classification Society.

W10.1.4 Where small castings are produced in large quantities the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of the Classification Society.

## W10.2 Manufacture (1978)

W10.2.1 All important castings are to be made at foundries where the manufacturer has demonstrated to the satisfaction of the Classification Society that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A programme of approval tests may be required in accordance with the procedures of individual Classification Societies.

W10.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

W10.2.3 Where castings of the same type are regularly produced in quantity, the manufacturer is to make any tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

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W10
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**W10.3 Quality of castings**
**(1978)**

W10.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

**W10.4 Chemical composition**
**(1978)**

W10.4.1 Unless otherwise specially required, the chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings. When required by individual Classification Societies the chemical composition of ladle samples is to be reported.

**W10.5 Heat treatment**
**(Rev. 1995)**

W10.5.1 Except as required by W10.5.2 castings may be supplied in either the as cast or heat treated condition.

W10.5.2 For some applications, such as high temperature service or where dimensional stability is important, it may be required that castings be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining. The special qualities with 350 $N/mm^2$ and 400 $N/mm^2$ nominal tensile strength and impact test shall undergo a ferritizing heat treatment.

W10.5.3 Where it is proposed to locally harden the surfaces of a casting full details of the proposed procedure and specification are to be submitted for approval by the Classification Society.

**W10.6 Mechanical tests**
**(Rev.2 May 2004)**

W10.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided for each casting or batch of castings.

W10.6.2 The test samples are generally to be one of the standard types detailed in Figs. 1, 2 and 3 with a thickness of 25 mm. Test samples of other dimensions, as detailed in Figs. 1, 2 and 3 may, however, be specially required for some components.

W10.6.3 At least one test sample is to be provided for each casting and unless otherwise required may be either gated to the casting or separately cast. Alternatively test material of other suitable dimensions may be provided integral with the casting.

W10.6.4 For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.

W10.6.5 As an alternative to W10.6.3, a batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2,0 tonnes of fettled castings in the batch.

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**W10**
cont'd

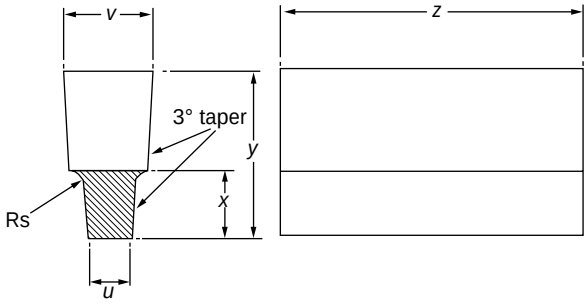


Fig. 1 Type A test samples ( U-type)

| Dimensions | Standard sample | Alternative samples when specially required | | |
|---|---|---|---|---|
| *u* (mm) | 25 | 12 | 50 | 75 |
| *v* (mm) | 55 | 40 | 90 | 125 |
| *x* (mm) | 40 | 30 | 60 | 65 |
| *y* (mm) | 100 | 80 | 150 | 165 |
| *z* | To suit testing machine | | | |
| Rs | Approximately 5mm | | | |

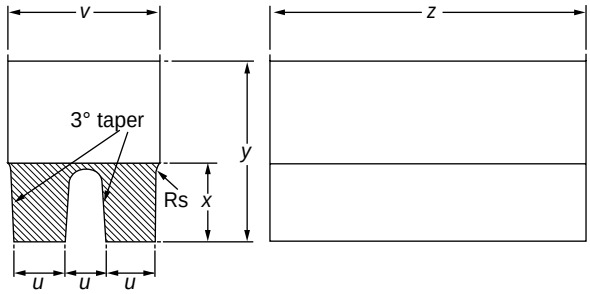


Fig. 2 Type B test samples (double U-type)

| Dimensions | Standard sample |
|---|---|
| *u* (mm) | 25 |
| *v* (mm) | 90 |
| *x* (mm) | 40 |
| *y* (mm) | 100 |
| *z* | To suit testing machine |
| Rs | Approximately 5mm |

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**W10**
cont'd

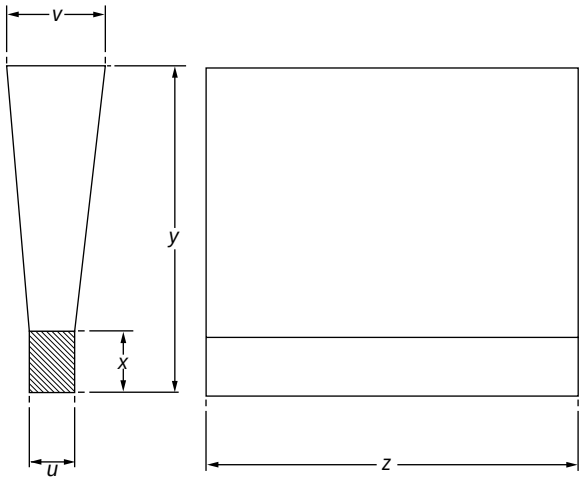


Fig. 3 Type C test samples (Y-type)

| Dimensions | Standard sample | Alternative samples when specially required | | |
|---|---|---|---|---|
| *u* (mm) | 25 | 12 | 50 | 75 |
| *v* (mm) | 55 | 40 | 100 | 125 |
| *x* (mm) | 40 | 25 | 50 | 65 |
| *y* (mm) | 140 | 135 | 150 | 175 |
| *z* | To suit testing machine | | | |
| Thickness of mould surrounding test sample | 40mm min. | 40mm min. | 80mm min. | 80mm min. |

W10.6.6 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are to be taken towards the end of pouring of the castings. The samples are not to be stripped from the moulds until the temperature is below 500°C.

W10.6.7 All test samples are to be suitably marked to identify them with the castings which they represent.

W10.6.8 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

W10.6.9 One tensile test specimen is to be prepared from each test sample and is to be machined to the dimensions given in W2.

W10.6.10 All tensile tests are to be carried out using test procedures in accordance with W2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

W10.6.11 Impact tests may additionally be required and in such cases a set of three test specimens of agreed type is to be prepared from each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with W2.

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**W10** cont'd

### W10.7 Mechanical properties
(Rev.2 May 2004)

W10.7.1 Table 1 gives the minimum requirements for 0,2% proof stress and elongation corresponding to different strength levels. Typical Brinell hardness values are also given in Table 1 and are intended for information purposes only.

W10.7.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 1 but subject to any additional requirements of the relevant construction Rules

**Table 1 Mechanical properties**

| Specified minimum tensile strength ($N/mm^2$) | 0,2% proof stress ($N/mm^2$) min. | Elongation on $5,65\sqrt{So}$ (%) min. | Typical hardness values (Brinell) (see W10.7.1) | Impact energy | | Typical structure of matrix (see W10.9.3) |
|---|---|---|---|---|---|---|
| | | | | Test temp °C | KV(2) J min | |
| 370 | 230 | 17 | 120-180 | - | - | Ferrite |
| 400 | 250 | 12 | 140-200 | - | - | Ferrite |
| Ordinary qualities 500 | 320 | 7 | 170-240 | - | - | Ferrite/Perlite |
| 600 | 370 | 3 | 190-270 | - | - | Ferrite/Perlite |
| 700 | 420 | 2 | 230-300 | - | - | Perlite |
| 800 | 480 | 2 | 250-350 | - | - | Perlite or Tempered structure |
| Special qualities 350 | 220 | 22(3) | 110-170 | +20 | 17(14) | Ferrite |
| 400 | 250 | 18(3) | 140-200 | +20 | 14(11) | Ferrite |

NOTE

1. For intermediate values of specified minimum tensile strength, the minimum values for 0,2% proof and elongation may be obtained by interpolation.
2. The average value measured on 3 Charpy V-notch specimens. One result may be below the average value but not less than the minimum shown in brackets.
3. In the case of integrally cast samples, the elongation may be 2 percentage points less.

W10.7.3 Unless otherwise agreed only the tensile strength and elongation need be determined. The results of all tensile tests are to comply with the appropriate requirements of Table 1.

W10.7.4 Re-test requirements for tensile tests are to be in accordance with UR W2.

W10 cont'd

**10.8 Inspection**
**(Rev. 1995)**

W10.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

W10.8.2 Before acceptance, all castings are to be visually examined including, where applicable, the examination of internal surfaces. Unless otherwise agreed the verification of dimensions is the responsibility of the manufacturer.

W10.8.3 Supplementary examination of castings by suitable nondestructive testing procedures is generally not required except in circumstances where there is reason to suspect the soundness of the casting.

W10.8.4 When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

W10.8.5 In the event of any casting proving defective during subsequent machining or testing is to be rejected notwithstanding any previous certification.

W10.8.6 Cast crankshaft are to be subjected to a magnetic particle inspection. Crack like indications are not allowed.

**W10.9 Metallographic examination**
**(Rev. 1995)**

**W10.9.1** For crankshafts the metallographic examination will be mandatory.

**W10.9.2** When required, a representative sample from each ladle of treated metal is to be prepared for metallographic examination. These samples may conviently be taken from the tensile test specimens but alternative arrangements for the provision of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

**W10.9.3** Examination of the samples is to show that at least 90% of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 1 and are intended for information purposes only.

**10.10 Rectification of defective castings**
**(1978)**

W10.10.1 At the discretion of the Surveyor, small surface blemishes mat be removed by local grinding.

W10.10.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

W10.10.3 Repairs by welding are generally not permitted.

**W10.11 Identification of castings**
**(Rev. 1995)**

W10.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original ladle of treated metal and the Surveyor is to be given full facilities for so tracing the castings when required.

W10.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of individual Classification Societies any of the following particulars may be required.

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**W10**
cont'd

(i) Quality of cast iron.
(ii) Identification number or other marking which will enable the full history of the casting to be traced.
(iii) Manufacturer's name or trade mark.
(iv) The Classification Society's name, initials or symbol.
(v) Abbreviated name of the Classification Society's local office.
(vi) Personal stamp of Surveyor responsible for inspection.
(vii) Where applicable, test pressure.
(viii) Date of final inspection.

W10.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Classification Society.

**W10.12 Certification**
**(1978)**

W10.12.1 The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:
(i) Purchaser's name and order number.
(ii) Description of castings and quality of cast iron.
(iii) Identification number.
(iv) Results of mechanical tests.
(v) Where applicable, general details of heat treatment.
(vi) Where specifically required, the chemical analysis of ladle samples.
(vii) Where applicable, test pressure.

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# W11 Normal and higher strength hull structural steels

(1979) (Rev.1 1986) (Rev. 2 1995 v.2.1) (Rev.3 June 2000) (Rev.4 May 2001) (Rev.5 July 2002) (Rev.6 May 2004) (Rev.7 Apr 2008) (Corr.1 Feb 2009)

## 1. Scope

1.1 These requirements apply to weldable normal and higher strength hot-rolled steel plates, wide flats, sections and bars intended for use in hull construction.

1.2 The requirements are primarily intended to apply to steel products with a thickness as follows:

For steel plates and wide flats;
- All Grades: Up to 100mm in thickness

For sections and bars;
- All Grades: Up to 50mm in thickness

For greater thickness certain variations in the requirements may be allowed or required in particular cases after consideration of the technical circumstances involved.

1.3 Provision is made for four grades of normal strength steel based on the impact test requirements. For higher strength steels provision is made for three strength levels (315, 355 and 390 $N/mm^2$) each subdivided into four grades based on the impact test temperature.

1.4 Steels differing in chemical composition, deoxidation practice, conditions of supply and mechanical properties may be accepted, subject to the special approval of the Classification Society. Such steels are to be given a special designation.

## 2. Approval

2.1 All materials are to be manufactured at works which have been approved by the Classification Society for the type and grade of steel which is being supplied. The suitability of each grade of steel for forming and welding is to be demonstrated during the initial approval tests at the steelworks. Approval of the steel works is to follow a scheme given in the Appendix A. For the steels intended for high heat input welding over 50kJ/cm, the approval of the manufacturer is to follow a scheme given in the Appendix B.

2.2 It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to within the manufacturing specifications. Where control imperfection inducing possible inferior quality of product occurs, the manufacturer is to identify the cause and establish a countermeasure to prevent its recurrence. Also, the complete investigation report is to be submitted to the Surveyor.

For further use, each affected piece is to be tested to the Surveyor's satisfaction.

The frequency of testing for subsequent products offered may be increased to gain confidence in the quality at the discretion of the Society.

2.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied to the Surveyor at the rolling mill stating the process by which it was manufactured, the name of the manufacturer who supplied it, the number of the cast from which it was made

**W11 (cont)**

and the ladle analysis. The Surveyor is to have access to the works at which the steel was produced.

**Note**:

1. The attention of the users must be drawn to the fact that when fatigue loading is present, the effective fatigue strength of a welded joint of higher strength steel may not be greater than that of a welded joint in normal strength steels.
2. Before subjecting steels produced by thermo-mechanical rolling to further heating for forming or stress relieving, or using high heat-input welding, special consideration must be given to the possibility of a consequent reduction in mechanical properties.

### 3. Method of Manufacture

3.1 Steel is to be manufactured by the basic oxygen, electric furnace or open hearth processes or by other processes specially approved by the Classification Society.

3.2 The deoxidation practice used for each grade is to comply with the appropriate requirements of Tables 1 and 2.

3.3 The rolling practice applied for each grade is to comply with the appropriate condition of supply of Tables 4 and 5.

The definitions of applicable rolling procedures and the schematic diagrams are given as follows:

(i) As Rolled, AR
This procedure involves the rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than steel heat treated after rolling or than steel produced by advanced processes.

(ii) Normalising, N
Normalising involves heating rolled steel above the critical temperature, $Ac_3$, and in the lower end of the austenite recrystallization region followed by air cooling. The process improves the mechanical properties of as rolled steel by refining the grain size.

(iii) Controlled Rolling, CR (Normalizing Rolling, NR):
A rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(iv) Quenching and Tempering, QT
Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the $Ac_3$ and then cooled with an appropriate coolant for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the $Ac_1$ to restore toughness properties by improving the microstructure.

(v) Thermo-Mechanical Rolling, TM (Thermo-Mechanical Controlled Processing, TMCP):
This is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the $Ar_3$ temperature and may involve the rolling in the dual phase temperature region.

**W11**
**(cont)**

Unlike controlled rolled (normalised rolling) the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment.

The use of accelerated cooling on completion of TM-rolling may also be accepted subject to the special approval of the Society. The same applies for the use of tempering after completion of the TM-rolling.

(vi) Accelerated Cooling, AcC
Accelerated cooling is a process, which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM-rolling operation. Direct quenching is excluded from accelerated cooling.

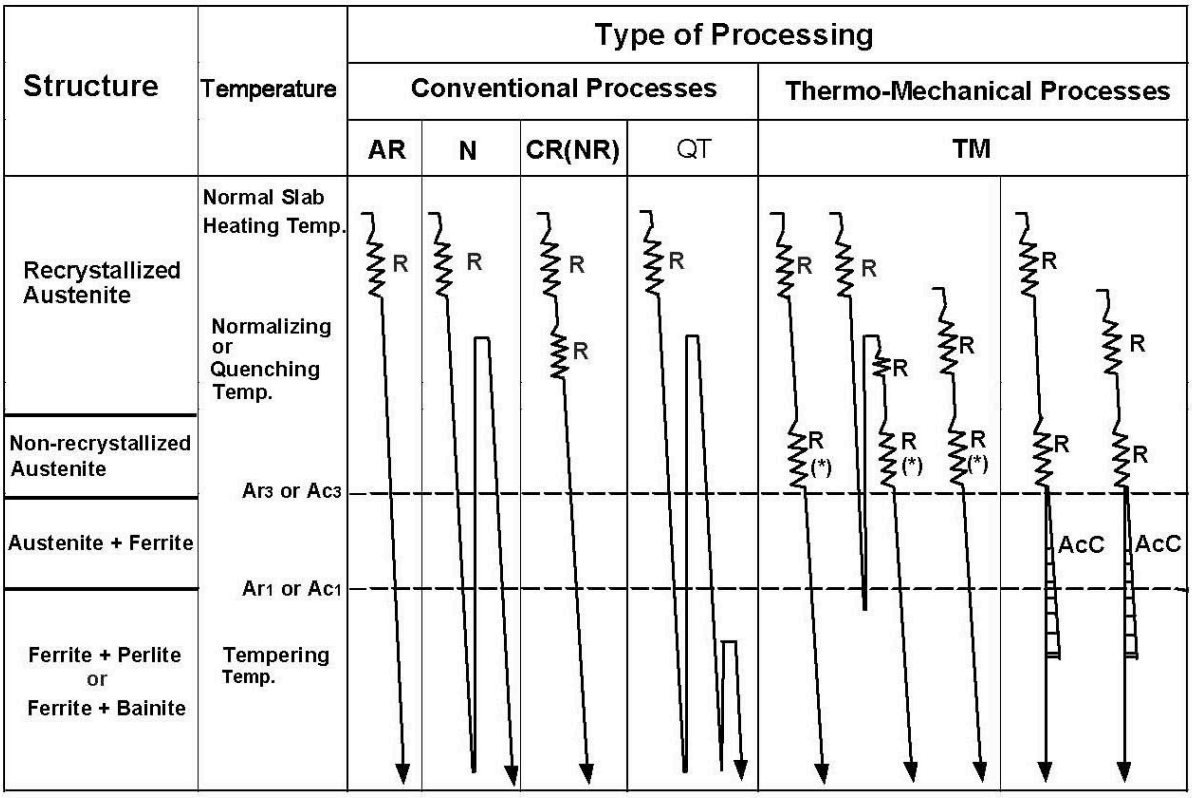
The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other heat treatment.

Where CR and TM with/without AcC are applied, the programmed rolling schedules are to be verified by the Classification Society at the time of the steel works approval, and are to be made available when required by the attending Surveyor. On the manufacturer's responsibility, the programmed rolling schedules are to be adhered to during the rolling operation. Refer to the above 2.2. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, the manufacturer shall take further measures required in the above 2.2 to the Surveyor's satisfaction.

**W11**
**(cont)**

**Schematic Diagrams of Thermo-Mechanical and Conventional Processes**




Notes:

| | |
|---|---|
| AR: | As Rolled |
| N: | Normalizing |
| CR(NR): | Controlled Rolling (Normalizing Rolling) |
| QT: | Quenching and Tempering |
| TM: | Thermo-Mechanical Rolling (Thermo-Mechanical Controlled Process) |
| R: | Reduction |
| (*): | Sometimes rolling in the dual-phase temperature region of austenite and ferrite |
| AcC: | Accelerated Cooling |

## 4. Chemical Composition

4.1 The chemical composition of samples taken from each ladle of each cast is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory and is to comply with the appropriate requirements of Tables 1 and 2. For steel plates and wide flats over 50 mm thick, slight deviations in the chemical composition may be allowed as approved by the Classification Society.

4.2 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyor.

**W11**
**(cont)**

**Table 1 Chemical composition and deoxidation practice for normal strength steels**

| Grade | A | B | D | E |
|---|---|---|---|---|
| Deoxidation Practice | For t ≤ 50 mm Any method except rimmed steel [1]<br>For t > 50 mm Killed | For t ≤ 50 mm Any method except rimmed<br>For t > 50 mm Killed | For t ≤ 25 mm Killed<br>For t > 25 mm Killed and fine grain treated | Killed and fine grain treated |
| Chemical Composition % [4] [7] [8] (ladle samples) | **Carbon plus 1/6 of the manganese content is not to exceed 0.40%** | | | |
| C max. | 0.21 [2] | 0.21 | 0.21 | 0.18 |
| Mn min. | 2.5 x C | 0.80 [3] | 0.60 | 0.70 |
| Si max. | 0.50 | 0.35 | 0.35 | 0.35 |
| P max. | 0.035 | 0.035 | 0.035 | 0.035 |
| S max. | 0.035 | 0.035 | 0.035 | 0.035 |
| Al (acid soluble min) | - | - | 0.015 [5] [6] | 0.015 [6] |

t = thickness

Notes:

1. Grade A sections up to a thickness of 12.5 mm may be accepted in rimmed steel subject to the special approval of the Classification Society.
2. Max. 0.23% for sections.
3. When Grade B steel is impact tested the minimum manganese content may be reduced to 0.60%.
4. When any grade of steel is supplied in the thermo-mechanically rolled condition variations in the specified chemical composition may be allowed or required by the Classification Society.
5. For Grade D steel over 25 mm thick.
6. For Grade D steel over 25 mm thick and Grade E steel the total aluminium content may be determined instead of acid soluble content. In such cases the total aluminium content is to be not less than 0.020%. A maximum aluminium content may also be specified by the Classification Society. Other suitable grain refining elements may be used subject to the special approval of the Classification Society.
7. The Classification Society may limit the amount of residual elements which may have an adverse effect on the working and use of the steel, e.g. copper and tin.
8. Where additions of any other element have been made as part of the steelmaking practice, the content is to be indicated.

**W11**
**(cont)**

**Table 2 Chemical composition and deoxidation practice for higher strength steels**

| Grade [1] | A32 D32 E32 F32<br>A36 D36 E36 F36<br>A40 D40 E40 F40 |
|---|---|
| Deoxidation Practice | killed and fine grain treated |
| Chemical Composition % [5] [7] (ladle samples) | |
| C max. | 0.18 / 0.16 |
| Mn | 0.90 – 1.60 [2] / 0.90 – 1.60 |
| Si max. | 0.50 / 0.50 |
| P max. | 0.035 / 0.025 |
| S max. | 0.035 / 0.025 |
| Al (acid soluble min) | 0.015 [3] [4] / 0.015 [3] [4] |
| Nb | 0.02 – 0.05 [4] ) total: / 0.02 – 0.05 [4] ) total: |
| V | 0.05 – 0.10 [4] ) 0.12 / 0.05 – 0.10 [4] ) 0.12 |
| Ti max. | 0.02 ) max. / 0.02 ) max. |
| Cu max. | 0.35 / 0.35 |
| Cr max. | 0.20 / 0.20 |
| Ni max. | 0.40 / 0.80 |
| Mo max. | 0.08 / 0.08 |
| N max. | - / 0.009 (0.012 if Al is present) |
| Carbon Equivalent [6] | |

Notes:

1. The letter “H” may be added either in front or behind the grade mark e.g. HA 32 or AH 32.
2. Up to a thickness of 12.5 mm the minimum manganese content may be reduced to 0.70%.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminim content is to be not less than 0.020%.
4. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of a fine graining element is not applicable.
5. When any grade of higher strength steel is supplied in the thermo-mechanically rolled condition variations in the specified chemical composition may be allowed or required by the Classification Society.
6. When required, the carbon equivalent value is to be calculated from the ladle analysis using the following formula.

   $$Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (\%)$$

   This formula is applicable only to steels which are basically of the carbon-manganese type and gives a general indication of the weldability of the steel.
7. Where additions of any other element have been made as part of the steelmaking practice, the content is to be indicated.

4.3 For TM (TMCP) steels the following special requirements apply:

(i) The carbon equivalent value is to be calculated from the ladle analysis using the following formula and to comply with the requirements of Table 3;

$$Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (\%)$$

(ii) The following formula (cold cracking susceptibility) may be used for evaluating weldability instead of the carbon equivalent at the discretion of the Classification Society;

**W11**
**(cont)**

$$Pcm = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B \ \%$$

In such cases the cold cracking susceptibility value required may be specified by the Classification Society.

**Table 3 Carbon equivalent for higher strength steels up to 100 mm in thickness produced by TM**

| Grade | Carbon Equivalent, max. (%) (1) | |
|---|---|---|
| | t ≤ 50 | 50 < t ≤ 100 |
| A32, D32, E32, F32 | 0.36 | 0.38 |
| A36, D36, E36, F36 | 0.38 | 0.40 |
| A40, D40, E40, F40 | 0.40 | 0.42 |

t: thickness (mm)

Notes:

(1) It is a matter for the manufacturer and shipbuilder to mutually agree in individual cases as to whether they wish to specify a more stringent carbon equivalent.

## 5. Condition of Supply

5.1 All materials are to be supplied in a condition complying with the appropriate requirements of Tables 4 and 5.

**Table 4 Condition of supply for normal strength steels (1)**

| Grades | Thickness | Condition of Supply |
|---|---|---|
| A | ≤ 50 mm | Any |
| | > 50 mm ≤ 100 mm | Normalized, controlled rolled or thermo-mechanically rolled (2) |
| B | ≤ 50 mm | Any |
| | > 50 mm ≤ 100 mm | Normalized, controlled rolled or thermo-mechanically rolled (2) |
| D | ≤ 35 mm | Any |
| | > 35 mm ≤ 100 mm | Normalized, controlled rolled or thermo-mechanically rolled (3) |
| E | ≤ 100 mm | Normalized or thermo-mechanically rolled (3) |

Notes:

(1) These conditions of supply and the impact test requirements are summarised in Table 8.
(2) Subject to the special approval of the Classification Society, Grades A and B steel plates may be supplied in the as rolled condition - see 11.13.2 (ii).
(3) Subject to the special approval of the Classification Society, sections in Grade D steel may be supplied in the as rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests. Similarly sections in Grade E steel may be supplied in the as rolled or controlled rolled condition. The frequency of impact tests is to be in accordance with W11.13.2 (ii) and W11.13.3 (iii) respectively.

**W11**
**(cont)**

**Table 5 Condition of supply for higher strength steels (1)**

| Grades | Grain Refining Elements Used | Thickness | Condition of supply |
|---|---|---|---|
| A32<br>A36 | Nb and/or V | ≤ 12.5 mm | Any |
| | | > 12.5 mm ≤ 100 mm | Normalized, controlled rolled or thermo-mechanically rolled (3) |
| | Al alone<br>or with Ti | ≤ 20 mm | Any |
| | | > 20 mm ≤ 35 mm | Any, as rolled subject to special approval of the Classification Society (2) |
| | | > 35 mm ≤ 100 mm | Normalized, controlled rolled or thermo-mechanically rolled (3) |
| A40 | Any | ≤ 12.5 mm | Any |
| | | > 12.5 mm ≤ 50 mm | Normalized, controlled rolled or thermo-mechanically rolled |
| | | > 50 mm ≤ 100 mm | Normalized, thermo-mechanically rolled or quenched and tempered |
| D32<br>D36 | Nb and/or V | ≤ 12.5 mm | Any |
| | | > 12.5 mm ≤ 100 mm | Normalized, controlled rolled or thermo-mechanically rolled (3) |
| | Al alone<br>or with Ti | ≤ 20 mm | Any |
| | | > 20 mm ≤ 25 mm | Any, as rolled subject to special approval of the Classification Society (2) |
| | | > 25 mm ≤ 100 mm | Normalized, controlled rolled or thermo-mechanically rolled (3) |
| D40 | Any | ≤ 50 mm | Normalized, controlled rolled or thermo-mechanically rolled |
| | | > 50 mm ≤ 100 mm | Normalized, thermo-mechanically rolled or quenched and tempered |
| E32<br>E36 | Any | ≤ 50 mm | Normalized or thermo-mechanically rolled (3) |
| | | > 50 mm ≤ 100 mm | Normalized, thermo-mechanically rolled |
| E40 | Any | ≤ 50 mm | Normalized, thermo-mechanically rolled or quenched and tempered |
| | | > 50 mm ≤ 100 mm | Normalized, thermo-mechanically rolled or quenched and tempered |
| F32<br>F36<br>F40 | Any | ≤ 50 mm | Normalized, thermo-mechanically rolled or quenched and tempered (4) |
| | | > 50 mm ≤ 100 mm | Normalized, thermo-mechanically rolled or quenched and tempered |

Notes:

(1) These conditions of supply and the requirements for impact tests are summarised in Table 9.
(2) The frequency of impact tests is to be in accordance with W11.13.2 (ii).
(3) Subject to the special approval of the Classification Society, sections in Grades A32, A36, D32 and D36 steels may be supplied in the as rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests. Similarly sections in Grades E32 and E36 steels maybe supplied in the as rolled or controlled rolled condition. The frequency of impact tests is to be in accordance with W11.13.2 (ii) and W11.13.2 (iii) respectively.
(4) Subject to the special approval of the Classification Society, sections in Grades F32 and F36 steels may be supplied in the controlled rolled condition. The frequency of impact tests is to be in accordance with W11.13.3 (iii).

**W11 (cont)**

## 6. Mechanical Properties

6.1 For tensile test either the upper yield stress (ReH) or where ReH cannot be determined, the 0.2 percent proof stress (Rp 0.2) is to be determined and the material is considered to comply with the requirements if either value meets or exceeds the specified minimum value for yield strength (Re).

6.2 The results obtained from tensile tests are to comply with the appropriate requirements of Tables 6 and 7.

**Table 6 Mechanical properties for normal strength steels**

| Grade | Yield Strength ReH ($N/mm^2$) min | Tensile Strength Rm ($N/mm^2$) | Elongation ($5.65\sqrt{S_0}$) $A_5$ (%) | Impact Test | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Test Temp. °C | Average Impact Energy (J) min | | | | | |
| | | | | | t ≤ 50 | | 50 < t ≤ 70 | | 70 < t ≤ 100 | |
| | | | | | Long[3] | Trans[3] | Long[3] | Trans[3] | Long[3] | Trans[3] |
| A | 235 | 400/520 [1] | 22 [2] | +20 | - | - | 34 [5] | 24 [5] | 41 [5] | 27 [5] |
| B | | | | 0 | 27 [4] | 20 [4] | 34 | 24 | 41 | 27 |
| D | | | | -20 | 27 | 20 | 34 | 24 | 41 | 27 |
| E | | | | -40 | 27 | 20 | 34 | 24 | 41 | 27 |

t: thickness (mm)

Notes:

(1) For all thicknesses of Grade A sections the upper limit for the specified tensile strength range may be exceeded at the discretion of the Classification Society.

(2) For full thickness flat tensile test specimens with a width of 25 mm and a gauge length of 200mm the elongation is to comply with the following minimum values:

| Thickness mm | | > 5 | > 10 | > 15 | > 20 | > 25 | > 30 | > 40 |
|---|---|---|---|---|---|---|---|---|
| | ≤ 5 | ≤ 10 | ≤ 15 | ≤ 20 | ≤ 25 | ≤ 30 | ≤ 40 | ≤ 50 |
| Elongation % | 14 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |

(3) See paragraph W11.6.3.

(4) Charpy V-notch impact tests are generally not required for Grade B steel with thickness of 25 mm or less.

(5) Impact tests for Grade A over 50 mm thick are not required when the material is produced using fine grain practice and furnished normalised. TM rolling may be accepted without impact testing at the discretion of the Society.

**W11 (cont)**

**Table 7 Mechanical properties for higher strength steels**

| Grade | Yield Strength ReH ($N/mm^2$) min | Tensile Strength Rm ($N/mm^2$) | Elongation ($5.65\sqrt{S_0}$) $A_5$ (%) | Impact Test | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Test Temp. °C | Average Impact Energy (J) min | | | | | |
| | | | | | t ≤ 50 | | 50 < t ≤ 70 | | 70 < t ≤ 100 | |
| | | | | | Long[2] | Trans[2] | Long[2] | Trans[2] | Long[2] | Trans[2] |
| A32 | 315 | 440/570 | 22 [1] | 0 | 31 [3] | 22 [3] | 38 | 26 | 46 | 31 |
| D32 | | | | -20 | 31 | 22 | 38 | 26 | 46 | 31 |
| E32 | | | | -40 | 31 | 22 | 38 | 26 | 46 | 31 |
| F32 | | | | -60 | 31 | 22 | 38 | 26 | 46 | 31 |
| A36 | 355 | 490/630 | 21 [1] | 0 | 34 [3] | 24 [3] | 41 | 27 | 50 | 34 |
| D36 | | | | -20 | 34 | 24 | 41 | 27 | 50 | 34 |
| E36 | | | | -40 | 34 | 24 | 41 | 27 | 50 | 34 |
| F36 | | | | -60 | 34 | 24 | 41 | 27 | 50 | 34 |
| A40 | 390 | 510/660 | 20 [1] | 0 | 39 | 26 | 46 | 31 | 55 | 37 |
| D40 | | | | -20 | 39 | 26 | 46 | 31 | 55 | 37 |
| E40 | | | | -40 | 39 | 26 | 46 | 31 | 55 | 37 |
| F40 | | | | -60 | 39 | 26 | 46 | 31 | 55 | 37 |

t: thickness (mm)

Notes:

(1) For full thickness flat tensile test specimens with a width of 25mm and a gauge length of 200 mm the elongation is to comply with the following minimum values:

| Thickness (mm) | Grade | ≤ 5 | > 5 ≤ 10 | > 10 ≤ 15 | > 15 ≤ 20 | > 20 ≤ 25 | > 25 ≤ 30 | > 30 ≤ 40 | > 40 ≤ 50 |
|---|---|---|---|---|---|---|---|---|---|
| Elongation % | A32, D32, E32 & F32 | 14 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| | A36, D36, E36 & F36 | 13 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| | A40, D40, E40 & F40 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

(2) See paragraph W11.6.3.
(3) For Grades A32 and A36 steels a relaxation in the number of impact tests for acceptance purposes may be permitted by special agreement with the Classification Society provided that satisfactory results are obtained from occasional check tests.

6.3 Minimum average energy values are specified for Charpy V-notch impact test specimens taken in either the longitudinal or transverse directions (see W11.12.2). Generally only longitudinal test specimens need to be prepared and tested except for special applications where transverse test specimens may be required by the purchaser or the Classification Society. Transverse test results are to be guaranteed by the supplier.

The tabulated values are for standard specimens 10 mm x 10 mm. For plate thicknesses less than 10 mm, impact test may be waived at the discretion of the Classification Society or sub-size specimens, as specified in UR W2, may be used.

6.4 The average value obtained from one set of three impact tests is to comply with the requirements given in Tables 6 and 7. One individual value only may be below the specified average value provided it is not less than 70% of that value.

**W11 (cont)**

6.5 Generally, impact tests are not required when the nominal plate thickness is less than 6 mm.

## 7. Freedom from Defects

7.1 The steel is to be reasonably free from segregations and non-metallic inclusions. The finished material is to have a workmanlike finish and is to be free from internal and surface defects prejudicial to the use of the material for the intended application.

7.2 The acceptance criteria for surface finish and procedures for the repair of defects, as detailed in Recommendation, No 12, "Guidance for the Surface Finish of Hot Rolled Steel Plates and Wide Flats" are to be observed.

## 8. Tolerances

8.1 Unless otherwise agreed or specially required the thickness tolerances in Unified Requirement W13 "Allowable under thickness tolerances of steel plates and wide flats" are applicable.

## 9. Identification of Materials

9.1 The steelmaker is to adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original cast.

9.2 The Surveyor is to be given full facilities for so tracing the material when required.

## 10. Testing and Inspection

10.1 Facilities for Inspection

The manufacturer is to afford the Surveyor all necessary facilities and access to all relevant parts of the works to enable him to verify that the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by the Rules, and for verifying the accuracy of the testing equipment.

10.2 Testing Procedures

The prescribed tests and inspections are to be carried out at the place of manufacture before dispatch. The test specimens and procedures are to be in accordance with Unified Requirement W2 “Test Specimens and Mechanical Testing Procedures for Materials”. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed.

10.3 Through Thickness Tensile Tests

If plates and wide flats with thickness of 15 mm and over are ordered with through thickness properties, the through thickness tensile test in accordance with Unified Requirement W14 “Steel Plates and Wide Flats with Improved Through Thickness Properties” is to be carried out.

**W11 (cont)**

10.4 Ultrasonic Inspection

If plates and wide flats are ordered with ultrasonic inspection, this is to be made in accordance with an accepted standard at the discretion of the Classification Society.

10.5 Surface Inspection and Dimensions

Surface inspection and verification of dimensions are the responsibility of the steel maker. The acceptance by the Classification Society's Surveyor shall not absolve the steel maker from this responsibility.

## 11. Test Material

11.1 Definitions

(a) Piece: the term "piece" is understood to mean the rolled product from a single slab, billet or ingot if this is rolled directly into plates, sections or bars.

(b) Batch: a number of similar pieces presented as a group for acceptance tests.

11.2 Test Samples

(a) All material in a batch presented for acceptance tests is to be of the same product form e.g. plates, flats, sections, etc. from the same cast and in the same condition of supply.

(b) The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed.

(c) The test specimens are not to be separately heat treated in any way.

(d) Unless otherwise agreed the test samples are to be taken from the following positions:

(i) *Plates and flats with a width ≥ 600 mm.* The test samples are to be taken from one end at a position approximately midway between the axis in the direction of the rolling and the edge of the rolled product (see Fig. 1). Unless otherwise agreed the tensile test specimens are to be prepared with their longitudinal axes transverse to the final direction of rolling.

(ii) *Flats with a width < 600 mm, bulb flats and other sections.* The test samples are to be taken from one end at a position approximately one third from the outer edge (see Figs. 2, 3 and 4) or in the case of small sections, as near as possible to this position. In the case of channels, beams or bulb angles, the test samples may alternatively be taken from a position approximately one quarter of the width from the web centre line or axis (see Fig. 3). The tensile test specimens may be prepared with their longitudinal axes either parallel or transverse to the final direction of rolling.

(iii) *Bars and other similar products.* The test samples are to be taken so that the longitudinal axes of the test specimens are parallel to the direction of rolling and are as near as possible to the following
– for non-cylindrical sections, at one third of the half diagonal from the outside,
– for cylindrical sections, at one third of the radius from the outside (see Fig. 6).

# W11
**(cont)**

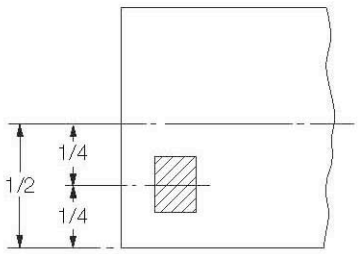



Fig. 1 Plates and flats

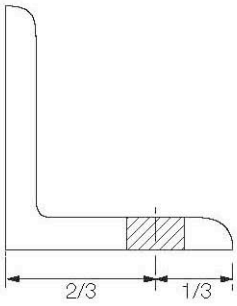



Fig. 2 Angles

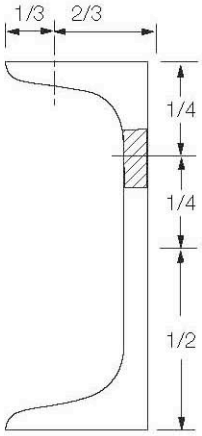



Fig. 3 Channel

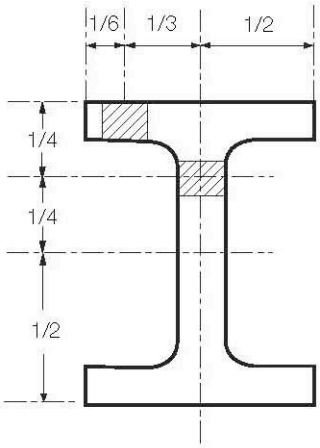



Fig. 4 H-sections

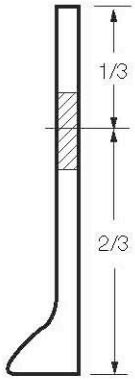



Fig. 5 Bulb flats

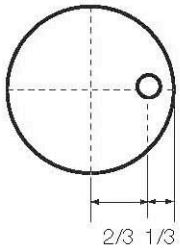



Fig. 6 Bars;

## 12. Mechanical Test specimens

12.1 Tensile Test Specimens. The dimensions of the tensil test specimens are to be in accordance with Unified Requirement, W2. Generally for plates, wide flats and sections flat test specimens of full product thickness are to be used. Round test specimens may be used when the product thickness exceeds 40 mm or for bards and other similar products. Alternatively for small sizes of bars, etc. test specimens may consist of a suitable length of the full cross section of the product.

12.2 Impact Test Specimens. The impact test specimens are to be of the Charpy V-notch type cut with their edge within 2 mm from the “as rolled” surface with their longitudinal axes either parallel (indicated “Long” in Table 6 & 7) or transverse (indicated "Trans" in Tables 6 & 7) to the final direction of rolling of the material. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is not to be nearer than 25 mm to a flame cut or sheared edge (see also W11.6.3). Where the product thickness exceeds 40 mm, the impact test specimens are to be taken with their longitudinal axis at a quarter thickness position.

**W11**
**(cont)**

## 13. Number of Test Specimens

13.1 Number of Tensile Tests. For each batch presented, except where specially agreed by the Classification Society, one tensile test is to be made from one piece unless the weight of finished material is greater than 50 tonnes or fraction thereof. Additionally tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

13.2 Number of Impact Tests (except for Grades E, E32, E36, E40, F32, F36 and F40), see Tables 8 & 9.

(i) Except where otherwise specified or specially agreed by the Classification Society, for each batch presented, at least one set of three Charpy V-notch test specimens is to be made from one piece unless the weight of finished material is greater than 50 tonnes, in which case one extra set of three test specimens is to be made from a different piece from each 50 tonnes or fraction thereof. When steel plates except for Grade A steel over 50 mm in thickness is supplied in the controlled rolled condition, the frequency of impact test is to be made from a different piece from each 25 tonnes or fraction thereof.

(ii) For steel plates of Grades A40 and D40 with thickness over 50 mm in normalized or TM condition, one set of impact test specimens is to be taken from each batch of 50 tonnes or fraction thereof. For those in QT condition, one set of impact test specimens is to be taken from each length as heat treated.

(iii) When, subject to the special approval of the Classification Society, material is supplied in the as rolled condition, the frequency of impact tests is to be increased to one set from each batch of 25 tonnes or fraction thereof. Similarly Grade A steel over 50 mm in thickness may be supplied in the as rolled condition. In such case one set of three Charpy V-notch test specimens is to be taken from each batch of 50 tonnes or fraction thereof.

(iv) The piece selected for the preparation of the test specimens is to be the thickest in each batch.

13.3 Number of Impact Tests (Grades E, E32, E36, E40, F32, F36 and F40).

(i) For steel plates supplied in the normalised or TM condition one set of impact test specimens is to be taken from each piece. For quenched and tempered steel plates one set of impact test specimens is to be taken from each length as heat treated.

(ii) For sections one set of impact tests is to be taken from each batch of 25 tonnes or fraction thereof.

(iii) When, subject to the special approval of the Classification Society, sections other than Grades E40 and F40 are supplied in the as rolled or controlled rolled condition, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

(iv) For (ii) and (iii) above the piece selected for the preparation of the test specimens is to be the thickest in each batch.

**W11 (cont)**

## 14. Retest Procedures

14.1 When the tensile test from the first piece selected in accordance with W11.13.1 fails to meet the requirements re-test requirements for tensile tests are to be in accordance with UR W2.

14.2 If one or both of the additional tests referred to above are unsatisfactory, the piece is to be rejected, but the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch selected in the same way, are tested with satisfactory results. If unsatisfactory results are obtained from either of these two pieces then the batch of material is to be rejected.

14.3 Re-test requirements for Charpy impact tests are to be in accordance with UR W2.

14.4 When the initial piece, representing a batch, gives unsatisfactory results from the additional Charpy V-notch impact tests referred to above, this piece is to be rejected but the remaining material in the batch may be accepted provided that two of the remaining pieces in the batch are tested with satisfactory results. If unsatisfactory results are obtained from either of these two pieces then the batch of material is to be rejected. The pieces selected for these additional tests are to be the thickest remaining in the batch.

14.5 If any test specimen fails because of faulty preparation, visible defects or (in the case of tensile test) because of fracturing outside the range permitted for the appropriate gauge length, the defective test piece may, at the Surveyors discretion, be disregarded and replayed by an additional test piece of the same type.

14.6 At the option of the steelmaker, when a batch of material is rejected, the remaining pieces in the batch may be resubmitted individually for test and those pieces which give satisfactory results may be accepted.

14.7 At the option of the steelmaker, rejected material may be resubmitted after heat treatment or reheat treatment, or may be resubmitted as another grade of steel and may then be accepted provided the required tests are satisfactory.

14.8 In the event of any material proving unsatisfactory during subsequent working or fabrication, such material may be rejected, notwithstanding any previous satisfactory testing and/or certification.

## 15. Branding

15.1 Every finished piece is to be clearly marked by the maker in at least one place with the Classification Society's brand and the following particulars:

(i) Unified identification mark for the grade steel (e.g. A, A36).
(ii) Steels which have been specially approved by the Classification Society and which differ from these requirements (see W11.1.4) are to have the letter "S" after the above identification mark (e.g. A36S, ES).
(iii) When required by the Classification Society, material supplied in the thermo-mechanically controlled process condition is to have the letters TM added after the identification mark (e.g. E36 TM).
(iv) Name or initials to identify the steelworks.
(v) Cast or other number to identify the piece.
(vi) If required by the purchaser, his order number or other identification mark.

**W11 (cont)**

15.2 The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products are to be encircled with paint or otherwise marked so as to be easily recognisable.

15.3 Where a number of light materials are securely fastened together in bundles the manufacturer may, subject to the agreement of the Classification Society, brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

15.4 In the event of any material bearing the Classification Society's brand failing to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

## 16. Documentation

16.1 The Surveyor is to be supplied with the number of copies as required by the Classification Society, of the test certificates or shipping statements for all accepted materials. The Classification Society may require separate documents of each grade of steel. These documents are to contain, in addition to the description, dimensions, etc., of the material, at least the following particulars:

(i) Purchaser's order number and if known the hull number for which the material is intended.
(ii) Identification of the cast and piece including, where appropriate, the test specimen number.
(iii) Identification of the steelworks.
(iv) Identification of the grade of steel.
(v) Ladle analysis (for elements specified in Tables 1 & 2).
(vi) Condition of supply when other than as rolled i.e. normalised, controlled rolled or thermomechanically rolled.
(vii) State if rimming steel has been supplied for grade A sections, up to 12.5 mm thick.
(viii) Test Results

16.2 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactory the required tests in the presence of the Surveyor or his authorized deputy. The name of the Classification Society is to appear on the test certificate. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the makers by an authorized official:

"We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of the Classification Society."

**W11**
**(cont)**

**Table 8 Required condition of supply and number of impact tests for normal strength steels**

| Grade | Deoxidation Practice | Products | Condition of Supply (Batch for Impact Tests) (1)(2) | | |
|---|---|---|---|---|---|
| | | | Thickness (mm) 10 12.5 20 25 30 35 40 50 100 | | |
| A | Rimmed | Sections | A(-) | Not applicable | |
| | For t ≤ 50mm Any method except rimmed For t > 50mm Killed | Plates | A(-) | | N(-) TM(-) (3) CR (50), AR* (50) |
| | | Sections | A(-) | | Not applicable |
| B | For t ≤ 50mm Any method except rimmed For t > 50mm Killed | Plates | A(-) | A(50) | N(50) TM(50) CR (25), AR* (25) |
| | | Sections | A(-) | A(50) | Not applicable |
| D | Killed | Plates Sections | A(50) | Not applicable | |
| | Plates Killed and fine grain treated | Plates | A(50) | N(50) CR(50) TM(50) | N(50) TM(50) CR(25) |
| | | Sections | A(50) | N(50) CR(50) TM(50) AR*(25) | Not applicable |
| E | Killed and fine grain treated | Plates | N(Each piece) TM(Each piece) | | |
| | | Sections | N(25) TM(25) AR* (15), CR*(15) | | Not applicable |

Remarks:

1. Condition of Supply
   A – Any
   N – Normalised Condition
   CR – Controlled Rolled Condition
   TM – Thermo-Mechanical rolling
   AR* – As Rolled Condition subject to special approval of the Classification Society
   CR* – Controlled Rolled Condition subject to special approval of the Classification Society
2. Number of Impact Tests
   One set of impact tests is to be taken from each batch of the "specified weight" in ( ) or fraction thereof.
3. See Note (5) of Table 6.

**W11**
**(cont)**

**Table 9 Required condition of supply and number of impact tests for higher strength steels**

| Grade | Deoxidation Practice | Grain Refining Elements | Products | Condition of supply (Batch for Impact Tests (1)(2)) Thickness (mm) 10 12.5 20 25 30 35 40 50 100 | | |
|---|---|---|---|---|---|---|
| A32 A36 | Killed and fine grain treated | Nb and/or V | Plates | A(50) | N(50) CR(50),TM(50) | N(50), CR(25), TM(50) |
| | | | Sections | A(50) | N(50) CR(50), TM(50) AR* (25) | Not applicable |
| | | Al alone or with Ti | Plates | A(50) | AR* (25) / N(50), CR(50) TM(50) | Not applicable / N(50), CR(25), TM(50) |
| | | | Sections | A (50) | N(50) CR(50) TM(50) AR* (25) | Not applicable |
| A40 | Killed and fine grain treated | Any | Plates | A(50) | N(50) CR(50) TM(50) | N(50) TM(50) QT(Each length as heat treated) |
| | | | Sections | A(50) | N(50) CR(50) TM(50) | Not applicable |
| D32 D36 | Killed and fine grain treated | Nb and/or V | Plates | A(50) | N(50) CR(50), TM(50) | N(50), CR(25), TM(50) |
| | | | Sections | A(50) | N(50) CR(50), TM(50) AR* (25) | Not applicable |
| | | Al alone or with Ti | Plates | A(50) | AR*(25) / Not applicable / N(50), CR(50), TM (50) | N(50), CR25, TM(50) |
| | | | Sections | A(50) | N(50) CR(50), TM(50) AR* (25) | Not applicable |
| D40 | Killed and fine grain treated | Any | Plates | N(50) CR(50) TM(50) | | N(50) TM(50) QT(Each length as heat treated) |
| | | | Sections | N(50) CR(50) TM(50) | | Not applicable |
| E32 E36 | Killed and fine grain treated | Any | Plates | N(Each piece) TM(Each piece) | | |
| | | | Sections | N(25) TM(25) AR* (15), CR* (15) | | Not applicable |
| E40 | Killed and fine grain treated | Any | Plates | N(Each piece) TM(Each piece) QT(Each length as heat treated) | | N (Each piece) TM(Each piece) QT(Each length as heat treated) |
| | | | Sections | N(25) TM(25) QT(25) | | Not applicable |

**W11**
**(cont)**

**Table 9 Required condition of supply and number of impact tests for higher strength steels (cont'd)**

| Grade | Deoxidation Practice | Grain Refining Elements | Products | Condition of supply (Batch for Impact Tests (1)(2) Thickness (mm) 10 12.5 20 25 30 35 40 50 100 | |
|---|---|---|---|---|---|
| F32 F36 | Killed and fine grain treated | Any | Plates | N(Each piece) TM(Each piece) QT(Each length as heat treated) | N(Each piece) TM(Each piece) QT(Each length as heat treated) |
| | | | Sections | N(25) TM(25) QT(25) CR*(15) | Not applicable |
| F40 | Killed and fine grain treated | Any | Plates | N(Each piece) TM(Each piece) QT (Each length as heat treated) | N(Each piece) TM(Each piece) QT (Each length as heat treated) |
| | | | Sections | N(25) TM(25) QT(25) | Not applicable |

Remarks:

(1) Condition of Supply
A - Any
N - Normalized Condition
CR - Controlled Rolled Condition
TM - Thermo-Mechanical Rolling
QT - Quenched and Tempered Condition
AR* - As Rolled Condition subject to the special approval of the Classification Society
CR* - Controlled Rolled Condition subject to the special approval of the Classification Society

(2) Number of Impact Tests
One set of impact tests is to be taken from each batch of the "specified weight" in ( ) or fraction thereof.
For grades A32 and A36 steels a relaxation in the number of impact tests may be permitted. (See Note(3) of Table 7.)

W11
(cont)

# Appendix A. Manufacturing Approval Scheme of Hull Structural Steels

## A1. Manufacturing Approval Scheme of Semi Finished Products for Hull Structural Steels

### 1. Scope of application

This document specifies, as given in W11.2.1, the scheme for the approval of the manufacturing process of semi-finished products such as ingots, slabs, blooms and billets for the structural steels.

The manufacturing approval scheme is valid for verifying the manufacturer's capability to provide satisfactory products stably under effective process and production controls in which is required in W11.2.2.

### 2. Approval application

### 2.1 Documents to be submitted

The manufacturer has to submit to the Society, request of approval, proposed approval test program (see 3.1) and general information relevant to:

a) Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

b) Organization and quality:
- organizational chart
- staff employed
- staff employed and organization of the quality control department
- qualification of the personnel involved in activities related to the quality of the products
- certification of compliance of the quality system with IS0 9001 or 9002, if any
- approval certificates already granted by other Classification Societies, if any

c) Manufacturing facilities
- flow chart of the manufacturing process
- origin and storage of raw materials
- storage of finished products
- equipment for systematic control during fabrication

d) Details of inspections and quality control facilities
- details of system used for identification of materials at the different stages of manufacturing
- equipment for chemical analyses and relevant calibration procedures
- list of quality control procedures

e) Type of products (ingots, slabs, blooms, billets); types of steel (normal or higher strength), range of thickness and aim material properties as follows:
- range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical

**W11**
**(cont)**

composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- aim maximum carbon equivalent according to IIW formula
- aim maximum Pcm content for higher strength grades with low carbon content C < 0.13 %
- production statistics of the chemical composition and, if available at rolling mills, mechanical properties (ReH, Rm, A% and KV). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

f) Steelmaking
- steel making process and capacity of furnace/s or converter/s
- raw material used
- deoxidation and alloying practice
- desulphurisation and vacuum degassing installations, if any
- casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided as appropriate.
- ingot or slab size and weight
- ingot or slab treatment: scarfing and discarding procedures

g) Approval already granted by other Classification Societies and documentation of approval tests performed.

### 2.2 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to the Society the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through c):

a) Change of the manufacturing process (steel making process, casting method, steel making plant, caster)
b) Change of the thickness range (dimension)
c) Change of the chemical composition, added element, etc.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

## 3. Approval tests

### 3.1 Extent of the approval tests

The extent of the test program is specified in 3.6, it may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular a reduction of the indicated number of casts, product thicknesses and types to be tested or complete suppression of the approval tests may be accepted by the Society taking into account:

a) Approval already granted by other Classification Societies and documentation of approval tests performed.
b) Types of steel to be approved and availability of long term statistic results of chemical properties and of mechanical tests performed on rolled products.

**W11 (cont)**

c) Change of the approval conditions.

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

### 3.2 Approval test program

Where the number of tests differs from those shown in 3.6, the program is to be confirmed by the Society before the tests are carried out.

### 3.3 Approval survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant and the execution of the plant inspection in operation may be required by the Surveyor during the visit for the approval.

If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

### 3.4 Selection of the test product

For each type of steel and for each manufacturing process (e.g. steel making, casting), one test product with the maximum thickness and one test product with the minimum thickness to be approved are in general to be selected for each kind of product (ingots, slabs, blooms/billets).

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified Ceq or Pcm values and grain refining micro-alloying additions.

### 3.5 Position of the test samples

The test samples are to be taken, unless otherwise agreed, from the product (slabs, blooms, billets) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

### 3.6 Tests on base material

#### 3.6.1 Type of tests

The tests to be carried out for the approval of the manufacturing process of semi-finished products are:

- Chemical analysis. The analysis is to be complete and is to include micro alloying elements.
- Sulphur prints.

In addition, for initial approval and for any upgrade of the approval, the Society will require full tests indicated in Appendix A2.3 to be performed at rolling mill on the minimum thickness semi finished product.

In case of a multi-caster work, full tests on finished products shall be carried out for one caster and reduced tests (chemical analysis and sulphur print) for the others. The selection of the caster shall be based on the technical characteristics of the casters to be evaluated on

**W11 (cont)**

case by case basis to be performed at rolling mill on products manufactured from the minimum thickness semi finished product.

### 3.6.2 Test specimens and testing procedure

The following tests and procedures apply:

a) Chemical analyses
Both the ladle and product analyses are to be reported. In general the content of the following elements is to be checked: C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti and, for steel manufactured from electric or open-hearth furnace, Sb and B.

b) Sulphur prints are to be taken from product edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600 mm long taken from the centre of the edge selected, i.e. on the ingot centreline, and are to include the full product thickness.

## 4. Results

All the results, which are in any case to comply with the requirements of the Rules, are evaluated for the approval; depending on the results, particular limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All the information required under Appendix A2.2, applicable to the products submitted to the tests, is to be collected by the manufacturer and put in the dossier which will include all the results of the tests and operation records relevant to steel making, casting and, when applicable, rolling and heat treatment of the test products.

## 5. Certification

### 5.1 Approval

Upon satisfactory completion of the survey, approval is granted by the Society.

On the approval certificate the following information is to be stated:

- Type of products (ingots, slabs, blooms, billets)
- Steelmaking and casting processes
- Thickness range of the semi-finished products
- Types of steel (normal or higher strength)

It is also to be indicated that the individual users of the semi finished products are to be approved for the manufacturing process of the specific grade of rolled steel products they are going to manufacture with those semi finished products.

### 5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

**W11**
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## 6. Renewal of approval

The validity of the approval is to be a maximum of five years.

Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period*. Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of results of production of similar grades of products, at the discretion of the Society, be re-approved.

## 7. Reconsideration of the approval

During the period of validity the approval may be reconsidered in the following cases:

a) in service failures, traceable to product quality

b) non conformity of the product revealed during fabrication and construction

c) discovered failure of the Manufacturer's quality system

d) changes brought by the Manufacturer, without preliminary agreement of the Society, to the extent of the approval defined at the time of the approval

e) evidence of major non conformities during testing of the products.

* The provision for renewal of approval is also to be applied to all grades and products which were approved by the Society prior to an implementation of revision 4 of this UR W 11 regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 4 becomes effective.

**W11**
**(cont)**

## A2. Manufacturing Approval Scheme of Hull Structural Steels

### 1. Scope of application

This document specifies, as given in W11.2.1, the scheme for the approval of the manufacturing process of normal and higher strength hull structural steels.

The manufacturing approval scheme is valid for verifying the manufacturer's capability to provide satisfactory products stably under effective process and production controls in operation including programmed rolling, which is required in W11.2.2 and W11.3.3.

### 2. Approval application

#### 2.1 Documents to be submitted

The manufacturer has to submit to the Society, request of approval, proposed approval test program (see 3.1) and general information relevant to:

a) Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

b) Organization and quality:
- organizational chart
- staff employed
- staff employed and organization of the quality control department
- qualification of the personnel involved in activities related to the quality of the products
- certification of compliance of the quality system with IS0 9001 or 9002, if any
- approval certificates already granted by other Classification Societies, if any

c) Manufacturing facilities
- flow chart of the manufacturing process
- origin and storage of raw materials
- storage of finished products
- equipment for systematic control during fabrication

d) Details of inspections and quality control facilities
- details of system used for identification of materials at the different stages of manufacturing
- equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- equipment for non destructive examinations
- list of quality control procedures

e) Type of products (plates, sections, coils), grades of steel, range of thickness and aim material properties as follows:
- range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- aim maximum carbon equivalent according to IIW formula

**W11**
**(cont)**

- aim maximum Pcm content for higher strength grades with low carbon content C < 0.13 %
- production statistics of the chemical composition and mechanical properties (ReH, Rm, A% and KV). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

f) Steelmaking
- steel making process and capacity of furnace/s or converter/s
- raw material used
- deoxidation and alloying practice
- desulphurisation and vacuum degassing installations, if any
- casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided as appropriate.
- ingot or slab size and weight
- ingot or slab treatment: scarfing and discarding procedures

g) Reheating and rolling
- type of furnace and treatment parameters
- rolling: reduction ratio of slab/bloom/billet to finished product thickness, rolling and finishing temperatures
- descaling treatment during rolling
- capacity of the rolling stands

h) Heat treatment
- type of furnaces, heat treatment parameters and their relevant records
- accuracy and calibration of temperature control devices

i) Programmed rolling
For products delivered in the controlled rolling(CR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:
- description of the rolling process
- normalizing temperature, re-crystallization temperature and Ar3 temperature and the methods used to determine them
- control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- calibration of the control equipment

j) Recommendations for working and welding in particular for products delivered in the CR or TM condition
- cold and hot working recommendations if needed in addition to the normal practice used in the shipyards and workshops
- minimum and maximum heat input if different from the ones usually used in the shipyards and workshops (15 - 50 kJ/cm)

k) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by the Society is to be included.

l) Approval already granted by other Classification Societies and documentation of approval tests performed.

W11
(cont)

### 2.2 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to the Society the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through e) as applicable:

a) Change of the manufacturing process (steel making, casting, rolling and heat treatment)
b) Change of the maximum thickness (dimension)
c) Change of the chemical composition, added element, etc.
d) Subcontracting the rolling, heat treatment, etc.
e) Use of the slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

## 3. Approval tests

### 3.1 Extent of the approval tests

The extent of the test program is specified in 3.6 and 3.7; it may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete suppression of the approval tests may be accepted by the Society taking into account:

a) Approval already granted by other Classification Societies and documentation of approval tests performed
b) Grades of steel to be approved and availability of long term statistic results of chemical and mechanical properties
c) Approval for any grade of steel also covers approval for any lower grade in the same strength level, provided that the aim analyses, method of manufacture and condition of supply are similar.
d) For higher tensile steels, approval of one strength level covers the approval of the strength level immediately below, provided the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.
e) Change of the approval conditions

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 3.6 and 3.7. A reduction or complete suppression of the approval tests may considered by the Society taking into account previous approval as follows:

- the rolled steel manufacturer has already been approved for the manufacturing process using other semi finished products characterized by the same thickness, steel grade, grain refining and micro-alloying elements, steel making and casting process;

**W11 (cont)**

- the semi finished products manufacturer has been approved for the complete manufacturing process with the same conditions (steelmaking, casting, rolling and heat treatment) for the same steel types.

### 3.2 Approval test program

Where the number of tests differs from those shown in 3.6 and 3.7, the program is to be confirmed by the Society before the tests are carried out.

### 3.3 Approval survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant and the execution of the plant inspection in operation may be required by the Surveyor during the visit for the approval.

If the testing facilities are not available at the works, the tests are to be carried out at recognised laboratories.

### 3.4 Selection of the test product

For each grade of steel and for each manufacturing process (e.g. steel making, casting, rolling and condition of supply), one test product with the maximum thickness (dimension) to be approved is in general to be selected for each kind of product.

In addition, for initial approval, the Society will require selection of one test product of average thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified Ceq or Pcm values and grain refining micro-alloying additions.

### 3.5 Position of the test samples

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

The position of the samples to be taken in the length of the rolled product, "piece" defined in W11.11.1(a), (top and/or bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in Table 1.

The position of the samples in the width of the product is to be in compliance with W11.11.2(d).

### 3.6 Tests on base material

#### 3.6.1 Type of tests

The tests to be carried out are indicated in the following Table 1.

**W11**
**(cont)**

**Table 1 Tests on base material**

| Type of test | Position of the samples and direction of the test specimens (1) | Remarks | | | |
|---|---|---|---|---|---|
| Tensile test | Top and bottom transverse (2) | ReH, Rm, $A_5$(%), RA(%) are to be reported | | | |
| Tensile test (stress relieved) only for TM steels | Top and bottom transverse (2) | Stress relieving at 600 °C (2 min/mm with minimum 1 hour) | | | |
| Impact tests (3) on non aged specimens for grades: | Top and bottom - longitudinal | Testing temperature (°C) | | | |
| A, B, A32, A36, A40 | | +20 | 0 | -20 | |
| D, D32, D36, D40 | | 0 | -20 | -40 | |
| E, E32, E36, E40 | | 0 | -20 | -40 | -60 |
| F32, F36, F40 | | -20 | -40 | -60 | -80 |
| A, B, A32, A36, A40 | Top - transverse (4) | +20 | 0 | -20 | |
| D, D32, D36, D40 | | 0 | -20 | -40 | |
| E, E32, E36, E40 | | -20 | -40 | -60 | |
| F32, F36, F40 | | -40 | -60 | -80 | |
| Impact test (3) on strain aged specimens (5) for grades: | Top - longitudinal | Testing temperature (°C) | | | |
| A32, A36, A40 | | +20 | 0 | -20 | |
| D, D32, D36, D40 | | 0 | -20 | -40 | |
| E, E32, E36, E40 | | -20 | -40 | -60 | |
| F32, F36, F40 | | -40 | -60 | -80 | |
| Chemical analyses (6) | Top | Complete analyses including micro alloying elements | | | |
| Sulphur prints | Top | | | | |
| Micro examination | Top | | | | |
| Grain size determination | Top | only for fine grain steels | | | |
| Drop weight test (4) | Top | only for grades E, E32, E36, E40, F32, F36, F40 | | | |
| Through thickness tensile tests | Top and bottom | only for grades with improved through thickness properties | | | |

1) For hot rolled strips see 3.6.2.
2) Longitudinal direction for sections and plates having width less than 600 mm.
3) One set of 3 Charpy V-notch impact specimens is required for each impact test.
4) Not required for sections and plates having width less than 600 mm.
5) Deformation 5% + 1 hour at 250°C.
6) Besides product analyses, ladle analyses are required.

### 3.6.2 Test specimens and testing procedure

The test specimens and testing procedures are to be, as a rule, in accordance with W2.

In particular the following applies:

a) Tensile test
- for plates made from hot rolled strip one additional tensile specimen is to be taken from the middle of the strip constituting the coil.
- for plates having thickness higher than 40 mm, when the capacity of the available testing machine is insufficient to allow the use of test specimens of full thickness, multiple flat specimens, representing collectively the full thickness, can be used. Alternatively two round specimens with the axis located at one quarter and at mid-thickness can be taken.

**W11 (cont)**

b) Impact test
- for plates made from hot rolled strip one additional set of impact specimens is to be taken from the middle of the strip constituting the coil.
- for plates having thickness higher than 40 mm one additional set of impact specimens is to be taken with the axis located at mid-thickness.
- in addition to the determination of the energy value, also the lateral expansion and the percentage crystallinity are to be reported.

c) Chemical analyses
Both the ladle and product analyses are to be reported. The material for the product analyses should be taken from the tensile test specimen. In general the content of the following elements is to be checked: C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti and, for steel manufactured from electric or open-hearth furnace, Sb and B.

d) Sulphur prints are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600 mm long taken from the centre of the edge selected, i.e. on the ingot centreline, and are to include the full plate thickness.

e) Micrographic examination: the micrographs are to be representative of the full thickness. For thick products in general at least three examinations are to be made at surface, one quarter and mid-thickness of the product.

All photomicrographs are to be taken at x100 magnification and where ferrite grain size exceeds ASTM 10, additionally at x500 magnification. Ferrite grain size should be determined for each photomicrograph.

f) Drop weight test: the test is to be performed in accordance with ASTM E208. The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report.

g) Through thickness tensile test: the test is to be performed in accordance with W14. The test results are to be in accordance, where applicable, with the requirements specified for the different steel grades in W11.

#### 3.6.3 Other tests

Additional tests such as CTOD test, large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of W11, or when deemed necessary by the Society.

### 3.7 Weldability tests

#### 3.7.1 General

Weldability tests are required for plates and are to be carried out on samples of the thickest plate. Tests are required for normal strength grade E and for higher strength steels.

#### 3.7.2 Preparation and welding of the test assemblies

The following tests are in general required:

a) 1 butt weld test assembly welded with a heat input approximately 15 kJ/cm

**W11 (cont)**

b) 1 butt weld test assembly welded with a heat input approximately 50 kJ/cm.

The butt weld test assemblies are to be prepared with the weld seam transverse to the plate rolling direction, so that impact specimens will result in the longitudinal direction.
The bevel preparation should be preferably 1/2V or K.
The welding procedure should be as far as possible in accordance with the normal welding practice used at the yards for the type of steel in question.
The welding parameters including consumables designation and diameter, pre-heating temperatures, interpass temperatures, heat input, number of passes, etc. are to be reported.

### 3.7.3 Type of tests

From the test assemblies the following test specimens are to be taken:

a) 1 cross weld tensile test

b) a set of 3 Charpy V-notch impact specimens transverse to the weld with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.

c) Hardness tests HV 5 across the weldment. The indentations are to be made along a 1 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:

- Fusion line
- HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

The maximum hardness value should not be higher than 350 HV.

A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations should be attached to the test report together with photomacrographs of the weld cross section.

### 3.7.4 Other tests

Additional tests such as cold cracking tests (CTS, Cruciform, Implant, Tekken, Bead-on plate), CTOD, or other tests may be required in the case of newly developed type of steel, outside the scope of W11, or when deemed necessary by the Society.

## 4. Results

All the results, which are in any case to comply with the requirements of the Rules, are evaluated for the approval; depending on the results, particular limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All the information required under Appendix 2.2, applicable to the products submitted to the tests, is to be collected by the manufacturer and put in the dossier which will include all the results of the tests and operation records relevant to steel making, casting, rolling and heat treatment of the test products.

**W11 (cont)**

## 5. Certification

### 5.1 Approval

Upon satisfactory completion of the survey, approval is granted by the Society.

### 5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

## 6. Renewal of approval

The validity of the approval is to be a maximum of five years.

Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period.*

Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of results of production of similar grades of products, at the discretion of the Society, be reapproved.

## 7. Reconsideration of the approval

During the period of validity the approval may be reconsidered in the following cases:

a) in service failures, traceable to product quality

b) non conformity of the product revealed during fabrication and construction

c) discovered failure of the Manufacturer's quality system

d) changes brought by the Manufacturer, without preliminary agreement of the Society, to the extent of the approval defined at the time of the approval

e) evidence of major non conformities during testing of the products.

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* The provision for renewal of approval is also to be applied to all grades and products which were approved by the Society prior to an implementation of revision 4 of this UR W 11 regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 4 becomes effective.

**W11**
**(cont)**

## Appendix B. Approval scheme for manufacturer of hull structural steels intended for welding with high heat input

### 1. Scope

This document specifies the weldability confirmation scheme of normal and higher strength hull structural steels stipulated in UR W11 intended for welding with high heat input over 50kJ/cm.

The weldability confirmation scheme is to be generally applied by manufacturer's option and valid for certifying that the steel has satisfactory weldability for high heat input welding concerned under testing conditions.

Demonstration of conformance to the requirements of this document approves a particular steel mill to manufacture grade of steel to the specific chemical composition range, melting practice, and processing practice for which conformance was established. The approval scheme does not apply to qualification of welding procedures to be undertaken by the shipyards.

### 2. Application of certification

The manufacturer is to submit to the Classification Society, request of certification, proposed weldability test program (see section 3.2) and technical documents relevant to:

a) Outline of steel plate to be certified
   - grade
   - thickness range
   - deoxidation practice
   - fine grain practice
   - aim range of chemical composition
   - aim maximum Ceq and Pcm
   - production statistics of mechanical properties (tensile and Charpy V-notch impact tests), if any

b) Manufacturing control points to prevent toughness deterioration in heat affected zone when welded with high heat input, relevant to chemical elements, steel making, casting, rolling, heat treatment etc.

c) Welding control points to improve joint properties on strength and toughness, if any.

### 3. Confirmation tests

#### 3.1 Range of certification

Range of certification for steel grades is to be the following a) through e) unless otherwise agreed by the Classification Society:

a) Approval tests on the lowest and highest toughness levels cover the intermediate toughness level.
b) Approval tests on normal strength level cover that strength level only.

**W11 (cont)**

c) For high tensile steels, approval tests on one strength level cover strength level immediately below.
d) Tests may be carried out separately subject to the same manufacturing process.
e) Certification and documentation of confirmation tests performed by other Classification Society may be accepted at the discretion of the Classification Society.

### 3.2 Weldability test program

Extent of the test program is specified in section 3.5 but it may be modified according to the contents of certification. In particular, additional test assemblies and/or test items may be required in the case of newly developed type of steel, welding consumable and welding method, or when deemed necessary by the Classification Society.

Where the content of tests differs from those specified in section 3.5, the program is to be confirmed by the Classification Society before the tests are carried out.

### 3.3 Test plate

Test plate is to be manufactured by a process approved by the Classification Society in accordance with the requirements of UR W11 Appendix A.

For each manufacturing process route, two test plates with different thickness are to be selected. The thicker plate (t) and thinner plate (less than or equal to t/2) are to be proposed by the manufacturer.

Small changes in manufacturing processing (e.g. within the TMCP process) may be considered for acceptance without testing, at the discretion of the Classification Society.

### 3.4 Test assembly

One butt weld assembly welded with heat input over 50kJ/cm is to be generally prepared with the weld axis transverse to the plate rolling direction.

Dimensions of the test assembly are to be amply sufficient to take all the required test specimens specified in section 3.5.

The welding procedures should be as far as possible in accordance with the normal practices applied at shipyards for the test plate concerned.

Welding process, welding position, welding consumable (manufacturer, brand, grade, diameter and shield gas) and welding parameters including bevel preparation, heat input, preheating temperatures, interpass temperatures, number of passes, etc. are to be reported.

### 3.5 Examinations and tests for the test assembly

The test assembly is to be examined and tested in accordance with the following a) through h) unless otherwise agreed by the Classification Society.

a) Visual examination
Overall welded surface is to be uniform and free from injurious defects such as cracks, undercuts, overlaps, etc.

**W11 (cont)**

b) Macroscopic test
One macroscopic photograph is to be representative of transverse section of the welded joint and is to show absence of cracks, lack of penetration, lack of fusion and other injurious defects.

c) Microscopic test
Along mid-thickness line across transverse section of the weld, one micrograph with x100 magnification is to be taken at each position of the weld metal centreline, fusion line and at a distance 2, 5, 10 and minimum 20 mm from the fusion line. The test result is provided for information purpose only.

d) Hardness test
Along two lines across transverse weld section 1 mm beneath plate surface on both face and root side of the weld, indentations by HV5 are to be made at weld metal centreline, fusion line and each 0.7 mm position from fusion line to unaffected base metal (minimum 6 to 7 measurements for each heat affected zone).

The maximum hardness value should not be higher than 350 HV.

e) Transverse tensile test
Two transverse (cross weld) tensile specimens are to be taken from the test assembly. Test specimens and testing procedures are to comply with the requirements of UR W2.

The tensile strength is to be not less than the minimum required value for the grade of base metal.

f) Bend test
Two transverse (cross weld) test specimens are to be taken from the test assembly and bent on a mandrel with diameter of quadruple specimen thickness. Bending angle is to be at least 120°. Test specimens are to comply with the requirements of UR W2.

For plate thickness up to 20 mm, one face-bend and one root-bend specimens or two side-bend specimens are to be taken. For plate thickness over 20 mm, two side-bend specimens are to be taken.

After testing, the test specimens shall not reveal any crack nor other open defect in any direction greater than 3 mm.

g) Impact test
Charpy V-notch impact specimens (three specimens for one set) are to be taken within 2 mm below plate surface on face side of the weld with the notch perpendicular to the plate surface.

One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.

For steel plate with thickness greater than 50 mm or one side welding for plate thickness greater than 20 mm, one additional set of the specimens is to be taken from the root side of the weld with the notch located at each the same position as for the face side.

The average impact energy at the specified test temperature is to comply with the Tables 6 or 7 of UR W11 depending on the steel grade and thickness. Only one individual value may be below the specified average value provided it is not less than 70% of that value.

**W11 (cont)**

Additional tests at the different testing temperatures may be required for evaluating the transition temperature curve of absorbed energy and percentage crystallinity at the discretion of the Classification Society.

h) Other test
Additional tests such as wide-width tensile test, HAZ tensile test, cold cracking tests (CTS, Cruciform, Implant, Tekken, and Bead-on plate), CTOD or other tests should be required at the discretion of the Classification Society (see section 3.2).

**4. Results**

The manufacturer is to submit to the Classification Society the complete test report including all the results and required information relevant to the confirmation tests specified in section 3.

The contents of the test report are to be reviewed and evaluated by the Classification Society in accordance with this weldability confirmation scheme.

**5. Certification**

The Classification Society issues the certificate where the test report is found to be satisfactory.

The following information is generally required to be included on the certificate:
a) Manufacturer
b) Grade designation with notation of heat input (see section 6)
c) Deoxidation practice
d) Fine grain practice
e) Condition of supply
f) Plate thickness tested
g) Welding process
h) Welding consumable (manufacturer, brand, grade), if desired
i) Actual heat input applied.

**6. Grade designation**

Upon issuance of the certificate, the notation indicating the value of heat input applied in the confirmation test may be added to the grade designation of the test plate, e.g. “E36-W300” (in the case of heat input 300 kJ/cm applied). The value of this notation is to be not less than 50 and every 10 added.

End of Document

# W12 Deleted

# W13 Thickness tolerances of steel plates and wide flats

(1981) (Rev.1 1989) (Rev.2 1992) (Rev.3 1995) (Rev.4 Oct 2009) (Rev.5 Feb 2012)

## W13.1 Scope

W13.1.1 These requirements apply to the tolerance on thickness of steel plates and wide flats with widths of 600 mm or greater (hereinafter referred to as: product or products) with thicknesses of 5 mm and over, covering the following steel grades:

(i) Normal and higher strength hull structural steels according to W11

(ii) High strength quenched and tempered steels for welded structure according to UR W16

(iii) Steels for machinery structures in accordance with the individual Rules of Classification Societies

The thickness tolerances for products below 5 mm may be specially agreed.

NOTE:
Tolerances for length, width, flatness and over thickness may be taken from national or international standards.

W13.1.2 These requirements do not apply to products intended for the construction of boilers, pressure vessels and independent tanks, e.g. for the transportation of liquefied gases or chemicals.

W13.1.3 Class C of ISO 7452 may be applied in lieu of W13.3, in which case the requirements in W13.4 and W13.5 need not be applied. If Class C of ISO 7452 is to be used, the portion of the footnote of ISO 7452, Table B.2, which reads “Also a minus side of thickness of 0,3 mm is permitted.” is not to be applied.

Additionally, if ISO 7452 is applied, it is required that the steel mill demonstrate to the satisfaction of the Classification Society that the number of measurements and measurement distribution is appropriate to establish that the mother plates produced are at or above the specified nominal thickness.

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Note:

1. Rev.4 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2011 and when the application for certification of steel plates is dated on or after 1 January 2011.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR)No. 29.

3. Rev.5 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2013 and when the application for certification of steel plates is dated on or after 1 January 2013.

**W13**
**(cont)**

### W13.2 Responsibility

W13.2.1 The responsibility for verification and maintenance of the production within the required tolerances rests with the manufacturer. The Surveyor may require to witness some measurements.

W13.2.2 The responsibility for storage and maintenance of the delivered product(s) with acceptable level of surface conditions rests with the shipyard before the products are used in fabrication.

### W13.3 Thickness tolerances

W13.3.1 The tolerances on thickness of a given product are defined as:

- Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

- Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

NOTE:
Nominal thickness is defined by the purchaser at the time of enquiry and order.

W13.3.2 The minus tolerance on thickness of products in accordance with UR W11 and UR W16 is 0.3 mm irrespective of nominal thickness.

W13.3.3 The minus tolerances for products for machinery structures are to be in accordance with Table 1.

**Table 1**

| Nominal thickness (t) (mm) | Tolerance (mm) |
|---|---|
| $5 \le t < 8$ | -0.4 |
| $8 \le t < 15$ | -0.5 |
| $15 \le t < 25$ | -0.6 |
| $25 \le t < 40$ | -0.8 |
| $t \ge 40$ | -1.0 |

W13.3.4 The tolerances on nominal thickness are not applicable to areas repaired by grinding which are to be in accordance with a recognized standard. The IACS recommendation No.12 may be used for this purpose.

W13.3.5 The plus tolerances on nominal thickness are to be in accordance with a recognized national or international standard.

### W13.4 Average thickness

W13.4.1 The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements of W13.5.

W13.4.2 The average thickness of a product or products in accordance with URs W11 or W16 is not to be less than the nominal thickness.

**W13**
**(cont)**

### W13.5 Thickness measurements

W13.5.1 The thickness is to be measured at locations of a product or products as defined in Annex.

W13.5.2 Automated method or manual method is applied to the thickness measurements.

W13.5.3 The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.

**W13**
**(cont)**

## ANNEX: Thickness Measuring Locations

### A.1 Scope of application

This Annex applies to the thickness measuring locations for the thickness tolerance and the average thickness of the product.

### A.2 Measuring locations

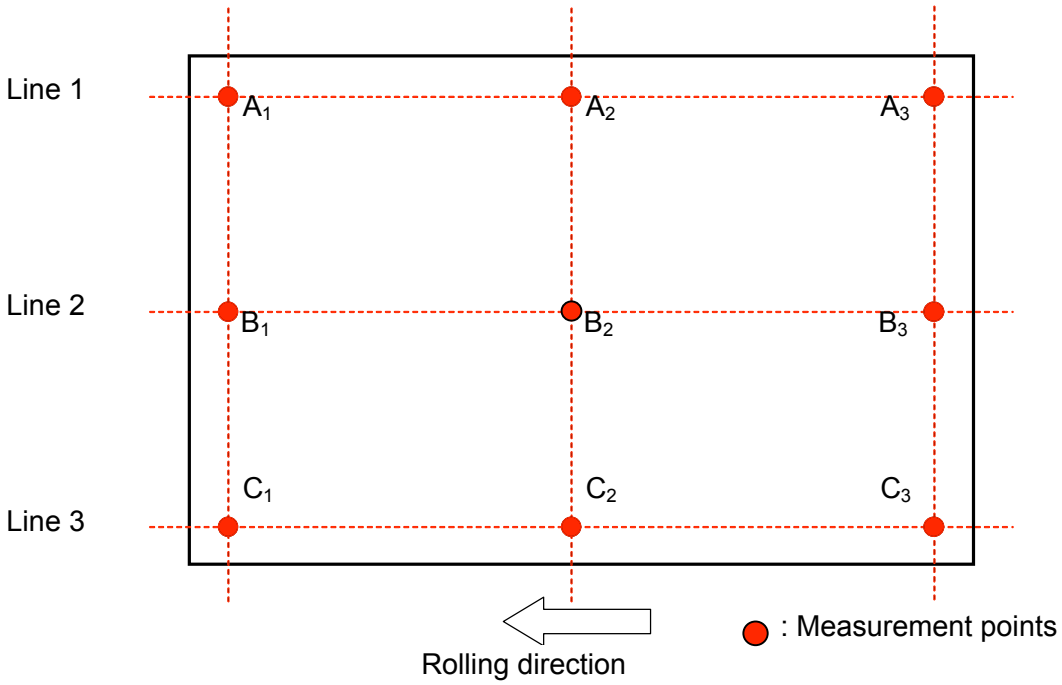
At least two lines among Line 1, Line 2 or Line 3 as shown in Figure A.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Figure A.1 are to be selected for thickness measurement. If more than three points are taken on each line the number of points shall be equal on each line.

NOTE:
The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in Figure A.2. It is to be noted that the examples shown are not representative of all possible cutting scenarios.

For automated methods, the measuring points at sides are to be located not less than 10 mm but not greater than 300 mm from the transverse or longitudinal edges of the product.

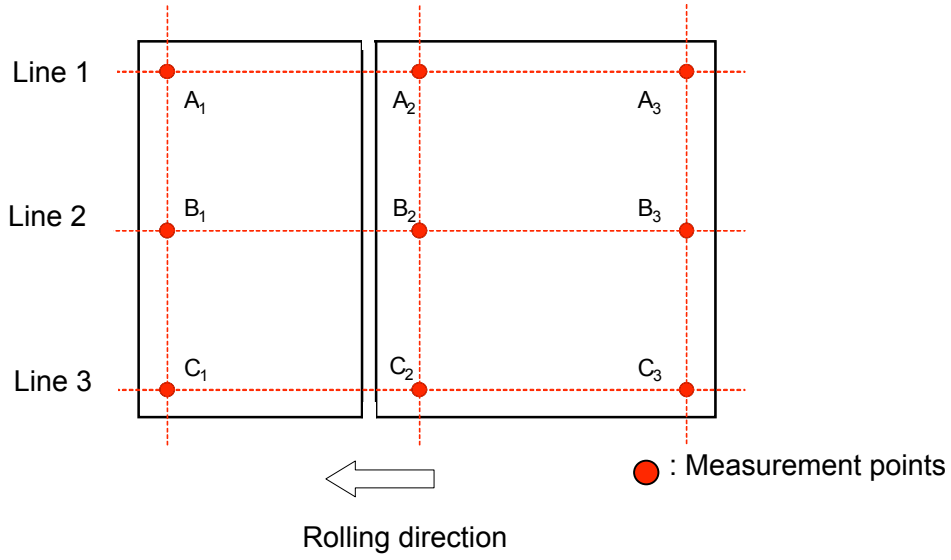
For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.

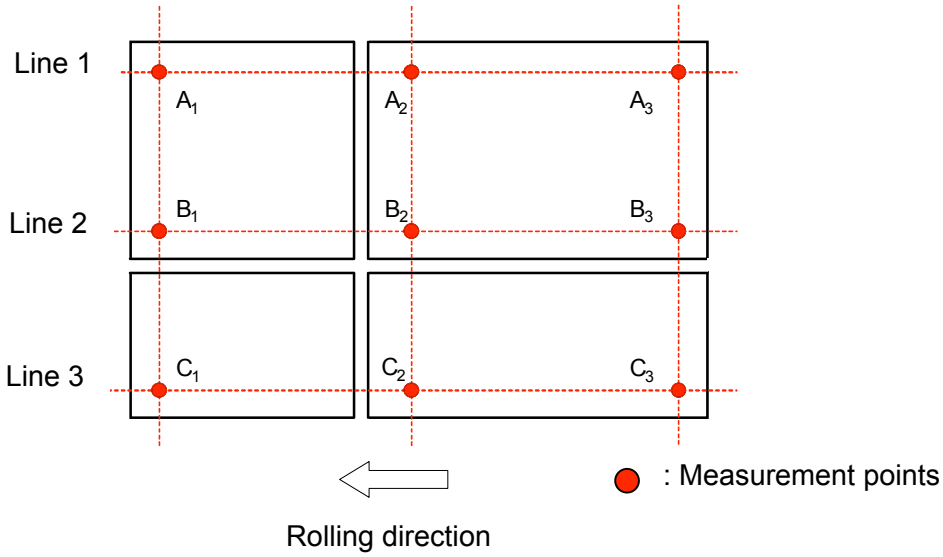
**Figure A.1 - Locations of Thickness Measuring Points for the Original Steel Plates**

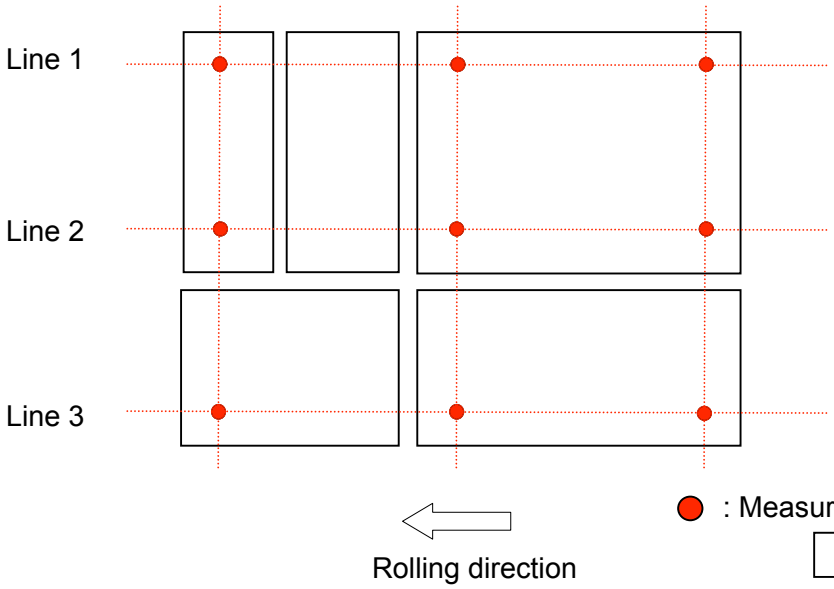


**W13**
**(cont)**

**Figure A.2 - Locations of Thickness Measuring Points for the Cut Steel Products**

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# W14 Steel plates and wide flats with specified minimum through thickness properties ("Z" quality)

(1982) (Rev.1 July 2002) (Rev.2 May 2004)

### W14.1 Scope

These requirements supplement those given in W11 and W16 for material with a thickness greater than or equal to 15mm and intended to have a specified minimum ductility in the through thickness or "Z" direction (Figure 1). Products with a thickness less than 15mm may be included at the discretion of the Society.

The use of such material, known as "Z" quality steel, is recommended for structural details subject to strains in the through thickness direction to minimise the possibility of lamellar tearing during fabrication. Two "Z" quality steels are specified, Z25 for normal ship applications and Z35 for more severe applications.

Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

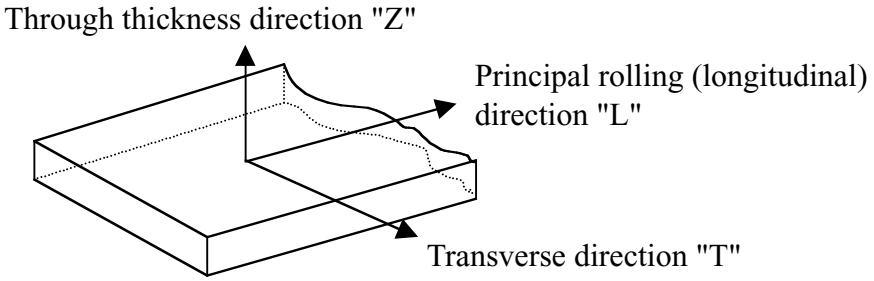


**Figure 1** Schematic of testing directions

**W14** (cont'd)

### W14.2 Manufacture

All the materials are to be manufactured at works approved by the Society for "Z" quality steels.

The approval should follow the procedure given in UR W11 Appendix A but take into account the improved steelmaking techniques of calcium treatment, vacuum degassing and argon stirring as well as the control of centre-line segregation during continuous casting.

### W14.2 *bis* Chemical composition

In addition to the requirements of the appropriate steel specification W11 or W16, the maximum sulphur content is to be 0.008% determined by the ladle analysis.

### W14.3 Test procedure

In addition to the requirements of the appropriate steel specification W11 or W16, preparation of specimens and testing procedures are to be as follows:

W14.3.1 Test sampling

For plates and wide flats, one test sample is to be taken close to the longitudinal centreline of one end of each rolled piece representing the batch. See Table 1 and Figure 2.

**Table 1** Batch size dependent on product and sulphur content

| Product | S > 0.005% | S ≤ 0.005% |
|---|---|---|
| Plates | Each piece(parent plate) | Maximum 50t of products of the same cast, thickness and heat treatment |
| Wide flats of normal thickness ≤ 25mm | Maximum 10t of products of the same cast, thickness and heat treatment | Maximum 50t of products of the same cast, thickness and heat treatment |
| Wide flats of nominal thickness >25mm | Maximum 20t of products of the same cast, thickness and heat treatment | Maximum 50t of products of the same cast, thickness and heat treatment |

W14.3.2 Number of tensile test specimens

The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

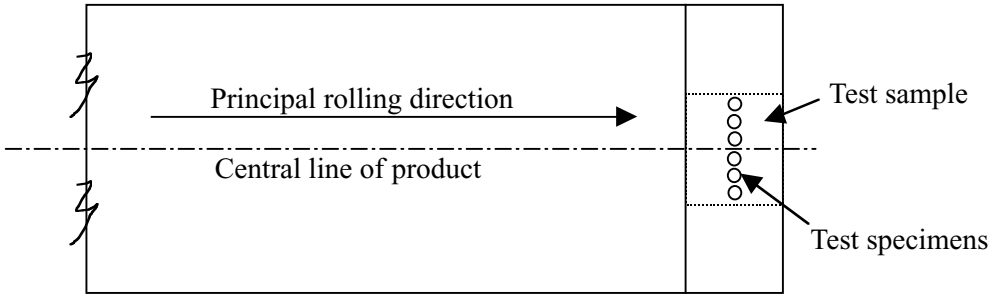


**Figure 2** Plate and wide flat sampling position

**W14** (cont'd)

W14.3.3 Tensile test specimen dimensions

Round test specimens including built-up type by welding are to be prepared in accordance with a recognised national standard.

W14.3.4 Tensile test results

The test is considered invalid and further replacement test is required if the fracture occurs in the weld or heat affected zone.

The minimum average value for the reduction of area of at least 3 tensile test specimens taken in the through thickness direction must be that shown for the appropriate grade given in Table 2. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade. See Figure 3.

A value less than the minimum individual value is a cause for rejection.

**Table 2** Reduction of area acceptance values

| Grade | Z25 | Z35 |
|---|---|---|
| Minimum average | 25% | 35% |
| Minimum individual | 15% | 25% |

**W14.4 Retest procedure**

Figure 3 shows the three cases where a retest situation is permitted. In these instances three more tensile tests are to be taken from the remaining test sample. The average of all 6 tensile tests is to be greater than the required minimum average with no greater than two results below the minimum average.

In the case of failure after retest, either the batch represented by the piece is rejected or each piece within the batch is required to be tested.

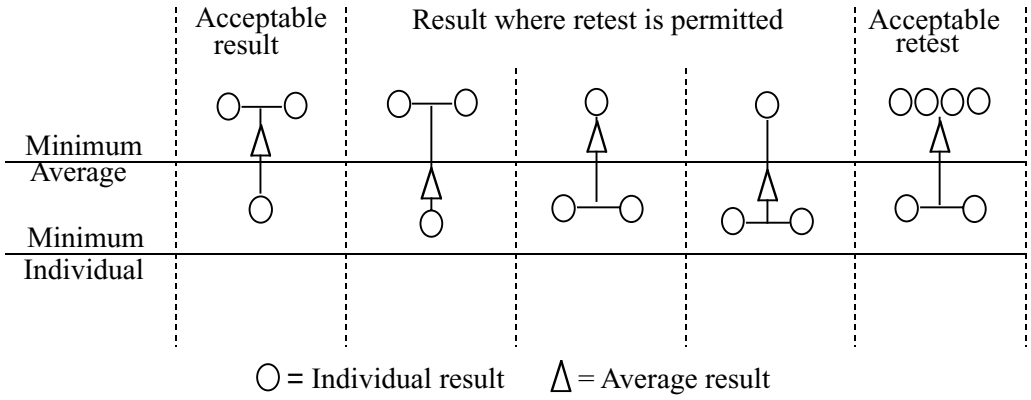


**Figure 3** Diagram showing acceptance / rejection and retest criteria

**W14**
(cont'd)

### W14.5 Ultrasonic tests

Ultrasonic testing is required and is to be performed in accordance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

Ultrasonic testing should be carried out on each piece in the final supply condition and with a probe frequency of 4MHz.

### W14.6 Marking

Products complying with these requirements are to be marked in accordance with the appropriate steel requirement W11 or W16 and in addition with the notation Z25 or Z35 added to the material grade designation, e.g. EH36Z25 or EH36Z35.

### W14.7 Certification

The following information is required to be included on the certificate in addition to the appropriate steel requirement given in W11 or W16:

(a) Through thickness reduction in area (%)
(b) Steel grade with Z25 or Z35 notation.

# W15 Deleted

# W16 High Strength Quenched and Tempered Steels for Welded Structures

(1984) (Rev.1 1994) (Rev.2 May 2004)

## W16.1 Scope

W16.1.1 These requirements apply to weldable high strength and tempered steel plates and wide flats up to 70 mm thickness. The application of these requirements for products with thicknesses above 70 mm are to be specially agreed with the Classification Society.

Product forms other than plates and wide flats, such as section and tubulars, may be provided to these requirements when specially agreed to by the Classification Society.

W16.1.2 Steel covered by the scope of these requirements are divided into six yield strength levels of 420, 460, 500, 550, 620 and 690 N/mm$^2$. For each yield strength level three grades D, E and F are specified, based on the impact test temperature.

W16.1.3 Steels differing in strength level, mechanical properties, chemical composition, etc, may be subject to special approval of the Classification Society.

W16.1.4 Special consideration may be given to the supply of those steels in thicknesses up to 50mm in the TMCP condition subject to approval of the Classification Society.

## W16.2 Approval

The steels must be approved by the Classification Society, and for this purpose the steel maker is to submit a specification containing such details as: chemical composition, manufacturing process, mechanical properties, delivery condition, recommendation for welding, cold and hot forming and heat treatment. In addition, the Classification Society may require initial approval tests to be performed.

Weldability of each grade of steel should be demonstrated by the steelmaker during the initial approval procedure to the satisfaction of the Classification Society.

## W16.3 Method of Manufacture

The steel is to be manufactured at works approved by the Classification Society, by the basic oxygen, electric furnace or open hearth process or by processes specially approved by the Classification Society. The steel shall be fully killed, and fine grain treated.

**Table 1**
**Chemical Composition**

| Yield Strength Level | Impact Grade | Maximum Content of Elements (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | C | Si | Mn | P | S | N |
| | A | 0,21 | 0,55 | 1,70 | 0,035 | 0,035 | 0,020 |
| 420 N/mm$^2$ to 690 N/mm$^2$ | D | 0,20 | 0,55 | 1,70 | 0,030 | 0,030 | 0,020 |
| | E | | | | | | |
| | F | 0,18 | 0,55 | 1,60 | 0,025 | 0,025 | 0,020 |

**W16** cont'd

### W16.4 Chemical composition

The chemical composition is to be determined by the steelmaker in an adequately equipped competently staffed laboratory from each cast or ladle and is to comply with the requirements of the approved specification and limits given in Table 1.

Elements used for alloying and fine grain treatment are to be as detailed in the approved specification,

The cold cracking susceptibility Pcm for evaluating weldability should be calculated from the ladle analysis in accordance with the following formula:

The maximum Pcm to be achieved is to be agreed with the Classification Society and included in the approved specification.

### W16.5 Heat treatment

The steels shall be in the quenched and tempered condition. See also W16.1.4.

### W16.6 Mechanical properties

W16.6.1 Tensile test

(a) For each piece as heat treated at least one tensile test specimen is to be taken and tested in accordance with UR W2. For continuous heat treated plates special consideration may be given regarding the number and location of test specimens required.

(b) Test specimens are to be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of section and rolled flats with a finished width of 600 m or less, where the tensile specimens may be taken in either the longitudinal or transverse direction as agreed by the Classification Society. Normally flat tensile test specimens are to be prepared in such a manner as to maintain the rolling scale at least at one side. Where the thickness exceeds 40mm, full thickness specimens may be prepared but when instead a machined round tensile test specimen is used then the axis must be located at a position lying at a distance of t/4 from the surface or as near as possible to this position.

(c) The results of the tests are to comply with the appropriate requirements of Table 2. In the case of other product forms where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those listed in Tables 2 and 3.

W16.6.2 Impact test

From each piece as heated treated at least one set of three V-notch impact test specimens in accordance with Requirement W2 is to be taken and tested. For continuous heat treated plates special consideration may be given to the number and location of test specimens required. Unless otherwise accepted by the Classification Society, the V-notch impact test specimens for plates and wide flats over 600 mm are to be taken with their axes transverse to the main rolling direction and the results should comply with the appropriate requirements of Table 2. For other product forms the impact tests are to be in the longitudinal direction, the results of the tests are to comply with the appropriate requirements of Table 2.

Normally sub-surface test specimens will be taken, however, for material with a thickness in excess of 40mm, impact tests should be taken at the quarter thickness (t/4) location.

▶

**W16**
cont'd

**Table 2**
**Mechanical properties requirements, 70 mm maximum thickness**

| Grade of Steel | | Tensile Properties: Yield Stress $R_{eH}$ ($N/mm^2$) Min (See Note 1) (See Note 2) | Tensile Properties: Tensile Strength ($R_m$) ($N/mm^2$) | Tensile Properties: $A_{min}$ Elongation ($L_o = 5.65\sqrt{S_0}$) (%) (See Note 3) | Charpy V notch impact test (See Note 4): Test temperature (°C) | Charpy V notch impact test (See Note 4): Average energy $J_{min}$ Long | trans |
|---|---|---|---|---|---|---|---|
| A | 420 | | | | 0 | | |
| D | 420 | | | | -20 | | |
| E | 420 | 420 | 530 ÷ 680 | 18 | -40 | 42 | 28 |
| F | 420 | | | | -60 | | |
| A | 460 | | | | 0 | | |
| D | 460 | | | | -20 | | |
| E | 460 | 460 | 570 ÷ 720 | 17 | -40 | 46 | 31 |
| F | 460 | | | | -60 | | |
| A | 500 | | | | 0 | | |
| D | 500 | | | | -20 | | |
| E | 500 | 500 | 610 ÷ 770 | 16 | -40 | 50 | 33 |
| F | 500 | | | | -60 | | |
| A | 550 | | | | 0 | | |
| D | 550 | | | | -20 | | |
| E | 550 | 550 | 670 ÷ 830 | 16 | -40 | 55 | 37 |
| F | 550 | | | | -60 | | |
| A | 620 | | | | 0 | | |
| D | 620 | | | | -20 | | |
| E | 620 | 620 | 720 ÷ 890 | 15 | -40 | 62 | 41 |
| F | 620 | | | | -60 | | |
| A | 690 | | | | 0 | | |
| D | 690 | | | | -20 | | |
| E | 690 | 690 | 770 ÷ 940 | 14 | -40 | 69 | 46 |
| F | 690 | | | | -60 | | |

Note 1 Where the Yield Stress reH does not mark in the tensile test the 0.2% proof stress $R_{po.2}$ is applicable.

Note 2 Subject to the discretion of the Classification Scoiety, a yield strength to ultimate tensile strength ratio may be required.

Note 3 For full thickness flat test specimens with a width of 25mm and a gauge length of 200mm the elongation is to comply with the minimum values shown in Table 3.

Note 4 For A grade steels, a relaxation in the number of impact tests required for acceptance purposes may be permitted by special agreement with the Classification Sociey tprovided that satisfactory results are obtained from occasional check tests.

▶

W16.6.3 Retest procedures

**W16** cont'd

Re-test procedures for tensile tests and Charpy impact tests are to be in accordance with UR W2.

**Table 3**
**Elongation Minimum Values for a Width of 25mm and a 200mm Gauge length**

| Strength Level | Thickness mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≤10 | >10 ≤15 | >15 ≤20 | >20 ≤25 | >25 ≤40 | >40 ≤50 | >50 ≤70 |
| 420 | 11 | 13 | 14 | 15 | 16 | 17 | 18 |
| 460 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 500 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 550 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 620 | 9 | 11 | 12 | 12 | 13 | 14 | 15 |
| 690 | 9 | 10 | 11 | 11 | 12 | 13 | 14 |

W16.6.4 Through thickness tensile test

If required by the Classification Society, through thickness tensile tests are to be performed in accordance with Requirement W14, "Steel plates and wide flats with improved thickness properties".

**W16.7 Tolerances**

Unless otherwise agreed or specially required, the thickness tolerances in Requirement W13, "Allowable under thickness tolerances of steel plates and wide flats" are applicable.

**W16.8 Identification of materials**

The steelmaker is to adopt a system for the identification of ingots, slabs and finished products, which will enable the material to be traced to its original cast.

**W16.9 Inspection**

W16.9.1 Facilities for inspection

The manufacturer is to afford the Surveyor all necessary facilities and access to all relevant parts of the works to enable him to verify the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by the Rules and for verifying the accuracy of the testing equipment.

W16.9.2 Freedom from defects

The steel is to be reasonably free from segregation and nonmetallic inclusions. The finished material is to be free from internal or surface defects prejudicial to the use of the materials for the intended application.

(a) Welding repair procedures and the method for reporting repairs are to be approved by the individual Classification Societies.

(b) Where repair by grinding is carried out then the remaining plate thickness below the ground area must be within the allowable under thickness tolerance.

**W16** cont'd

W16.9.3 Surface inspection and dimensions

Surface inspection and verification of dimensions are the responsibility of the steelmaker, and acceptance by the Classification Society's Surveyor of material later found to be defective shall not absolve the steelmaker of this responsibility.

W16.9.4 Ultrasonic examination

If required by the Classification Society the manufacturer is to perform ultrasonic examinations in accordance with an approved standard.

**W16.10 Branding**

Every finished piece is to be clearly marked by the maker in at least one place with the Classification Society's brand and the following particulars :

(a) Unified identification mark for the grade of steel (e.g. E620)
(b) Name or initials to identify the steelworks
(c) Heat number, plate number or equivalent identification mark.

The entire markings are to be encircled with paint or otherwise marked so as to be easily recognised.

**W16.11 Documentation**

The Surveyor is to be supplied with the number of copies, as required by the Classification Society of the test certificates or shipping statements for all accepted materials. The Classification Societies may require separate documents for each grade of steel. These documents are to contain, in addition to the description, dimensions, etc, of the material, at least the following particulars:

(a) Purchaser's order number and if known the ship number for which the material is intended.
(b) Identification of the cast and piece.
(c) Identification of the steelworks.
(d) Identification of the grade of steel.
(e) Ladle analysis (elements given in the approved specification).
(f) Condition of supply with heat treatment temperatures.

Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the tests required by the Rules of the Classification Societies. The name of the Classification Society is to appear on the test certificate. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the makers by an authorised official:

"We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of the Classification Society".

# W17 Approval of consumables for welding normal and higher strength hull structural steels

(1986) (Rev.1 1993) (Rev.2 May 2004) (Rev.3 June 2005)

## 1. General

### 1.1 Scope

1.1.1 These requirements give the conditions of approval and inspection of welding consumables used for hull structural steel welding as follows:

- normal strength steels Grades A, B, D and E ,
- higher strength steels Grades A32, D32, E32, A36, D36 and E36,
- higher strength steels with minimum yield strength 390 N/mm$^2$: Grades A 40, D 40 and E40,
- higher strength steels for low temperature application: Grades F 32, F 36 and F 40.

Welding consumables for high strength quenched and tempered steels for welded structures acc. to URW 16 are subject to special consideration by the individual Classification Society.

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

1.1.2 Categories of products
The concerned welding consumables are divided into several categories as follows:

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

### 1.2 Grading

1.2.1 Basic groups and grades
Filler metals are divided into two groups:

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

Each of the three groups is based on corresponding tensile strength requirements.
Each filler metal group is further divided into several grades:

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

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

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

1.2.2 Correlation of welding consumables to hull structural steel grades
The correlation between the hull steel grades and the welding consumables grades that must be used for the hull steel welding, is stated in the following Table 1:

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**W17**
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**Table 1 - Correlation of welding consumables to hull structural steels**

| Grades of welding | Hull structural steel grades | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| consumables (see notes) | A | B | D | E | A32/36 | D32/36 | E32/36 | F32/36 | A40 | D40 | E40 | F40 |
| 1, 1S. 1T, 1M, 1TM, IV | X | | | | | | | | | | | |
| 1YS, 1YT, 1YM, 1YTM, 1YV | X | | | | X[2)] | | | | | | | |
| 2, 2S, 2T, 2M, 2TM, 2V | X | X | X | | | | | | | | | |
| 2Y, 2YS, 2YT, 2YM, 2YTM, 2YV | X | X | X | | X | X | | | | | | |
| 2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V | 1) | 1) | 1) | | X | X | | | X | X | | |
| 3, 3S, 3T, 3M, 3TM, 3V | X | X | X | X | | | | | | | | |
| 3Y, 3YS, 3YT, 3YM, 3YTM, 3YV | X | X | X | X | X | X | X | | | | | |
| 3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V | 1) | 1) | 1) | 1) | X | X | X | | X | X | X | |
| 4Y, 4YS, 4YT, 4YM, 4YTM, 4YV | X | X | X | X | X | X | X | X | | | | |
| 4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V | 1) | 1) | 1) | 1) | X | X | X | X | X | X | X | X |
| 1) see note d)<br>2) see note e) | | | | | | | | | | | | |

NOTES:

(a) When joining normal to higher strength structural steel, consumables of the lowest acceptable grade for either material being joined may be used.

(b) When joining steels of the same strength level but of different toughness grade, consumables of the lowest acceptable grade for either material being joined may be used.

(c) It is recommended that controlled low hydrogen type consumables are to be used whenjoining higher strength structural steel to the same or lower strength level, except that other consumables may be used at the discretion of the Society when the carbon equivalent is below or equal to 0.41%.When other than controlled low hydrogen type electrodes are used appropriate procedure tests for hydrogen cracking may be conducted at the discretion of the Society.

(d) The welding consumables approved for steel Grades A 40, D 40, E 40 and/or F 40 may also be used for welding of the corresponding grades of normal strength steels subject to the special agreement with the Classification Society

(e) When joining higher strength steels using Grade 1Y welding consumables, the material thicknesses should not exceed 25 mm.

1.2.3 Hydrogen marks

Welding consumables of Grades 2 and 3 and Grades 2Y, 3Y and 4Y and of Grades 2Y 40, 3Y 40 and 4Y 40, for which the hydrogen content has been controlled in accordance with paragraph 4.5.3 are identified by the mark H15, H10 or H5.

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W17 cont'd

### 1.3 Manufacture

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

## 2. Approval procedure

### 2.1 Plant inspection

2.1.1 The Surveyor is to be satisfied that the manufacturer's plant, methods of production and quality control of welding consumables are to be such as to ensure a reasonable uniformity in manufacture, as mentioned in 1.3.1 above.

### 2.2 Test assemblies

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

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

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

### 2.3 Firms with several factories - sister firms

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

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

### 2.4 Annual inspection and tests

The production techniques and associated quality control procedures at all establishments approved for the manufacture of welding consumables are to be subjected to an annual re-appraisal. On these occasions, samples of the approved consumable are to be selected by the Surveyor and subjected to the tests detailed in subsequent sections of these Requirements. These are to be completed and reported within the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year. Equivalent alternative arrangements may be accepted subject to special agreement with the Classification Society.

### 2.5 Alterations to approved consumables

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

### 2.6 Upgrading and uprating

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

W17 cont'd

**2.7 Additional tests**

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

**3. Mechanical testing procedure**

**3.1 Test specimens**

3.1.1 Specimens dimensions
Deposited metal and butt weld tensile, butt weld bend and Charpy V-notch impact test specimens are to be machined to the dimensions given in UR W2.

3.1.2 Specimens location and preparation

.1 Deposited metal tensile
The longitudinal axis must coincide with the centre of the weld and:

(i) the mid thickness of the weld in the deposited metal test assemblies;
(ii) the mid thickness of the 2nd run in the two-run welded test assemblies.

The specimens may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal prior to testing.

.2. Butt weld tensile
The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

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

.4 Charpy V-notch impact
The test specimens shall be cut with their longitudinal axes transverse to the weld length and:

(i) at mid thickness of the weld in the deposit metal and butt weld test assemblies with multirun technique;
(ii) on the 2nd run side, 2 mm maximum below the surface in the two-run welded test assemblies;
(iii) 2 mm maximum below one surface in the electroslag or electrogas welded test assemblies.

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

**3.2 Testing procedures**

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

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

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

3.2.3 Charpy V-notch impact
Impact tests are to be carried out on a Charpy impact machine of an approved type.

A set of three test specimens is to be prepared and tested. The average absorbed energy value is to comply with the requirements of subsequent sections. One individual value may be less than the required average value provided that it is not less than 70% of this value.

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

**3.3 Re-test procedures**

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

3.3.2 Charpy V-notch impact
Re-test requirements for Charpy impact tests are to be in accordance with UR W2. Further re-tests may be made at the Surveyor's discretion, but these must be made on a new welded assembly and must include all tests required for the original assembly, even those which were previously satisfactory.

**4. Covered electrodes for manual arc welding**

**4.1 General**

4.1.1 Grades
Depending on the results of the Charpy V-notch impact tests, electrodes are divided into the following grades:
- for normal strength steel: Grades 1, 2 and 3
- for higher strength steel with minimum yield strength up to 355 N/mm$^2$: Grades 2Y and 3Y and 4Y (Grade 1Y not applicable for manual welding).
- for higher strength steels with minimum yield strength up to 390 N/mm$^2$: Grades 2Y 40, 3Y40, and 4Y 40.

4.1.2 Hydrogen marks
If the electrodes are in compliance with the requirements of the hydrogen test given in 4.5 hereafter, a suffix H15, H10 or H5 will be added to the Grade mark.

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### 4.2 Deposited metal tests

4.2.1 Preparation of deposited metal test assemblies
Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig 4.1, one with 4 mm diameter electrodes and the other with the largest size manufactured. If an electrode is available in one diameter only, one test assembly is sufficient. Any grade of ship structural steel may be used for the preparation of these test assemblies.

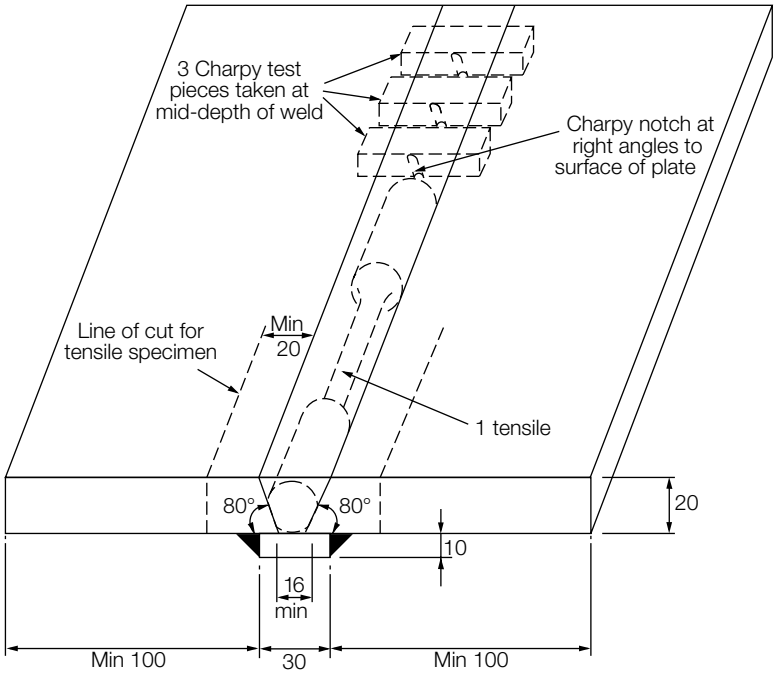


**Figure 4.1 Deposited metal test assembly**

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

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

4.2.3 Execution of tests
One tensile and three impact test specimens are to be taken from each test assembly as shown in Figure 4.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. Tests are to be performed according to Section 3 of these requirements.

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4.2.4 Results of tests and requirements
The results of all tests are to comply with the requirements of Table 4a as appropriate.

**Table 4a Requirements for deposited metal tests (covered manual electrodes)**

| Grade | Yield stress $N/mm^2$ minimum | Tensile Strength N/mm2 | Elongation on 50 mm gauge length ($L_o$ = 5 d) % minimum | Charpy V-notch impact tests | |
|---|---|---|---|---|---|
| | | | | Test Temperature oC | Average Energy J minimum |
| 1 | 305 | 400 - 560 | 22 | 20 | 47 |
| 2 | | | | 0 | 47 |
| 3 | | | | -20 | 47 |
| 2Y | 375 | 490 - 660 | 22 | 0 | 47 |
| 3Y | | | | -20 | 47 |
| 4Y | | | | -40 | 47 |
| 2Y 40 | 400 | 510 - 690 | 22 | 0 | 47 |
| 3Y 40 | | | | -20 | 47 |
| 4Y 40 | | | | -40 | 47 |

### 4.3 Butt weld tests

4.3.1 Preparation of butt weld test assemblies
Butt weld assemblies as shown in Fig 4.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward and overhead) for which the electrode is recommended by the manufacturer, except that electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position subject to the agreement of the Classification Society.

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

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

- Grade 1 electrodes : A
- Grade 2 electrodes : A, B, D
- Grade 3 electrodes : A, B, D, E
- Grade 2Y electrodes : A32, A36, D32, D36
- Grade 3Y electrodes : A 32, A 36, D32, D36, E32, E36.
- Grade 4Y electrodes : A32, A36, D 32, D 36, E 32, E 36, F 32, F 36
- Grade 2Y 40 electrodes : A 40, D 40
- Grade 3Y 40 electrodes : A 40, D 40, E 40
- Grade 4Y 40 electrodes : A 40, D 40, E 40, F 40

Where higher strength steel with minimum yield strength 315 $N/mm^2$ is used for grade 2Y, 3Y and 4Y electrodes, the actual tensile strength of the steel is to be not less than 490 $N/mm^2$. The chemical composition including the content of grain refining elements is to be reported.

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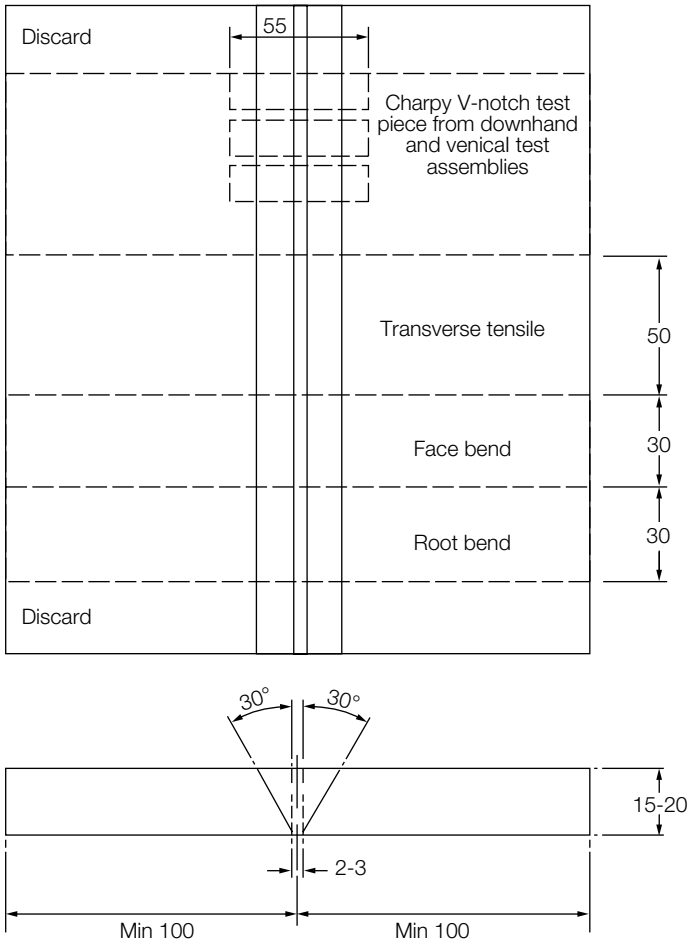


All dimensions in mm unless otherwise indicated

**Figure 4.2 Butt weld test assembly**

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4.3.2 Sequence of welding
The following welding procedure is to be adopted in making test assemblies:

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

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

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

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

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

For all assemblies the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

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

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

4.3.4 Execution of tests
The test specimens as shown in Figure 4.2 are to be prepared from each test assembly. Tests are to be performed according to Section 3 requirements.

4.3.5 Result of tests and requirements
The results of all tensile and impact tests are to comply with the requirements of table 4b as appropriate. The position of fracture in the transverse tensile test is to be reported. The bend test specimens can be considered as complying with the requirements if, after bending, no crack or defect having any dimensions exceeding 3 mm can be seen on the outer surface of the test specimen.

**Table 4b Requirements for butt weld test (covered manual electrodes)**

| Grade | Tensile strength (transverse test) N/mm2 | Charpy V-notch impact tests | | |
|---|---|---|---|---|
| | | Test Temperature $^{o}C$ | Average energy - J minimum | |
| | | | Downhand, horizontal-vertical, overhead | Vertical (upward and downward) |
| 1 | 400 | 20 | 47 | 34 |
| 2 | | 0 | 47 | 34 |
| 3 | | -20 | 47 | 34 |
| 2Y | 490 | 0 | 47 | 34 |
| 3Y | | -20 | 47 | 34 |
| 4Y | | -40 | 47 | 34 |
| 2Y 40 | 510 | 0 | 47 | 39 |
| 3Y 40 | | -20 | 47 | 39 |
| 4Y 40 | | -40 | 47 | 39 |

W17
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### 4.4 Hot cracking test

4.4.1 Hot cracking test may be required at the discretion of each individual Society.

### 4.5 Hydrogen test

4.5.1 Hydrogen marks
At the request of the manufacturer, electrodes may be submitted to a hydrogen test. A suffix H15, H10 or H 5 will be added to the grade number to indicate compliance with the requirements of this test.

4.5.2 Execution of hydrogen test
The mercury method as specified in the Standard ISO 3690-1977, or any method such as the gas chromatographic method which correlates with that method, must be used. The use of the glycerine method may be admitted at the Classification Society discretion. This method is described hereafter.

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

The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer. Within 30 seconds of the completion of the welding of each specimen the slag is to be removed and the specimen quenched in water at approximately 20°C.

After 30 seconds in the water, the specimen is to be cleaned and dried, and then placed in an apparatus suitable for the collection of hydrogen by displacement of glycerine. The glycerine is to be kept at a temperature of 45°C during the test. All four specimens are to be welded and placed in individual hydrogen collecting apparatus within a period of time which will limit any variation in hydrogen content due to variation in exposure to moisture absorption following any drying treatment. This should not exceed 30 minutes.

The specimens are to be kept immersed in the glycerine for a period of 48 hours and, after removal, are to be cleaned in water and spirit dried and weighed to the nearest 0.1 gram to determine the amount of weld deposit. The amount of gas involved is to be measured to the nearest 0.05 $cm^3$ and corrected for temperature and pressure to 0°C and 760 mm Hg.

4.5.3 Results to be obtained
The individual and average diffusible hydrogen contents of the four specimens are to be reported, and the average value in $cm^3$ per 100 grams is not to exceed the following:

| Mark | Mercury Method (ISO 3690 - 1977) |
|---|---|
| H 15 | 15 1) |
| H 10 | 10 2) |
| H 5 | 5 |

1) 10 $cm^3$ per 100 grams where the glycerine method is used
2) 5 $cm^3$ per 100 grams where the glycerine method is used

NOTE:
For H5 mark only the mercury method is to be used.

### 4.6 Covered electrodes for manual fillet welding

4.6.1 General
Where an electrode is submitted only to approval for fillet welding and to which the butt weld test provided in 4.3 is not considered applicable, the first approval tests are to consist of the fillet weld tests given in 4.6.2, and deposited metal tests similar to those indicated in 4.2. Where an electrode is submitted to approval for both butt and fillet welding, the first approval tests may, at the discretion of the Classification Society, include one fillet weld test as detailed hereunder and welded in the horizontal-vertical position. ▶

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4.6.2 Fillet weld test assemblies

When the electrode is proposed only for fillet welding, fillet weld assemblies as shown in figure 4.3, are to be prepared for each welding position (horizontal-vertical, vertical upwards, vertical downwards or overhead) for which the electrode is recommended by the manufacturer. The length of the test assemblies L is to be sufficient to allow at least the deposition of the entire length of the electrode being tested.

The grade of steel used for the test assemblies is to be as detailed in 4.3.1.

The first side is to be welded using the maximum size of electrode manufactired and the second side is to be welded using the minimum size of electrode manufactured and recommended for fillet welding.

The fillet size will in general be determined by the electrode size and the welding current employed during testing.

4.6.3 Tests on fillet weld assemblies

.1 Macrographs

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

.2 Hardness

At the discretion of each Classification Society, the hardness of the weld, of the heat affected zone (HAZ) and of parent metal may be determined, and reported for information (see figure 4.4).

.3 Fracture

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

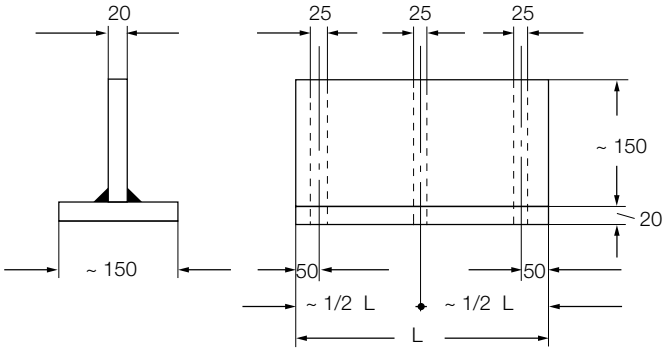


**Figure 4.3 Fillet weld test assembly**

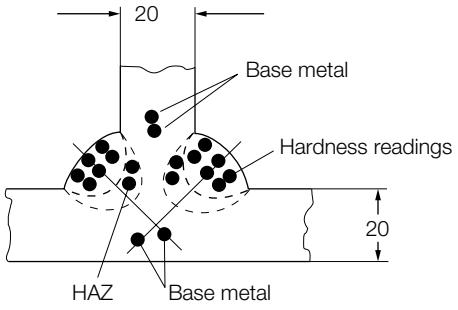


**Figure 4.4 Hardness readings**

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### 4.7 Covered electrodes for gravity or contact welding

Where an electrode is submitted solely to approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, fillet weld tests (see 4-6) and, where appropriate, but weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

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

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

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

### 4.8 Annual tests and upgrading

4.8.1 Annual tests and periodical inspection of manufacturer's plant
All establishments where approved electrodes are manufactured shall be subject to annual inspection.

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

.1 Covered electrode for normal manual arc welding
Two deposited metal test assemblies are to be prepared in accordance with 4.2. The mechanical properties (one tensile test, 3 Charpy-V impact tests on each assembly) are to be in accordance with Table 4.a. This also applies to electrodes which are approved only for fillet welding.

At the discretion of the Society a butt weld test to be welded in down-hand or in vertical position, can be required in lieu of the deposited metal test 4 mm electrodes. Three Charpy V-notch impact test specimens are to be taken from the butt weld assembly.
For Mark H 10 and Mark H 5 covered electrodes, an hydrogen test following 4.5 can also be required for each annual test at the discretion of the Society.

.2 Covered electrodes for gravity or contact welding
Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer. If this electrode is approved also for normal manual arc welding the annual test is to be performed according to 4.8.1.1.

4.8.2 Upgrading and uprating of electrodes

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

.2 Upgrading refers to notch toughness and consequently, only Charpy V impact tests are required from the respective butt-weld assemblies as required by 4-3 (downhand, horizontal vertical, vertical up or/and down, overhead, as applicable), and have to be performed at the upgraded temperature.

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

.3 Uprating refers to the extension of approval in order to cover the welding of higher strength steels; of course, welding of normal strength steels continue to be covered by the extended approval, as stated in 1.2.1.

For this purpose all butt-weld tests are to be made again, as required in 4.3 and using higher strength steel, as parent metal.

W17 cont'd

## 5. Wire flux combinations for submerged arc welding

### 5.1 General

5.1.1 Categories

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

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

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

5.1.2 Grades

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

– For normal strength steel: Grades 1, 2 or 3
– For higher strength steels with minimum yield strength up to 355 N/mm$^2$: Grades 1Y, 2Y, 3Y or 4Y.
- for higher strength steels with minimum yield strength up to 390 N/mm$^2$: Grades 2Y 40, 3Y 40 or 4Y 40.

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

5.1.3 Multiple electrode submerged arc welding

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

5.1.4 Mechanical tests on assemblies

Mechanical tests on assemblies with submerged arc welding for wire/flux approval are given in Table 5a.

### 5.2 Approval tests for multi run technique

5.2.1 Grades of steel

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

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

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

| | | | |
|---|---|---|---|
| - | Grade 1 wire-flux combinations | : | A |
| - | Grade 2 wire-flux combinations | : | A, B, D |
| - | Grade 3 wire-flux combinations | : | A, B, D, E |
| - | Grade 1 Y wire-flux combinations | : | A 32, A 36 |
| - | Grade 2 Y wire-flux combinations | : | A32, A 36, D 32, D 36 |
| - | Grade 3 Y wire-flux combinations | : | A32, A 36, D 32, D 36, E 32, E 36 |
| - | Grade 4 Y wire-flux combinations | : | A32, A 36, D 32, D 36, E 32, E 36, F 32, F 36 |
| - | Grade 2 Y 40 wire-flux combinations | : | A40, D 40 |
| - | Grade 3 Y 40 wire-flux combinations | : | A40, D 40 E 40 |
| - | Grade 4 Y 40 wire-flux combinations | : | A40, D 40, E 40, F 40 |

**W17**
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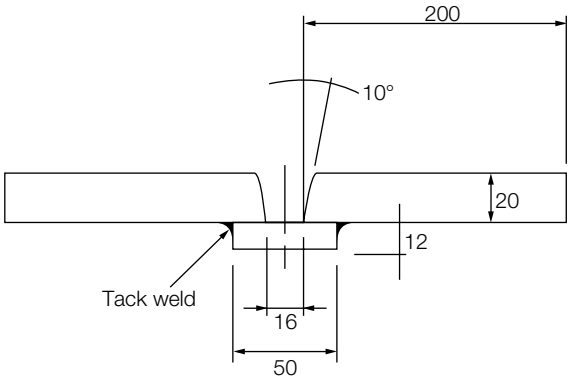
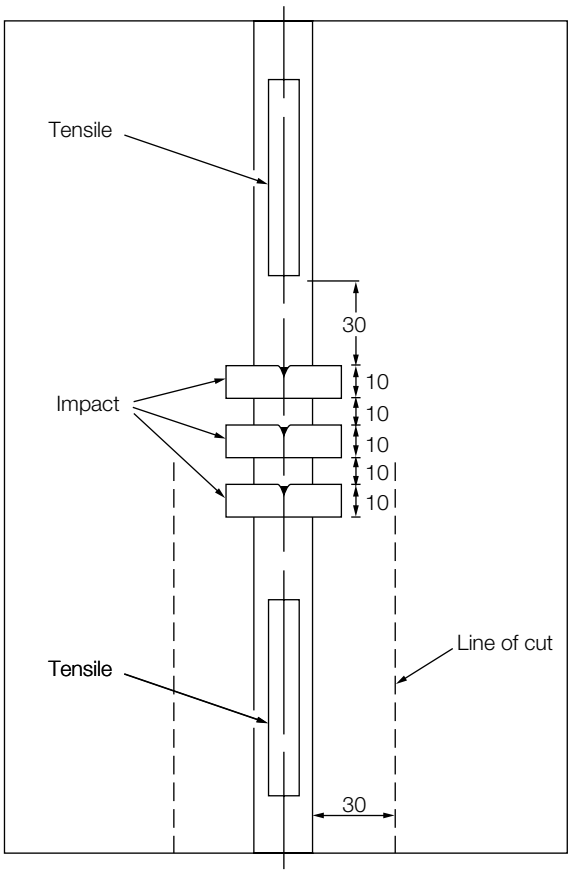
5.2.2 Deposited metal test assembly

.1 Preparation

One deposited metal test assembly is to be prepared as shown in Figure 5.1.




All dimensions in mm unless otherwise indicated




All dimensions in mm unless otherwise indicated

**Figure 5.1**

**W17** cont'd

**Table 5a General table giving the mechanical tests on assemblies with submerged arc welding for wire/flux approval**

| M (multi-run technique) | | T (two-run technique) | | TM two-run and multi-run technique) | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Butt Weld Assembly | | |
| | | | | | | Two-run technique | |
| Deposited metal assembly | Butt weld assembly | Butt weld assembly (minimum thickness) | Butt weld assembly (maximum thickness) | Deposited metal assembly | Multi-run technique | (Minimum thickness) | (Maximum thickness) |
| 3 CV<br>2 LT | 2 TT<br>4 TB<br>3 CV | 2 TT<br>2 TB<br>3 CV<br>1 LT | 2 TT<br>2 TB<br>3 CV | 3 CV<br>1 LT | 2 TT<br>4 TB<br>3 CV | 2 TT<br>2 TB<br>3 CV | 2 TT<br>2 TB<br>3 CV<br>1 LT |

Symbol Definition: TT: Transverse Tensile Test on the butt weld assembly
TB : Transverse Bend Test on the butt weld assembly
CV : Charpy-V Impact Test in the axis of the weld
LT : Longitudinal Tensile Test in the weld

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

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

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

.3 Execution of tests
In accordance with Table 5a, the test specimens as shown in Figure 5.1 are to be prepared from each test assembly. Tests are to be performed according to Section 3 requirements.

.4 Results and requirements
The results of all tests are to comply with the requirements of Table 5b, as appropriate.

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**W17** cont'd

**Table 5b Requirements for deposited metal tests (wire-flux combinations)**

| Grade | Yield stress $N/mm^2$ minimum | Tensile Strength N/mm2 | Elongation on 50 mm gauge length ($L_o$ = 5 d) % minimum | Charpy V-notch impact tests | |
|---|---|---|---|---|---|
| | | | | Test Temperature $^oC$ | Average Energy J minimum |
| 1 | 305 | 400 - 560 | 22 | 20 | 34 |
| 2 | | | | 0 | 34 |
| 3 | | | | -20 | 34 |
| 1Y | 375 | 490 - 660 | 22 | 20 | 34 |
| 2Y | | | | 0 | 34 |
| 3Y | | | | -20 | 34 |
| 4Y | | | | -40 | 34 |
| 2Y 40 | 400 | 510 - 690 | 22 | 0 | 39 |
| 3Y 40 | | | | -20 | 39 |
| 4Y 40 | | | | -40 | 39 |

5.2.3 Butt Weld Test Assembly

.1 Preparation

One butt weld test assembly is to be prepared as shown in Figure 5.2 in the downhand position by welding together two plates (20 to 25 mm thick), each not less than 150 mm in width and sufficient length to allow the cutting out of test specimens of the prescribed number and size.

The plate edges are to be prepared to form a single vee joint, the included angle between the fusion faces being 60° and the root face being 4 mm.

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

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

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

**W17**
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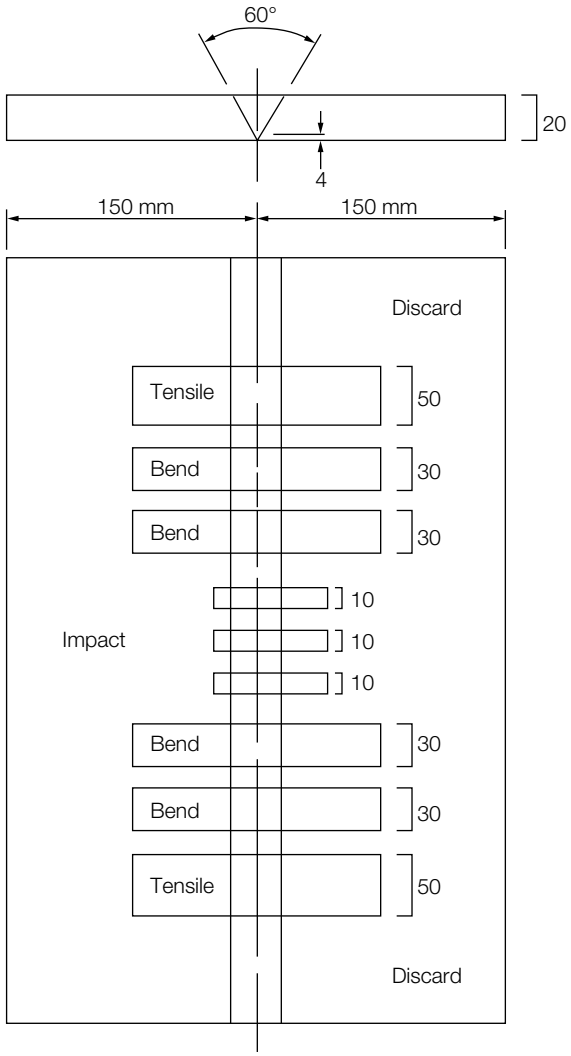


**Figure 5.2 Multi-run butt weld test assembly (submerged arc welding)**

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

.3 Execution of tests
The test specimen to be prepared from the welded assembly are given in Table 5a and shown in Fig. 5.2. The tests are to be performed according to the requirements of Section 3.

.4 Results of tests and requirements
The results of all tensile and impact tests are to comply with the requirements of Table 5c as appropriate. The position of the fracture in the transverse tensile test is to be reported.

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

▶

**W17** cont'd

**Table 5c Requirements for butt weld tests (wire-flux combinations)**

| Grade | Tensile strength (transverse test) N/mm$^2$ | Charpy V-notch impact tests | |
|---|---|---|---|
| | | Test temperature $^oC$ | Average energy J minimum |
| 1 | 400 | 20 | 34 |
| 2 | | 0 | 34 |
| 3 | | -20 | 34 |
| 1Y | 490 | 20 | 34 |
| 2Y | | 0 | 34 |
| 3Y | | -20 | 34 |
| 4Y | | -40 | 34 |
| 2Y40 | 510 | 0 | 39 |
| 3Y40 | | -20 | 39 |
| 4Y40 | | -40 | 39 |

### 5.3 Approval tests for two run techniques

5.3.1 Number of test assemblies

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

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

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

When a wire-flux combination is offered to approval for use with the two-run technique only, it is reminded that no deposited metal test assemblies have to be done. In this case approval tests are limited to the butt welds on two-run assemblies described in 5.3.2 hereafter.

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

5.3.2 Butt weld test assemblies

.1 Preparation of assemblies

The maximum diameter of wire, grades of steel plate and edge preparation to be used are to be in accordance with Fig. 5.3. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The root gap should not exceed 1 mm.

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

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

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

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W17
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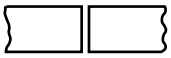
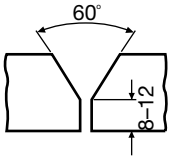
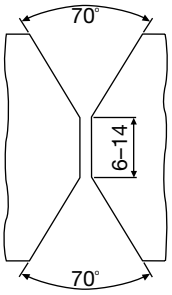
| Plate thickness [mm] | Recommended preparation [mm] | Maximum diameter of wire [mm] | Grade of wire-flux combination | Grade of normal strength steel | Grade of higher strength steel |
|---|---|---|---|---|---|
| about 12 – 15 |  | 5 | 1 | A | – |
| | | | 1 Y | – | A 32, A 36 |
| about 20 – 25 |   | 6 | 1 | A | – |
| | | | 1 Y | – | A 32, A 36 |
| | | | 2 | A, B or D | – |
| | | | 2 Y | – | A 32, A 36, D 32, D 36 |
| | | | 2 Y 40 | – | A 40, D 40 |
| | | | 3 | A, B, D or E | – |
| | | | 3 Y | – | A 32, A 36, D 32, D 36, E 32, E 36 |
| | | | 3 Y 40 | – | A 40, D 40, E 40 |
| | | | 4 Y | – | A 32, A 36, D 32, D 36, E 32, E 36, F 32, F 36 |
| | | | 4 Y 40 | – | A 40, D 40, E 40, F 40 |
| about 30 – 35 |   | 7 | 2 | A, B or D | – |
| | | | 2 Y | – | A 32, A 36, D 32, D 36 |
| | | | 2 Y 40 | – | A 40, D 40 |
| | | | 3 | A, B, D or E | – |
| | | | 3 Y | – | A 32, A 36, D 32, D 36, E 32, E 36 |
| | | | 3 Y 40 | – | A 40, D 40, E 40 |
| | | | 4 Y | – | A 32, A 36, D 32, D 36, E 32, E 36, F 32, F 36 |
| | | | 4 Y 40 | – | A 40, D 40, E 40, F 40 |

**Figure 5.3 Butt weld test assemblies (two-run technique)**

.2 Radiographic examination

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

.3 Execution of tests

The test specimens indicated in Table 5a and shown in Figure 5.4 are to be prepared from each test assembly. Tests are to be performed according to Section 3 requirements. The Charpy V-notch impact test specimens are to be machined from each welded assembly from the positions and with the orientations shown in Fig. 5.5.

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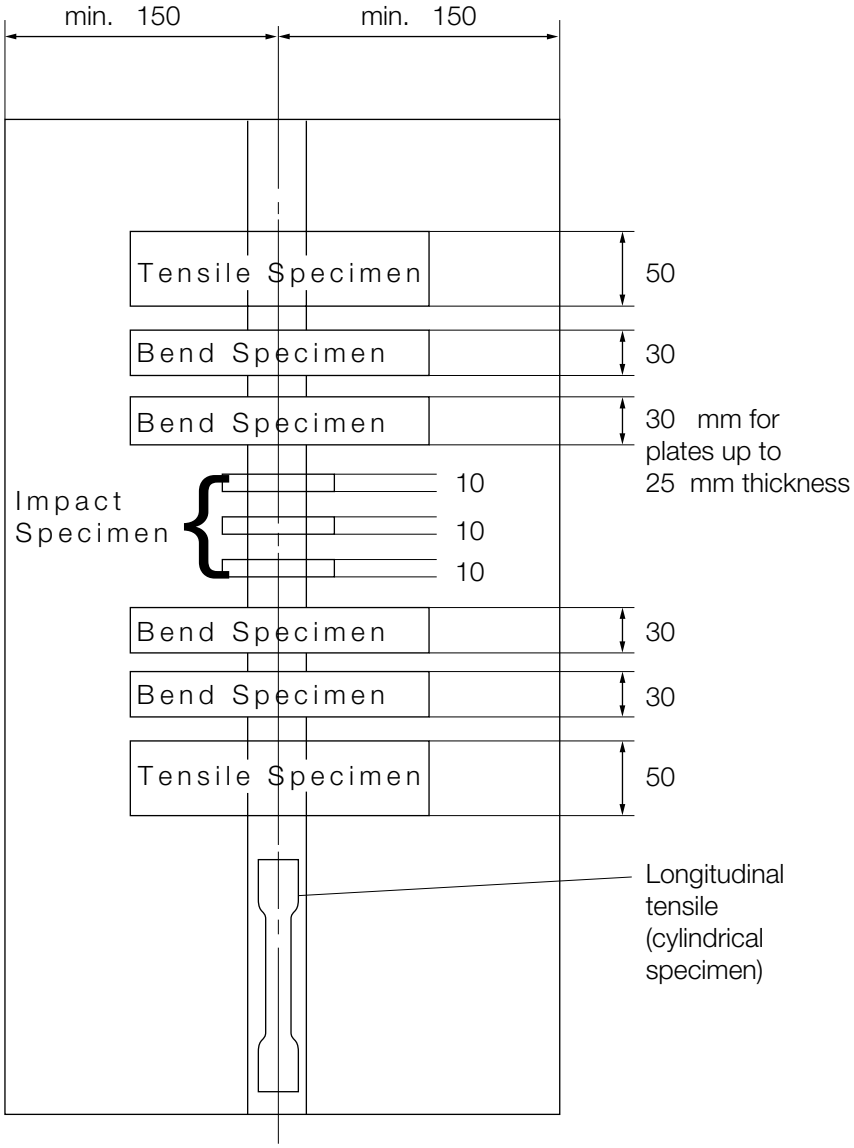
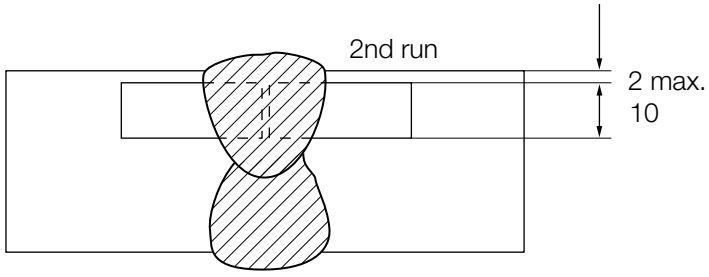



All dimensions in mm unless otherwise indicated

Figure 5.4




All dimensions in mm unless otherwise indicated

Figure 5.5

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.4 Results of tests and requirements

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

.5 Chemical analysis

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

**5.4 Annual tests - upgrading**

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

Annual tests are to consist of at least the following:

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

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

Where a wire-flux combination is approved for welding both normal strength and higher strength steel, the latter steel is to be used for the preparation of the butt weld assembly required by 5.4.1 b).

5.4.2 Upgrading and rating

5.4.2.1 Upgrading of wire-flux combinations in connection with the impact properties will be considered as detailed in 4.8.2.2, and for wire-flux combinations approved for two runs welding, a butt-weld in the maximum thickness approved is to be made and sampled for Charpy-V testing in accordance with 5.3.2.3.

5.4.2.2 Uprating of wire-flux combinations in connection with the tensile properties will be considered as detailed in 4.6.2.3.

**6. Wires and wire-gas combinations for metal arc welding**

**6.1 General**

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

a) For use in semi-automatic mulitrun welding.
b) For use in single electrode automatic multirun welding.
c) For use in single electrode automatic two-run welding.

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

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**W17**
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6.1.2 Grades and suffixes

.1 Depending on the results of impact tests, wires and wire-gas combinations are divided into the following grades:
- For normal strength steel Grades 1, 2 and 3;
- For higher strength steels with minimum yield strength up to 355 N/mm$^2$: Grades 1Y, 2Y, 3Y and 4Y.
- For higher strength steems with minimum yield strength up to 390 N/mm$^2$: Grades 2Y 40, 3Y 40, and 4Y 40.

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

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

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

6.1.3 Composition of shielding gas

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

.2 The approval of a wire in combination with any particular gas can be applied or transferred to any combination of the same wire and any gas in the same numbered group as defined in Table 6a, subject to the agreement of the Classification Society.

**Table 6a Compositional limits of designated groups of gas types and mixtures.**

| Group | | Gas composition (Vol. %) | | | |
|---|---|---|---|---|---|
| | | $CO_2$ | $O_2$ | $H_2$ | Ar |
| M1 | 1 | > 0 to 5 | - | > 0 to 5 | Rest 1) 2) |
| | 2 | > 0 to 5 | - | - | Rest 1) 2) |
| | 3 | - | > 0 to 3 | - | Rest 1) 2) |
| | 4 | > 0 to 5 | > 0 to 3 | - | Rest 1) 2) |
| M2 | 1 | > 5 to 25 | - | - | Rest 1) 2) |
| | 2 | - | > 3 to 10 | - | Rest 1) 2) |
| | 3 | > 5 to 25 | > 0 to 8 | - | Rest 1) 2) |
| M3 | 1 | >25 to 50 | - | - | Rest 1) 2) |
| | 2 | - | > 10 to 15 | - | Rest 1) 2) |
| | 3 | > 5 to 50 | > 8 to 15 | - | Rest 1) 2) |
| C | 1 | 100 | - | - | - |
| | 2 | Rest | > 0 to 30 | - | - |

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

**W17**
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6.1.4 Low hydrogen approval

.1 Flux-cored or flux-coated wires which have satisfied the requirements for Grades 2, 2Y, 2Y40,3, 3Y, 3Y40, 4Y or 4Y40 may, at manufacturer's option, be submitted to the hydrogen test as detailed in 4,5. using the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weight of weld deposit per sample similar to that deposited when using manual electrodes.

.2 A suffix H15, H10 or H5 will be added to the grade mark, in the same conditions as for manual arc welding electrodes (see 4.5.3 above) to indicate compliance with the requirements of the test.

**6.2 Approval for semi-automatic mulitrun welding**

6.2.1 General
Approval tests for semi-automatic multirun welding are to be carried out generally in accordance with Section 4, except as required by 6.2, using the semi-automatic mulitrun technique for the preparation of all test assemblies.

6.2.2 Preparation of deposited metal assemblies

.1 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 4.1, one using the smallest diameter, and the other using the largest diameter of wire intended for the welding of ship structures. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

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

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

6.2.4 Mechanical tests
On each assembly, tests are to be made in accordance with 4.2.3, and the results are to comply with the requirements of 4.2.4, appropriate to the required grade.

6.2.5 Preparation of butt weld assemblies

.1 Butt weld assemblies as shown in Fig. 4.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical upwards, vertical downwards and overhead) for which the wire or wire-gas combination is recommended by the manufacturer.

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

.3 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using wires of different diameter from those required by 6.2.5.2. Where only one diameter is manufactured, only one downhand butt weld assembly is to be prepared.

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

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

6.2.7 On each assembly, tests are to be made in accordance with 4.3.4, and the results are to comply with the requirements of 4.3.5.

6.2.8 Fillet weld tests
Fillet weld test assemblies are required to be made in accordance with 4.6.1 and 4.6.2, and tested in accordance with 4.6.3.

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### 6.3 Approval for automatic multirun welding

6.3.1 General
Approval tests for automatic multirun welding are to be carried out generally in accordance with section 5 multirun approval, except as required by 5.2, using the automatic multirun technique for the preparation of all test assemblies.

6.3.2 Preparation of deposited metal assembly
One deposited metal assembly is to be prepared as shown in Fig. 5.1. Welding is to be as detailed in 5.2.2.1, except that the thickness of each layer is to be not less than 3 mm.

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

6.3.4 Mechanical tests
Tests on this assembly are to be made in accordance with 5.2.2.3, and the results are to comply with the requirements of 5.2.2.4.

6.3.5 Preparation of butt weld weld assemblies
One butt weld assembly is to be prepared in each welding position which is to be approved. Generally, this will be the downhand position only, in which case only one assembly is required. Preparation of the assembly is to be in accordance with 5.2.3.1.

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

6.3.7 Mechanical tests
Tests are to be made on each assembly in accordance with 5.2.3.3 and the results are to comply with the requirements of Table 5c. Where more than one assembly is prepared and tested, the number of transverse tensile and bend test specimens from each assembly may be halved.

6.3.8 Discretionary approval
At the discretion of each individual Classification Society, wires or wire-gas combinations approved for semi-automatic multirun welding may also be approved, without additional tests, for automatic multirun welding approval.
This is generally the case when automatic multirun welding is performed in the same conditions of welding current and energy as semi automatic welding with the concerned wire-gas combination.

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

### 6.4 Approval for automatic two-run welding

6.4.1 General
Approval tests for automatic two-run welding are to be carried out generally in accordance with the requirements of Section 5.3, except as required by 6.4, using the automatic two-run welding technique for the preparation of all test assemblies.

6.4.2 Preparation of butt weld assemblies

.1 Two butt weld test assemblies are to be prepared, generally as detailed in 5.3.1 and 5.3.2, using plates 12-15 mm and 20-25 mm in thickness. If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

.2 The plate preparation of the test assemblies is to be as shown in Fig. 6.1. Small deviations in the edge preparation may be allowed, if requested by the manufacturer. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information. Deviations or variations will be expected to form part of the manufacturer's standard recommended procedure for this technique and thickness range.

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**W17**
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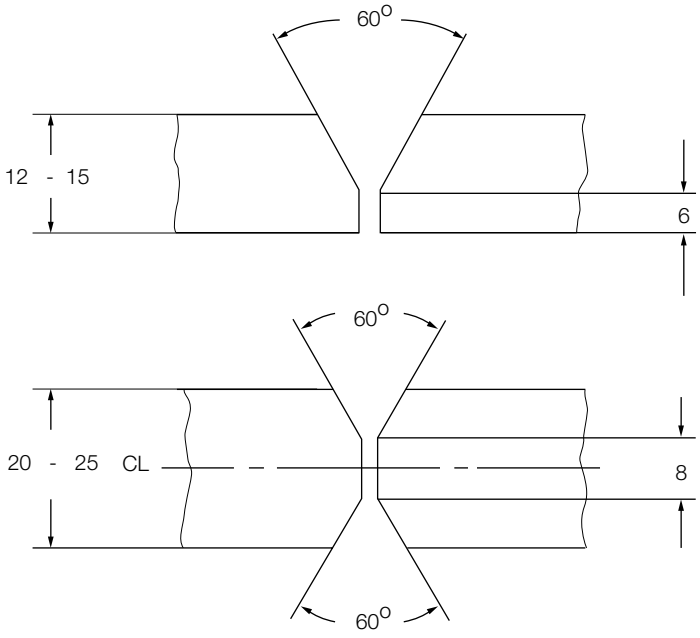


All dimensions in mm unless otherwise indicated

**Figure 6.1 Recommended edge preparation for two-run butt weld test assemblies**

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

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

6.4.4 Mechanical tests
Tests are to be made on each assembly in accordance with 5.3.2.3 to 5.3.2.6 and the results are to comply with the requirements of 5.2.2.4 and Table 5c.

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

**6.5 Annual tests and up-grading**

6.5.1 Annual tests

.1 Annual tests are to consist of at least:
a) Wires approved for semi-automatic or both semi-automatic and automatic multirun welding : one deposited metal test assembly prepared in accordance with 6.2.2 using a wire of diameter within the range approved for the semi-automatic multirun welding of ship structures.

▶

**W17** (cont'd)

b) Wires approved for automatic multirun welding : one deposited metal test assembly prepared in accordance with 6.3.2 using a wire of diameter within the range approved for automatic multirun welding of ship structures.

c) Wires approved for automatic two-run welding : one butt weld test assembly prepared in accordance with 6.4.2 using plates of 20-25 mm in thickness. The wire diameter used is to be reported.

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

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

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

Note:
At the discretion of each individual Classification Society, hydrogen test can be carried out following 4.5.

6.5.2 Up-grading and up-rating

.1 Up-grading of flux cored wires and wire-gas combinations in connection with the impact properties will be considered as detailed in 4.8.2.2.

.2 Up-rating of flux cored wires and wire-gas combinations with the tensile properties will be considered as detailed in 4.8.2.3.

## 7. Consumables for use in eletroslag and electrogas vertical welding

### 7.1 General

7.1.1 The requirements for the two-run technique as detailed in Section 5 are applicable for the approval of special consumables used in electro-slag and electro-gas vertical welding with or without consumable nozzles except as otherwise required by the following requirements especially as regards the number and kind of the test-pieces used for the mechanical tests and taken from the butt welded assemblies.

7.1.2 For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 approval of the consumables may be restricted for use only with specific types of higher strength steel. This is in respect of the content of grain refining elements, and if general approval is required, a niobium treated steel is to be used for the approval tests.

7.1.3 For these special welding consumables, the prescription 1.2.1 may not be entirely applicable for technical reasons.

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

### 7.2 Butt weld tests

7.2.1 Preparation of test assemblies
Two butt weld test assemblies are to be prepared, one of them with plates 20/25 mm thick, the other with plates 35/40 mm thick or more. The grade of the steel to be used for each one of these assemblies must be selected according to the requirements given in the figure 5.3 for two-run submerged arc welding.

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

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

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

**W17**
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7.2.3 Test series
Each assembly shall be cut to give test specimens according to Figure 7.1.

The length of the assembly should be sufficient to allow the selection of all the test specimens:
– 2 longitudinal tensile test specimens with their axis at the centre of the weld.
– 2 transverse tensile test specimens.
– 2 side bend test specimens.
– 2 sets of 3 Charpy-V notch impact test specimens in accordance with Figure 7.1:

.1 set with the notch in the axes of the weld,
.1 set with the notch at 2 mm from the fusion line in the deposited metal.

– 2 macro-sections to the weld (towards the middle of the weld and towards one end).

7.2.4 Results to be obtained
The results of the tensile, bend and impact tests are to comply with the requirements of paragraph 5.3 (two-run welding) for the class of filler product in question.

**7.3 Annual tests and up-grading**

7.3.1 All factories which manufacture approved consumables for use in electroslag and electrogas welding must be subject to an annual inspection and tests in accordance with 2.4.

7.3.2 One test assembly must be prepared from plates 20/25 mm thick, and tested as indicated in 7.2.

The following specimens are to be selected:
– 1 longitudinal tensile specimen from the axis of the weld,
– 1 transverse tensile specimen,
– 2 side bend specimens,
– 3 Charpy-V specimens notched at the centre of the weld (position 1 Fig. 7.1),
– 3 Charpy-V specimens cut out transverse to the weld with their notches at 2 mm from the fusion line, in the weld,
– macro section.

7.3.3 The results to be obtained should meet the requirements given in 5.3 (two-run welding) for the class of the consumables in question.

7.3.4 Upgrading and uprating

Upgrading and uprating will be considered only at the manufacturers request, at the time of annual testing. Generally, for this purpose, full tests from butt weld assemblies as indicated in 7.2 will be required, irrespective of the other tests requested if the concerned consumable is also approved (and possibly upgraded or uprated) according to Section 5 or Section 6.

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**W17**
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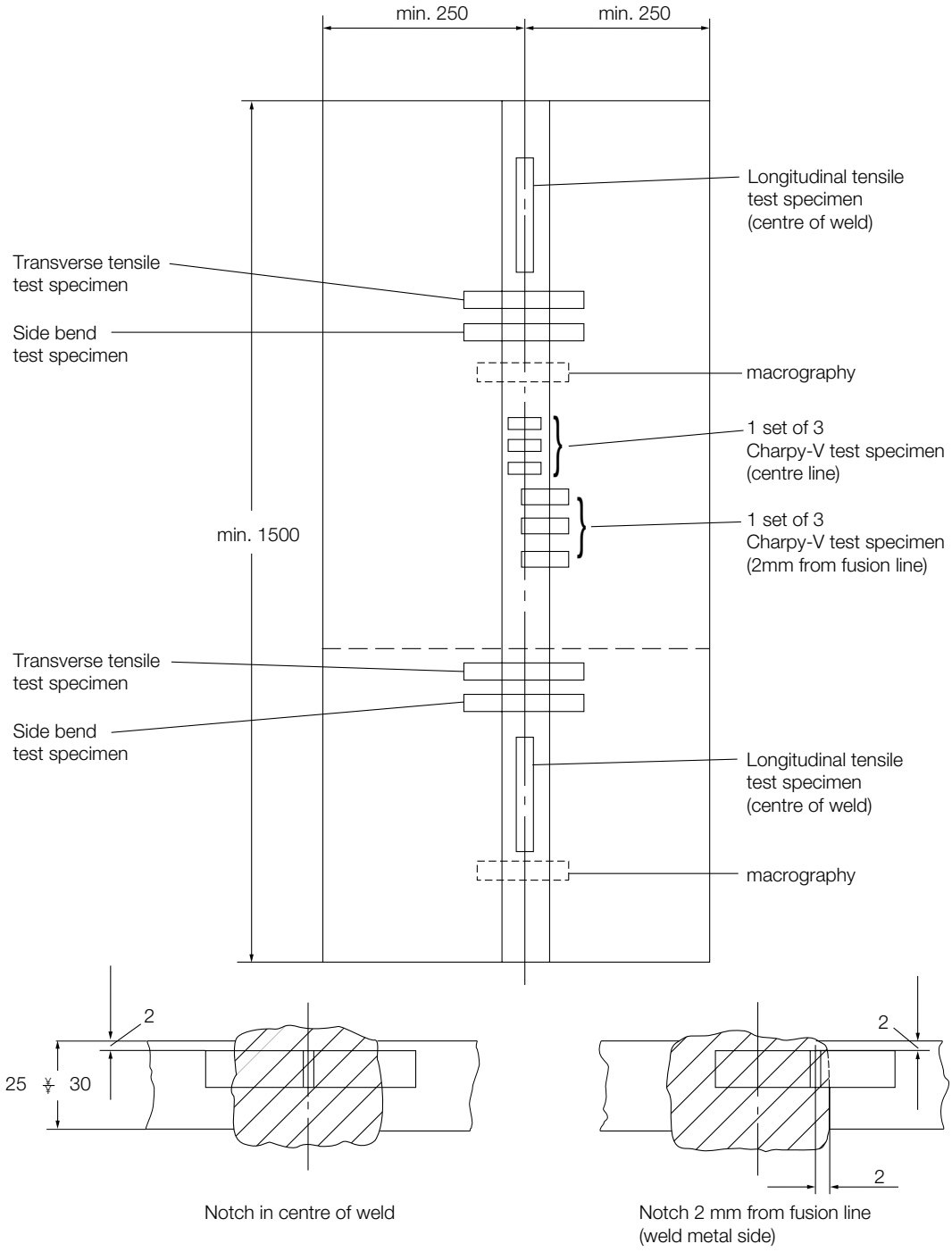


**Figure 7.1 Electroslag and electrogas butt weld test assembly**

# W18 Anchor chain cables and accessories including chafing chain for emergency towing arrangements

(1988) (Rev 1 1997) (Rev. 2 July 1999) (Rev.3 July 2002) (Rev.4 July 2003) (Rev.5 May 2004)

## W18.1 General requirements

### 1.1 Scope

These rules apply to the materials, design, manufacture and testing of stud link anchor chain cables and accessories used for ships. Where, in exceptional cases, studless short link chain cables are used with the consent of the individual Society, they must comply with recognized national or international standards. The requirements for chafing chain for Emergency Towing Arrangements (ETA) are given in the Appendix A.

### 1.2 Chain cable grades

Depending on the nominal tensile strength of the chain cable steel used for manufacture, stud link chain cables are to be subdivided into Grades 1, 2 and 3.

### 1.3 Approval of chain manufacturers

1.3.1 Anchor chain cables and accessories are to be manufactured only by works approved by the Society. For this purpose approval tests are to be carried out, the scope of which is to be agreed with the Society.

1.3.2 Applications for approval are to be made to the Society, stating the method of manufacture used, the grades of materials, the nominal dimensions and - where applicable - the material specification. A procedure test carried out on a high-strength chain cable may cover approval of lesser grades, provided that the material type, method of manufacture and the nature of the heat treatment are the same.

## W18.2 Materials

### 2.1 Scope

These rules apply to rolled steels, forgings and castings used for the manufacture of anchor chain cables and accessories.

### 2.2 Requirements for material manufacturers

2.2.1 All materials used for the manufacture of anchor chain cables and accessories are to be supplied by manufacturers approved by the Society. Society approval is not required for Grade 1 steel bars.

2.2.2 Materials suppliers or chain cable manufacturers are to submit specifications for Grade 3 steel bars. These specifications should contain all necessary details, such as manufacturing procedure, deoxydation practice, specified chemical composition, heat treatment, and mechanical properties.

2.2.3 (void)

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**W18**
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## 2.3 Rolled steel bars

2.3.1 Supply condition
Unless otherwise stipulated, the steel bars will be supplied in as rolled condition.

2.3.2 Chemical composition
The chemical composition of the steel bars is to be generally within the limits given in Table 1.

**Table 1** Chemical composition of rolled steel bars

| Grade | Chemical composition in maximum percent, unless specified. | | | | | |
|---|---|---|---|---|---|---|
| | C | Si | Mn | P | S | Al tot [1] min. |
| 1 | 0.20 | 0.15-0.35 | min. 0.40 | 0.040 | 0.040 | NR |
| 2[2] | 0.24 | 0.15-0.55 | 1.60 | 0.035 | 0.035 | 0.020 |
| 3[3] | In accordance with an approved specification | | | | | |

[1] Aluminum may be replaced partly by other grain refining elements.
[2] If the Society agrees, additional alloying elements may be added.
[3] To be killed and fine grain.
NR = Not required.

2.3.3 Mechanical tests

2.3.3.1 Mechanical tests representing the steel bars are normally to be carried out by the steel mill, and the results are to meet the requirements in Table 2. The test coupons are to be in a heat treatment condition equivalent to that of the finished chain cable and accessories.

**Table 2** Mechnical properties of rolled steel bars

| Grade | $R_{eH}$ $N/mm^2$ min. | $R_m$ $N/mm^2$ | $A_5$ % min. | Z % min. | Charpy V-notch impact test | |
|---|---|---|---|---|---|---|
| | | | | | Test temp. in °C | Absorbed energy in Joules, min. |
| 1 | NR | 370-490 | 25 | NR | NR | NR |
| 2 | 295 | 490-690 | 22 | NR | 0 | 27[1] |
| 3 | 410 | min. 690 | 17 | 40 | 0[2] | 60 |
| | | | | | -20 | 35 |

[1] The impact test of Grade 2 materials may be waived, if the chain cable is to be supplied in a heat treated condition as per Table 6.
[2] Testing is normally to be carried out at $0^oC$.

NR = Not required.

**W18**
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2.3.3.2 For performance of the mechanical tests the steel bars shall be sorted according to heats and diameters into test units not exceeding 50 tons each. From each test unit a test sample shall be taken for the tests mentioned in 2.3.3.4 and 2.3.3.5. Prior to sampling, the test samples must be subjected to the heat treatment provided for the finished chain cable; see Section 3.3. Details of the heat treatment must be indicated by the chain cable manufacturer.

2.3.3.3 Tensile and Charpy V-notch impact test specimens shall be taken from the test sample in the longitudinal direction at a distance of 1/6 diameter from the surface or as close as possible to this position, as shown in Figure 1.

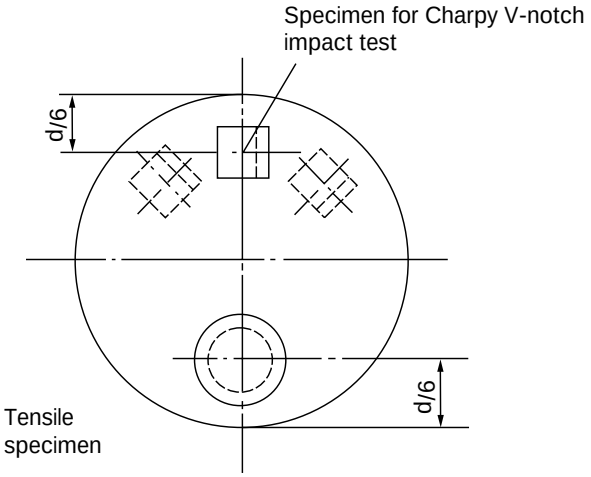


**Figure 1** Sampling Locations

2.3.3.4 For the tensile test, one specimen shall be taken from each test unit and tested, all in accordance with UR W2.

2.3.3.5 One set of longitudinal Charpy V-notch test specimens shall be taken from each test unit and tested at the temperature prescribed in Table 2, all in accordance with UR W2. The specimen transverse axis is to be radial to the steel bar. The average value obtained from one set of three impacts specimens is to comply with the requirements given in Table 2. One individual value only may be below the specified average value provided it is not less than 70% of that value.

2.3.3.6 Re-test requirements for tensile tests are to be in accordance with UR W2 with specimens taken from the same sample. Failure to meet the specified requirements of either of both additional tests will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment; see 2.3.3.8.

2.3.3.7 Re-test requirements for Charpy impact tests are to be in accordance with UR W2. Specimens are to be selected from the same sample. Failure to meet the requirements will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment; see 2.3.3.8.

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**W18**
cont'd

2.3.3.8 If failure to pass the tensile test or the Charpy V-notch impact test is definitely attributable to improper heat treatment of the test sample, a new test sample may be taken from the same piece and reheat treated. The complete test (both tensile and impact test) is to be repeated; and the original results obtained may be disregarded.

2.3.4 Dimensional tolerances
The diameter and roundness shall be within the tolerances specified in Table 3 unless otherwise agreed.

**Table 3 Dimensional tolerance of rolled steel bars**

| Nominal diameter mm | Tolerance on diameter mm | Tolerance on roundness ($d_{max}$ - $d_{min}$) mm |
|---|---|---|
| less than 25 | -0 + 1.0 | 0.6 |
| 25 - 35 | -0 + 1.2 | 0.8 |
| 36 - 50 | -0 + 1.6 | 1.1 |
| 51 - 80 | -0 + 2.0 | 1.5 |
| 81 - 100 | -0 + 2.6 | 1.95 |
| 101 - 120 | -0 + 3.0 | 2.25 |
| 121 - 160 | -0 + 4.0 | 3.00 |

2.3.5 Freedom from defects
The materials have to be free from internal and surface defects that might impair proper workability and use. Surface defects may be repaired by grinding, provided the admissible tolerance is not exceeded.

2.3.6 Identification of material
Manufacturers are to effectively operate an identification system ensuring traceability of the material to the original cast.

2.3.7 Marking
The minimum markings required for the steel bars are the manufacturers' brandmark, the steel grade and an abbreviated symbol of the heat. Steel bars having diameters of up to and including 40 mm and combined into bundles, may be marked on permanently affixed labels.

2.3.8 Material certification
Bar material for Grade 2 or Grade 3 is to be certified by the Society. For each consignment manufacturers shall forward to the Surveyor a certificate containing at least the following data:
– manufacturer's name and/or purchaser's order No.
– number and dimensions of bars and weight of consignment
– steel specification and chain grade
– heat number
– manufacturing procedure
– chemical composition
– details of heat treatment of the test sample (where applicable)
– results of mechanical tests (where applicable)
– number of test specimens (where applicable)

## 2.4 Forged steels for chain cables and accessories

2.4.1 General requirements
Forged steels used for the manufacture of chain cables and accessories are to be in compliance with UR W7, Hull and machinery steel forgings, unless otherwise specified in the following paragraphs.

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**W18** cont'd

2.4.2 Chemical composition
The chemical composition is to comply with the specification approved by the Society. The steel manufacturer must determine and certify the chemical composition of every heat of material.

2.4.3 Heat treatment
The stock material may be supplied in the as rolled condition. Finished forgings are to be properly heat treated, i.e. normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant steel grade in Table 4.

2.4.4 (void)

2.4.5 (void)

### 2.5 Cast steels for chain cables and accessories

2.5.1 General requirements

Cast steels used for the manufacture of chain cables and accessories are to be in compliance with UR W8, Hull and machinery steel castings, unless otherwise specified in the following paragraphs.

2.5.2 Chemical composition
The chemical composition is to comply with the specification approved by the Society. The foundry is to determine and certify the chemical composition of every heat.

2.5.3 Heat treatment
All castings must be properly heat treated, i.e., normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant cast steel grade in Table 4.

2.5.4 (void)

2.5.5 (void)

### 2.6 Materials for studs

The studs are to be made of steel corresponding to that of the chain cable or from rolled, cast or forged mild steels. The use of other materials, e.g. grey or nodular cast iron is not permitted.

## W18.3 Design and manufacture of chain cables and accessories

### 3.1 Design

Chain cables must be designed according to a standard recognized by the Society, such as ISO 1704. A length of chain cable must comprise an odd number of links. Where designs do not comply with this and where accessories are of welded construction, drawings giving full details of the design, the manufacturing process and the heat treatment are to be submitted to the Society for approval.

**W18**
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### 3.2 Dimensions and dimensional tolerances

3.2.1 The shape and proportions of links and accessories must conform to a recognized standard, such as ISO 1704 or the designs specially approved.

3.2.2. The following tolerances are applicable to links:

a) Diameter measured at the crown (Two measurements are to be taken at the same location: one in the plane of the link{see dp in Figure 2}, and one perpendicular to the plane of the link):
up to 40mm nominal diameter : –1mm
over 40 up to 84mm nominal diameter : – 2mm
over 84 up to 122mm nominal diameter : – 3mm
over 122mm nominal diameter : – 4mm
The plus tolerance may be up to 5% of the nominal diameter. The cross sectional area of the crown must have no negative tolerance.

b) Diameter measured at locations other than the crown:
The diameter is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter. The approved manufacturer's specification is applicable to the plus tolerance of the diamter at the flush-butt weld.

c) The maximum allowable tolerance on assembly measured over a length of 5 links may equal +2.5%, but may not be negative (measured with the chain under tension after proof load test).

d) All other dimensions are subject to a manufacturing tolerance of ±2.5%, provided always that all of the final link parts of the chain cable fit together properly.

e) Studs must be located in the links centrally and at right angles to the sides of the link, although the studs at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances are regarded as being inherent in the method of manufacture and will not be objected to provided that the stud fits snugly and its ends lie practically flush against the inside of the link.
Maximum off-centre distance "X" : 10% of the nominal diameter d
Maximum deviation "α" from the 90° - position : 4°
The tolerances are to be measured in accordance with Figure 2.

3.2.3 The following tolerances are applicable to accessories:
nominal diameter : + 5%, -0%
other dimentions : ± 2.5%

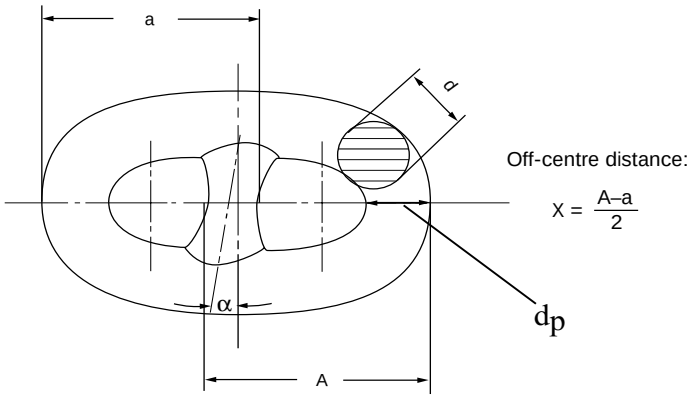


Figure 2 Manufacturing tolerances

### 3.3 Manufacturing process

3.3.1 Stud link chain cables should preferably be manufactured by flash butt welding using Grade 1, 2 or 3 bar material. Manufacture of the links by drop forging or castings is permitted. On request, pressure butt welding may also be approved for studless, Grade 1 and 2 chain cables, provided that the nominal diameter of the chain cable does not exceed 26mm.

3.3.2 Accessories such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade 2. The welded construction of these parts may also be approved.

**W18** cont'd

### 3.4 Welding of studs

The welding of studs is to be in accordance with an approved procedure subject to the following conditions:

a) The studs must be of weldable steel; cf. 2.6.
b) The studs are to be welded at one end only, i.e., opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.
c) The welds, preferably in the horizontal position, shall be executed by qualified welders using suitable welding consumables.
d) All welds must be carried out before the final heat treatment of the chain cable.
e) The welds must be free from defects liable to impair the proper use of the chain. Under-cuts, end craters and similar defects shall, where necessary, be ground off.

The Society reserves the right to call for a procedure test for the welding of chain studs.

### 3.5 Heat treatment

According to the grade of steel, chain cables and accessories are to be supplied in one of the conditions specified in Table 4. The heat treatment shall in every case be performed before the proof load test, the breaking load test, and all mechanical testing.

The mechanical properties of finished chain cables and accessories are to be in accordance with Table 7.

**Table 4 Condition of supply of chain cables and accessories**

| Grade | Chain cables | Accessories |
|---|---|---|
| 1 | As welded or Normalized | NA |
| 2 | As welded or Normalized [1)] | Normalized |
| 3 | Normalized, Normalized and tempered or Quenched and tempered | Normalized, Normalized and tempered or Quench and tempered |

1) Grade 2 chain cables made by forging or casting are to be supplied in the normalized condition.

NA = Not Applicable.

**W18**
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### 3.6 Freedom from defects

3.6.1 All individual parts must have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects imparing the performance of the product. The flashes produced by upsetting or drop forging must be properly removed.

3.6.2 Minor surface defects may be ground off so as to leave a gentle transition to the surrounding surface. Remote from the crown local grinding up to 5% of the nominal link diameter may be permitted.

## W18.4 Testing and certification of finished chain cables

### 4.1 Proof and breaking load tests

4.1.1 Finished chain cables are to be subjected to the proof load test and the breaking load test in the presence of the Surveyor, and shall not fracture or exhibit cracking. Special attention is to be given to the visual inspection of the flash-butt weld, if present. For this purpose, the chain cables must be free from paint and anti-corrosion media.

4.1.2 Each chain cable length (27.5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as given by Table 5 and using an approved testing machine.

**Table 5 Formulas for proof load and breaking load tests**

| Test | Grade 1 | Grade 2 | Grade 3 |
|---|---|---|---|
| Proof load (kN) | $0.00686d^2(44-0.08d)$ | $0.00981d^2(44-0.08d)$ | $0.01373d^2(44-0.08d)$ |
| Breaking load (kN) | $0.00981d^2(44-0.08d)$ | $0.01373d^2(44-0.08d)$ | $0.01961d^2(44-0.08d)$ |

***Note*: d = nominal diameter, in mm.**

4.1.3 For the breaking load test, one sample comprising at least of three links is to be taken from every four lengths or fraction of chain cables and tested at the breaking loads given by Table 5. The breaking load is to be maintained for a minimum of 30 seconds. The links concerned shall be made in a single manufacturing cycle together with the chain cable and must be welded and heat treated together with it. Only after this may they be separated from the chain cable in the presence of the Surveyor.

4.1.4 If the tensile loading capacity of the testing machine is insufficient to apply the breaking load for chain cables of large diameter, another equivalent testing method shall be agreed with the Society.

### 4.2 Retests

4.2.1 Should a breaking load test fail, a further test specimen may be taken from the same length of chain cable and tested. The test shall be considered successful if the requirements are then satisfied.
If the retest fails, the length of chain cable concerned shall be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the unit test quality may then be individually subjected to test at the breaking load. If one such test fails to meet the requirements, the entire unit test quantity is rejected.

4.2.2 Should a proof load test fail, the defective link(s) is (are) to be replaced, a local heat treatment to be carried out on the new link(s) and the proof load test is to be repeated. In addition, an investigation is to be made to identify the cause of the failure.

**W18**
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### 4.3 Mechanical tests on grade 2 and 3 chain cable

4.3.1 For Grade 2 and 3 chain cables, mechanical test specimens required in Table 6 are to be taken from every four lengths in accordance with 4.3.2. For forged or cast chain cables where the batch size is less than four lengths, the sampling frequency will be by heat and heat treatment charge. Mechanical tests are to be carried out in the presence of the Surveyor. For the location of the test specimens see 2.3.3.3 and Figure 1. Testing is to follow 2.3.3.4 and 2.3.3.5. Retesting is to follow 2.3.3.6 and 2.3.3.7.

4.3.2 An additional link (or where the links are small, several links) for mechanical test specimen removal is (are) to be provided in a length of chain cable not containing the specimen for the breaking test. The specimen link must be manufactured and heat treated together with the length of chain cable.

**Table 6 Number of mechanical test specimens for finished chain cables and accessories**

| Grade | Manufacturing method | Condition of supply[1)] | Number of test specimens | | |
|---|---|---|---|---|---|
| | | | Tensile test for base metal | Charpy V-notch impact test | |
| | | | | Base metal | Weldment |
| 1 | Flush-butt welded | AW<br>N | NR | NR | NR |
| 2 | Flush-butt welded | AW | 1 | 3 | 3 |
| | | N | NR | NR | NR |
| | Forged or Cast | N | 1 | 3[2)] | NA |
| 3 | Flush-butt welded | N<br>NT<br>QT | 1 | 3 | 3 |
| | Forged or Cast | N<br>NT<br>QT | 1 | 3 | NA |

1) AW = As welded, N = Normalized, NT = Normalized and tempered, QT = Quenched and tempered
2) For chain cables, Charpy V-notch impact test is not required.
NR = Not required
NA = Not applicable

**W18** cont'd

4.3.3 The mechanical properties must be in accordance with the values indicated in Table 7.

**Table 7 Mechanical properties of finished chain cables and accessories**

| Grade | $R_{eH}$ N/mm² min. | $R_m$ N/mm² | $A_5$ % min. | Z % min. | Charpy V-notch impact test | | |
|---|---|---|---|---|---|---|---|
| | | | | | Test temperature, in °C | Absorbed energy, in Joules min. | |
| | | | | | | Base metal | Weldment |
| 1 | NR | NR | NR | NR | NR | NR | NR |
| 2 | 295 | 490-690 | 22 | NR | 0 | 27 | 27 |
| 3 | 410 | 690 min. | 17 | 40 | 0[1)] | 60 | 50 |
| | | | | | -20 | 35 | 27 |

[1)] Testing is normally to be carried out at 0°C.

NR = Not required.

### 4.4 Marking

Chain cables which meet the requirements are to be stamped at both ends of each length at least with the following marks; cf. Figure 3.

- Chain cable grade
- Certificate number
- Society's stamp

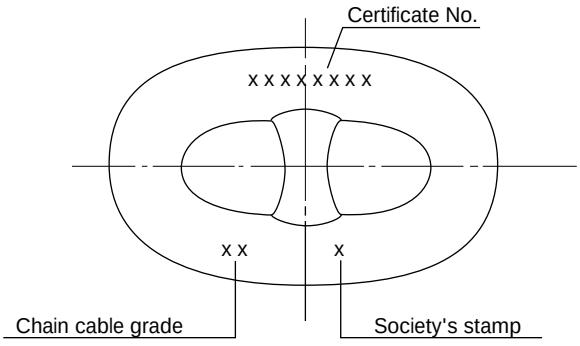


Figure 3 Marking of chain cables

**W18** cont'd

**4.5 Certification**

Chain cables which meet the requirements are to be certified by the Society at least with the following items:

- Manufacturer's name
- Grade
- Chemical composition (including total aluminum content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to chain
- Length
- Mechanical properties, where applicable

## W18.5 Testing and certification of accessories

**5.1 Proof load test**

All accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain given by Table 5, and in accordance with the provisions of 4.1, as appropriate.

**5.2 Breaking load test**

5.2.1 From each manufacturing batch (same accessory type, grade, size and heat treatment charge, but not necessarily representative of each heat of steel or individual purchase order) of 25 units or less of detachable links, shackles, swivels, swivel shackles, enlarged links, and end links, and from each manufacturing batch of 50 units or less of kenter shackles, one unit is to be subjected to the breaking load test at the break load specified for the corresponding chain given by Table 5 and in accordance with the provisions of 4.1, as appropriate. Parts tested in this way may not be put to further use. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

5.2.2 The Society may waive the breaking load test if:

a) the breaking load has been demonstrated on the occasion of the approval testing of parts of the same design, and
b) the mechanical properties of each manufacturing batch are proved, and
c) the parts are subjected to suitable non-destructive testing.

5.2.3 Notwithstanding the above, the accessories, which have been successfully tested at the prescribed breaking load appropriate to the chain, may be used in service at the discretion of the Society where the accessories are manufactured with the following:

a) the material having higher strength characteristics than those specified for the part in question (e.g. Grade 3 material for accessories for Grade 2 chain),
b) or alternatively, the same grade material as the chain but with increased dimensions subject to the successful procedure tests that such accessories are so designed that the breaking strength is not less than 1.4 times the prescribed breaking load of the chain for which they are intended.

**5.3 Mechanical properties and tests**

Unless otherwise specified, the forging or casting must at least comply with the mechanical properties given in Table 7, when properly heat treated. For test sampling, forgings or castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. Mechanical tests are to be carried out in the presence of the Surveyor depending on the type and grade of material used. From each test unit, one tensile test specimen and three Charpy V-notch impact test specimens are to be taken in accordance with Table 6 and tested in accordance with UR W2. For the location of the test specimens see 2.3.3.3 and Figure 1. Testing is to follow 2.3.3.4 and 2.3.3.5. Retesting is to follow 2.3.3.6 and 2.3.3.7. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

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**W18**
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**5.4 Marking**

Accessories which meet the requirements are to be stamped as follows:

- Chain cable grade
- Certificate number
- Society's stamp

**5.5 Certification**

Chain accessories which meet the requirements are to be certified by the Society at least with the following items:

- Manufacturer’s name
- Grade
- Heat Number
- Chemical composition (including total aluminum content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to accessory
- Mechanical properties, where applicable

**W18**
cont'd

# Appendix A

## Chafing Chain for Emergency Towing Arrangements

### 1. Scope

These requirements apply to the chafing chain for chafing gear of two types of Emergency Towing Arrangement (ETA) with specified safe working load (SWL) of 1000kN (ETA1000) and 2000kN (ETA2000). Chafing chains other than those specified can be used subject to special agreement with the Classification Society.

### 2. Approval of manufacturing

The chafing chain is to be manufactured by works approved by the Society according to W18.1.3.

### 3. Materials

The materials used for the manufacture of the chafing chain are to satisfy the requirements of W 18.2.

### 4. Design, manufacture, testing and certification of chafing chain

4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements of W18.3, W18.4 and W18.5.

4.2 The arrangement at the end connected to the strongpoint and the dimensions of the chafing chain are determined by the type of ETA. The other end of the chafing chain is to be fitted with a pear-shaped open link allowing connection to a shackle corresponding to the type of ETA and chain cable grade. A typical arrangement of this chain end is shown in Figure 1.

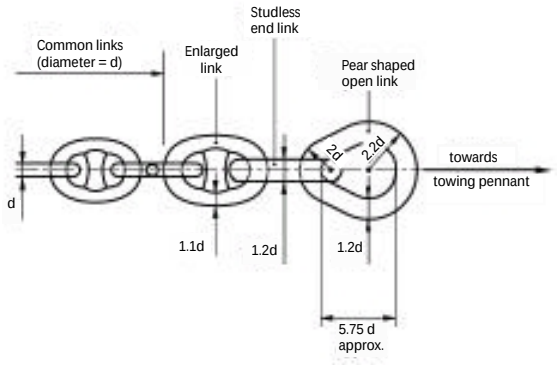
4.3 The common link is to be of stud link type grade 2 or 3.

4.4 The chafing chain is to be able to withstand a breaking load not less than twice the SWL. For each type of ETA, the nominal diameter of common link for chafing chains is to comply with the value indicated in Table 1.

Table 1 : Nominal diameter of common link for chafing chains

| Type of ETA | Nominal diameter of common link, d min. | |
|---|---|---|
| | Grade 2 | Grade 3 |
| ETA1000 | 62mm | 52mm |
| ETA2000 | 90mm | 76mm |

**Figure 1: Typical outboard chafing chain end**



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# W22 Offshore Mooring Chain

(1993) (Rev.1 1997) (Rev.2 July 1999) (Rev.3 May 2004) (Rev.4 Sept 2006) (Rev.5 Dec 2009) (Corr.1 June 2011)

## 1 GENERAL REQUIREMENTS

### 1.1 Scope

1.1.1 These requirements apply to the materials, design, manufacture and testing of offshore mooring chain and accessories intended to be used for applications such as: mooring of mobile offshore units, mooring of floating production units, mooring of offshore loading systems and mooring of gravity based structures during fabrication.

1.1.2 Mooring equipment covered are common stud and studless links, connecting common links (splice links), enlarged links, end links, detachable connecting links (shackles), end shackles, swivels and swivel shackles.

1.1.3 Studless link chain is normally deployed only once, being intended for long-term permanent mooring systems with pre-determined design life.

1.1.4 Requirements for chafing chain for single point mooring arrangements are given in Appendix A.

### 1.2 Chain grades

1.2.1 Depending on the nominal tensile strength of the steels used for manufacture, chains are to be subdivided into five grades, i.e.: R3, R3S, R4, R4S and R5.

1.2.2 Manufacturers propriety specifications for R4S and R5 may vary subject to design conditions and the acceptance of the Classification Society.

1.2.3 Each Grade is to be individually approved. Approval for a higher grade does not constitute approval of a lower grade.

### 1.3 Approval of chain manufacturers

1.3.1 Offshore mooring chain are to be manufactured only by works approved by the Society. For this purpose approval tests are to be carried out, the scope of which is to include proof and breaking load tests, measurements and mechanical tests including fracture mechanics tests.

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Note:

1. This UR is to be uniformly implemented by IACS Societies on offshore units and single point moorings contracted for construction on or after 1 July 2011 and when the application for certification of mooring chains and accessories is dated on or after 1 July 2011.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

**W22 (cont)**

1.3.2 Manufacturers are to submit for review and approval the sequence of operations from receiving inspection to shipment and details of the following manufacturing processes:

a) bar heating and bending including method, temperatures, temperature control and recording,
b) flash welding including current, force, time and dimensional variables as well as control and recording of parameters,
c) flash removal including method and inspection,
d) stud insertion method, for stud link chain,
e) heat treatment including furnace types, means of specifying, controlling and recording of temperature and chain speed and allowable limits, quenching bath and agitation, cooling method after exit,
f) proof and break loading including method/machine, means of horizontal support (if applicable), method of measurement and recording,
g) non-destructive examination procedures,
h) the manufacturer's surface quality requirement of mooring components is to be submitted.

1.3.3 For initial approval CTOD tests are to be carried out on the particular IACS mooring grade of material. CTOD tests are to be tested in accordance with a recognized standard such as BS 7448 Parts 1 & 2. The CTOD test piece is to be a standard 2 x 1 single edge notched bend piece, test location as shown in Figure 1. The minimum test piece size shall be 50 x 25mm for chain diameters less than 120mm, and 80 x 40mm for diameters 120mm and above. CTOD specimens are to be taken from both the side of the link containing the weld and from the opposite side. Three links are to be selected for testing, a total of six CTOD specimens. The tests are to be taken at minus 20º C and meet the minimum values indicated below:

| *Chain Type* | *R3 in mm* | | *R3S in mm* | | *R4 in mm* | | *R4S & R5 in mm* | |
|---|---|---|---|---|---|---|---|---|
| | *BM* | *WM* | *BW* | *WM* | *BM* | *WM* | *BM* | *WM* |
| Stud link | 0.20 | 0.10 | 0.22 | 0.11 | 0.24 | 0.12 | 0.26 | 0.13 |
| Studless | 0.20 | 0.14 | 0.22 | 0.15 | 0.24 | 0.16 | 0.26 | 0.17 |

1.3.4 Calibration of furnaces shall be verified by measurement and recording of a calibration test piece with dimensions equivalent to the maximum size of link manufactured. Thermocouples are to be placed both on the surface and in a drilled hole located to the mid thickness position of the calibration block.

1.3.5 For R4S and R5 chain and accessories, prior to approval, the manufacturer is to have undertaken experimental tests or have relevant supporting data to develop the chain and accessory material. The tests and data may include: fatigue tests, hot ductility tests (no internal flaws are to develop whilst bending in the link forming temperature range), welding parameter research, heat treatment study, strain age resistance, temper embrittlement study, stress corrosion cracking (SCC) data and hydrogen embrittlement (HE) study, using slow strain test pieces in hydrated environments. Reports indicating the results of experimental tests are to be submitted.

**W22**
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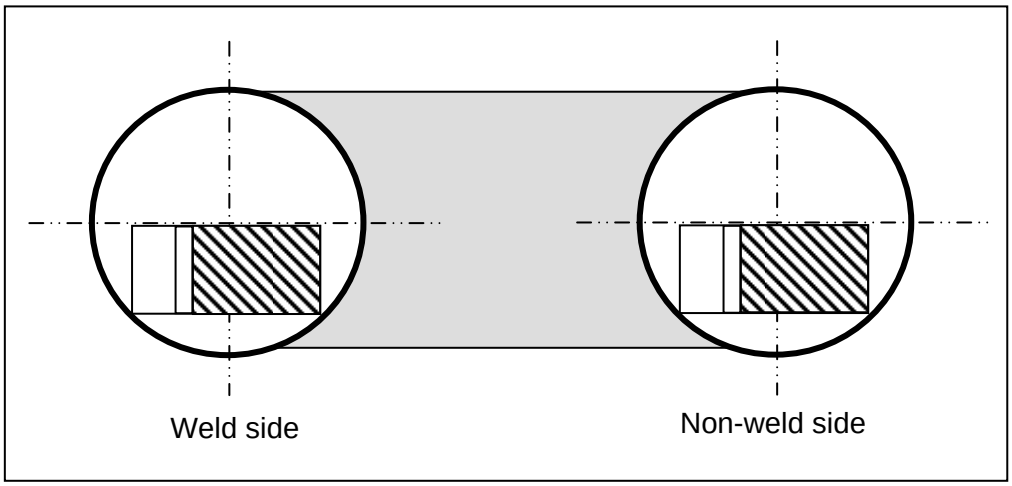


**Figure 1 Location of CTOD test specimens**

### 1.4 Approval of quality system at chain and accessory manufacturers

1.4.1 Chain and accessory manufacturers are to have a documented and effective quality system approved by the Society. The provision of such a quality system is required in addition to, and not in lieu of, the witnessing of tests by a Surveyor as specified in Sections 2 to 5 of this Unified Requirement.

### 1.5 Approval of steel mills; Rolled Bar

1.5.1 Bar materials intended for chain and accessories are to be manufactured only by works approved by the Society. The approval is limited to a nominated supplier of bar material. If a chain manufacturer wishes to use material from a number of suppliers, separate approval tests must be carried out for each supplier.

1.5.2 Approval will be given only after successful testing of the completed chain. The approval will normally be limited up to the maximum diameter equal to that of the chain diameter tested. The rolling reduction ratio is to be recorded and is to be at least 5:1. The rolling reduction ratio used in production can be higher, but should not be lower than that qualified.

1.5.3 The steelmaker is to submit a specification of the chemical composition of the bar material, which must be approved by the Society and by the chain manufacturer. For Grade R4, R4S and R5 chain the steel should contain a minimum of 0.20 per cent molybdenum.

1.5.4 A heat treatment sensitivity study simulating chain production conditions shall be applied in order to verify mechanical properties and establish limits for temperature and time combinations. All test details and results are to be submitted to the Classification society.

1.5.5 The bar manufacturer is to provide evidence that the manufacturing process produces material that is resistant to strain ageing, temper embrittlement and for R3S, R4, R4S and R5, hydrogen embrittlement. All test details and results are to be submitted to the Classification society.

### 1.6 Approval of forges and foundries; Accessories

1.6.1 Forges and foundries intending to supply finished or semi-finished accessories are to be approved by the Society. A description of manufacturing processes and process controls is to be submitted to the Society. The scope of approval is to be agreed with the Society. The approval is to be limited to a nominated supplier of forged or cast material. If an accessory

**W22 (cont)**

manufacturer wishes to use material from a number of suppliers, a separate approval must be carried out for each supplier.

1.6.2 Approval will be given only after successful testing of the completed accessory. The approval will normally be limited to the type of accessory and the IACS designated mooring grade of material up to the maximum diameter or thickness equal to that of the completed accessory used for qualification. Qualification of accessory pins to maximum diameters is also required. Individual accessories of complex geometries will be subject to the Classification Society requirements.

1.6.3 For forgings - The forging reduction ratio, used in the qualification tests, from cast ingot/slab to forged component is to be recorded. The forging reduction ratio used in production can be higher, but should not be lower than that qualified.

1.6.4 The forge or foundry is to submit a specification of the chemical composition of the forged or cast material, which must be approved by the Society. For Grade R4, R4S and R5 chain the steel should contain a minimum of 0.20 per cent molybdenum.

1.6.5 Forges and foundries are to provide evidence that the manufacturing process produces material that is resistant to strain ageing, temper embrittlement and for R4S and R5 grades, hydrogen embrittlement. A heat treatment sensitivity study simulating accessory production conditions shall be applied in order to verify mechanical properties and establish limits for temperature and time combinations. (Cooling after tempering shall be appropriate to avoid temper embrittlement). All test details and results are to be submitted to the Classification society.

1.6.6 For initial approval CTOD tests are to be carried out on the particular IACS mooring grade of material. Three CTOD tests are to be tested in accordance with a recognized standard such as BS 7448 Parts 1 & 2. The CTOD test piece is to be a standard 2 x 1 single edge notched bend specimen taken from the quarter thickness location. The minimum test piece size shall be 50 x 25mm for chain diameters less than 120mm, and 80 x 40mm for diameters 120mm and above. The tests are to be taken at minus 20º C and the results submitted for review.

1.6.7 Calibration of furnaces shall be verified by measurement and recording of a calibration test piece with dimensions equivalent to the maximum size of link manufactured. Thermocouples are to be placed both on the surface and in a drilled hole located to the mid thickness position of the calibration block.

1.6.8 For R4S and R5 refer to additional requirements in 1.3.5.

### 1.7 Approval of quality system at accessory manufacturers

1.7.1 Refer to 1.4.

## 2 MATERIALS

### 2.1 Scope

2.1.1 These requirements apply to rolled steels, forgings and castings used for the manufacture of offshore mooring chain and accessories.

**W22 (cont)**

## 2.2 Rolled steel bars

### 2.2.1 Steel manufacture

2.2.1.1 The steels are to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steels are to be killed and fine grain treated. The austenitic grain size is to be 6 or finer in accordance with ASTM E112.

2.2.1.2 Steel for bars intended for R4S and R5 chain is to be vacuum degassed.

2.2.1.3 For R4S and R5 the following information is to be supplied by the bar manufacturer to the mooring chain manufacturer and the results included in the chain documentation:

a) Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed; to be sure inclusion levels are acceptable for the final product.
b) A sample from each heat is to be macro etched according to ASTM E381 or equivalent, to be sure there is no injurious segregation or porosity.
c) Jominy hardenability data, according to ASTM A255, or equivalent, is to be supplied with each heat.

### 2.2.2 Chemical composition

2.2.2.1 For acceptance tests, the chemical composition of ladle samples of each heat is to be determined by the steel maker and is to comply with the approved specification.

### 2.2.3 Mechanical tests

2.2.3.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same heat. Test specimens are to be taken from material heat treated in the same manner as intended for the finished chain.

2.2.3.2 Each heat of Grade R3S, R4, R4S and R5 steel bars is to be tested for hydrogen embrittlement. In case of continuous casting, test samples representing both the beginning and the end of the charge shall be taken. In case of ingot casting, test samples representing two different ingots shall be taken.

2.2.3.2.1 Two (2) tensile test specimens shall be taken from the central region of bar material which has been subjected to the heat treatment cycle intended to be used in production. A specimen with a diameter of 20 mm is preferred (consideration will be given to a diameter of 14 mm).

2.2.3.2.2 One of the specimens is to be tested within a maximum of 3 hours after machining (for a 14 mm diameter specimen, the time limit is 1½ hours). Where this is not possible, the specimen is to be immediately cooled to -60°C after machining and kept at that temperature for a maximum period of 5 days.

2.2.3.2.3 The second specimen is to be tested after baking at 250°C for 4 hours, alternatively 2 hours for 14 mm diameter specimen.

2.2.3.2.4 A slow strain rate < 0,0003 $s^{-1}$ must be used during the entire test, until fracture occurs (This is approximately 10 minutes for the 20 mm diameter specimen). Tensile strength, elongation and reduction of area are to be reported.

**W22 (cont)**

2.2.3.2.5 The acceptance requirement for the test is:

$$Z_1/Z_2 \geq 0.85$$

where:

$Z_1$ = Reduction of area without baking
$Z_2$ = Reduction of area after baking

If the requirement $Z_1/Z_2 \geq 0.85$ is not achieved, the bar material may be subjected to a hydrogen degassing treatment after agreement with the Society. New tests shall be performed after degassing.

2.2.3.3 For all grades, one tensile and three Charpy V-notch specimens are to be taken from each sample selected. The test specimens are to be taken at approx. one-third radius below the surface, as shown in Figure 2 and prepared in accordance with UR W2. The results of all tests are to be in accordance with the appropriate requirements of Table 1.

2.2.3.4 Re-test requirements for tensile and Charpy impact tests are detailed in UR W2.

2.2.3.5 Failure to meet the requirements will result in rejection of the batch represented unless it can be clearly attributable to improper simulated heat treatment.

**Table 1 Mechanical properties of offshore mooring chain and accessories**

| Grade | Yield stress $N/mm^2$ minimum (1) | Tensile strength N/mm minimum (1) | Elongation % minimum | Reduction (3) of area % minimum | Charpy V-notch impact tests | | |
|---|---|---|---|---|---|---|---|
| | | | | | Test temperature °C (2) | Average energy J minimum | Avg. energy flash weld J minimum |
| **R3** | 410 | 690 | 17 | 50 | 0<br>-20 | 60<br>40 | 50<br>30 |
| **R3S** | 490 | 770 | 15 | 50 | 0<br>-20 | 65<br>45 | 53<br>33 |
| **R4** | 580 | 860 | 12 | 50 | -20 | 50 | 36 |
| **R4S(4)** | 700 | 960 | 12 | 50 | -20 | 56 | 40 |
| **R5(4)** | 760 | 1000 | 12 | 50 | -20 | 58 | 42 |

NOTES
1. Aim value of yield to tensile ratio: 0.92 max.
2. At the option of the Society the impact test of Grade R3 and R3S may be carried out at either 0°C or minus 20°C (See Table 1).
3. Reduction of area of cast steel is to be for Grades R3 and R3S: min. 40 %, for R4, R4S and R5: min. 35 %, cf. item 2.4.4.
4. Aim maximum hardness for R4S is HB330 and R5 HB340.

**W22**
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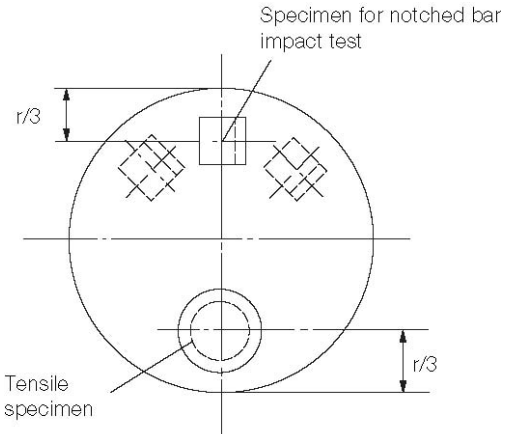



**Figure 2 Sampling of steel bars, forgings and castings**

### 2.2.4 Dimensional tolerances

2.2.4.1 The diameter and roundness shall be within the tolerances specified in Table 2, unless otherwise agreed.

**Table 2 Dimensional tolerance of bar stock**

| Nominal diameter mm | Tolerance on diameter mm | Tolerance on roundness ( $d_{max}$ - $d_{min}$) mm |
|---|---|---|
| less than 25 | -0 + 1.0 | 0.6 |
| 25 - 35 | -0 + 1.2 | 0.8 |
| 36 - 50 | -0 + 1.6 | 1.1 |
| 51 - 80 | -0 + 2.0 | 1.5 |
| 81 - 100 | -0 + 2.6 | 1.95 |
| 101 - 120 | -0 + 3.0 | 2.25 |
| 121 - 160 | -0 + 4.0 | 3.00 |
| 161 - 210 | -0 + 5.0 | 4.00 |

### 2.2.5 Non-destructive examination and repair

2.2.5.1 Non-destructive examination is to be performed in accordance with recognized Standards. Non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to the Classification Society.

2.2.5.2 Non-destructive examination operators are to be appropriately qualified (to a minimum level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program) in the method of non-destructive examination.

2.2.5.3 100 percent of bar material intended for either chain or fittings is to be subjected to ultrasonic examination at an appropriate stage of the manufacture. The bars shall be free of pipe, cracks and flakes.

**W22 (cont)**

2.2.5.4 100 percent of the bar material is to be examined by magnetic particle or eddy current methods. The bars shall be free of injurious surface imperfections such as seams, laps and rolled-in mill scale. Provided that their depth is not greater than 1% of the bar diameter, longitudinal discontinuities may be removed by grinding and blending to a smooth contour.

2.2.5.5 The frequency of NDE may be reduced at the discretion of the Society provided it is verified by statistical means that the required quality is consistently achieved.

### 2.2.6 Marking

2.2.6.1 Each bar is to be stamped with the steel grade designation and the charge number (or a code indicating the charge number) on one of the end surfaces. Other marking methods may be accepted subject to agreement.

## 2.3 Forged steel

### 2.3.1 Manufacture

2.3.1.1 Forged steels used for the manufacture of accessories must be in compliance with approved specifications and the submitted test reports approved by the Classification Surveyor. Steel is to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steel is to be killed and fine grain treated. The austenitic grain size is to be 6 or finer in accordance with ASTM E112.

2.3.1.2 Steel for forgings intended for R4S and R5 chain is to be vacuum degassed.

2.3.1.3 For steel intended for R4S and R5 accessories the following information is to be supplied by the steel manufacturer to the mooring accessory manufacturer and the results included in the accessory documentation:

a) Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed, to be sure inclusion levels are acceptable for the final product.
b) A sample from each heat is to be macroetched according to ASTM E381 or equivalent, to be sure there is no injurious segregation or porosity.
c) Jominy hardenability data, according to ASTM A255, or equivalent, is to be supplied with each heat.

### 2.3.2 Chemical composition (See 2.2.2)

### 2.3.3 Heat treatment

2.3.3.1 Finished forgings are to be properly heat treated in compliance with specifications submitted and approved.

### 2.3.4 Mechanical properties

2.3.4.1 The forgings must comply with the mechanical properties given in Table 1, when properly heat treated.

**W22 (cont)**

### 2.3.5 Mechanical tests

2.3.5.1 For test sampling, forgings of similar dimensions (diameters do not differ by more than 25mm) originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. From each test unit one tensile and three impact test specimens are to be taken and tested in accordance with UR W2. For the location of the test specimens see Figure 2.

### 2.3.6 Ultrasonic examination

2.3.6.1 Non-destructive examination is to be performed in accordance with recognized Standards and the non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to the Classification Society.

2.3.6.2 Non-destructive examination Operators are to be appropriately qualified (to a minimum level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program) in the method of non-destructive examination.

2.3.6.3 The forgings are to be subjected to one hundred percent ultrasonic examination at an appropriate stage of manufacture and in compliance with the standard submitted and approved.

### 2.3.7 Marking

2.3.7.1 Marking is to be similar to that specified in 2.2.6.

## 2.4 Cast steel

### 2.4.1 Manufacture

2.4.1.1 Cast steel used for the manufacture of accessories must be in compliance with approved specifications and the submitted test reports approved by the Classification Surveyor. Steel is to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steel is to be killed and fine grain treated. The austenitic grain size is to be 6 or finer in accordance with ASTM E112.

2.4.1.2 Steel for castings intended for R4S and R5 accessories is to be vacuum degassed.

2.4.1.3 For steel intended for R4S and R5 accessories the following information is to be obtained and the results included in the accessory documentation:

a) Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed; to be sure inclusion levels are acceptable for the final product.
b) A sample from each heat is to be macro etched according to ASTM E381 or equivalent, to be sure there is no injurious segregation or porosity.
c) Jominy hardenability data, according to ASTM A255, or equivalent, is to be supplied with each heat.

### 2.4.2 Chemical composition (See 2.2.2)

W22
(cont)

### 2.4.3 Heat treatment

2.4.3.1 All castings are to be properly heat treated in compliance with specifications submitted and approved.

### 2.4.4 Mechanical properties

2.4.4.1 The castings must comply with the mechanical properties given in Table 1. The acceptance requirement for reduction of area is, however, reduced to 40 percent for grades R3 and R3S and 35 percent for grades R4, R4S and R5.

### 2.4.5 Mechanical tests

2.4.5.1 For test sampling, castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. From each test unit one tensile and three impact test specimens are to be taken and tested. For the location of the test specimens see Figure 2.

### 2.4.6 Ultrasonic examination

2.4.6.1 Non-destructive examination is to be performed in accordance with recognized standards and the non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to the Classification Society.

2.4.6.2 Non-destructive examination operators are to be appropriately qualified (to a minimum level II in accordance with a recognized standard such as ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program) in the method of non-destructive examination.

2.4.6.3 The castings are to be subjected to one hundred percent ultrasonic examination in compliance with the standard submitted and approved.

### 2.4.7 Marking (See 2.3.7)

## 2.5 Materials for studs

2.5.1 Studs intended for stud link chain cable are to be made of steel corresponding to that of the chain or in compliance with specifications submitted and approved. In general, the carbon content should not exceed 0.25 percent if the studs are to be welded in place.

# 3 DESIGN AND CHAIN MANUFACTURE

## 3.1 Design

3.1.1 Drawings accompanied by design calculations, giving detailed design of chain and accessories made by or supplied through the chain manufacturer are to be submitted for approval. Typical designs are given in ISO 1704. For Studless chain the shape and proportions are to comply with the requirements of this UR. Other studless proportions are to be specially approved. It should be considered that new or non-Standard designs of chain, shackles or fittings, may require a fatigue analysis and possible performance, fatigue or corrosion fatigue testing.

3.1.2 In addition, for stud link chain, drawings showing the detailed design of the stud shall be submitted for information. The stud shall give an impression in the chain link which is sufficiently deep to secure the position of the stud, but the combined effect of shape and

**W22 (cont)**

depth of the impression shall not cause any harmful notch effect or stress concentration in the chain link.

3.1.3 Machining of Kenter shackles shall result in fillet radius min. 3 percent of nominal diameter.

### 3.2 Chain cable manufacturing process

#### 3.2.1 General

3.2.1.1 Offshore mooring chains shall be manufactured in continuous lengths by flash butt welding and are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.2.1.2 The use of joining shackles to replace defective links is subject to the written approval of the end purchaser in terms of the number and type permitted. The use of connecting common links is restricted to 3 links in each 100m of chain.

#### 3.2.2 Chain cable manufacturing process records

3.2.2.1 Records of bar heating, flash welding and heat treatment shall be made available for inspection by the Surveyor.

#### 3.2.3 Bar heating

3.2.3.1 For electric resistance heating, the heating phase shall be controlled by an optical heat sensor. The controller shall be checked at least once every 8 hours and records made.

3.2.3.2 For furnace heating, the heat shall be controlled and the temperature continuously recorded using thermocouples in close proximity to the bars. The controls shall be checked at least once every 8 hours and records made.

#### 3.2.4 Flash welding of chain cable

3.2.4.1 The following welding parameters shall be controlled during welding of each link:

a) Platen motion
b) Current as a function of time
c) Hydraulic pressure

3.2.4.2 The controls shall be checked at least every 4 hours and records made.

#### 3.2.5 Heat treatment of chain cable

3.2.5.1 Chain shall be austenitized, above the upper transformation temperature, at a combination of temperature and time within the limits established.

3.2.5.2 When applicable, chain shall be tempered at a combination of temperature and time within the limits established. Cooling after tempering shall be appropriate to avoid temper embrittlement.

3.2.5.3 Temperature and time or temperature and chain speed shall be controlled and continuously recorded.

**W22 (cont)**

### 3.2.6 Mechanical properties

3.2.6.1 The mechanical properties of finished chain and accessories are to be in accordance with Table 1. For the location of test specimens see Figures 2 and 3.

### 3.2.7 Proof and breaking test loads

3.2.7.1 Chains and accessories are to withstand the proof and break test loads given in Table 3.

### 3.2.8 Freedom from defects

3.2.8.1 All chains are to have a workmanlike finish consistent with the method of manufacture and be free from defects. Each link is to be examined in accordance with section 4.5 using approved procedures.

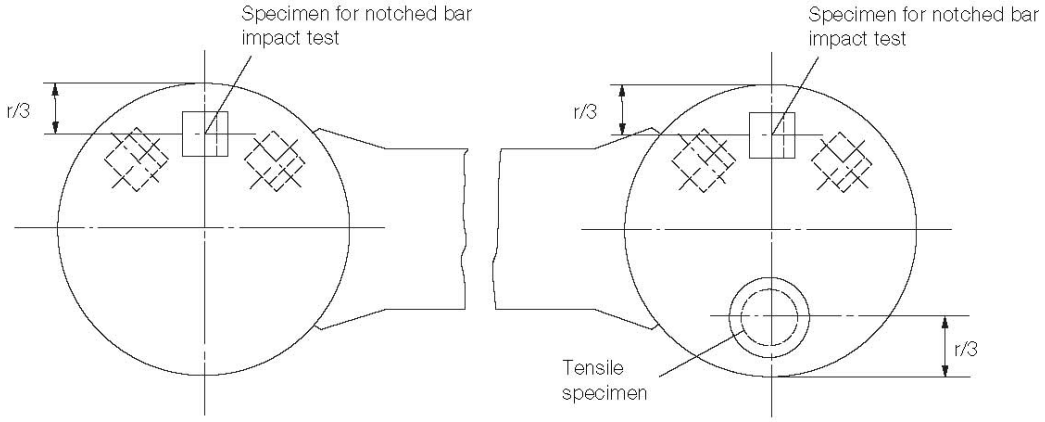



**Figure 3 Sampling of chain links**

**Table 3 Formulas for proof and break test loads, weight and length over 5 links**

| ***Test Load, in kN*** | ***Grade R3 Stud Link*** | ***Grade R3S Stud Link*** | ***Grade R4 Stud Link*** | ***Grade R4S Stud Link*** | ***Grade R5 Stud Link*** |
|---|---|---|---|---|---|
| Proof | $0.0148\ d^2$ $(44 - 0.08d)$ | $0.0180\ d^2$ $(44 - 0.08d)$ | $0.0216\ d^2$ $(44 - 0.08d)$ | $0.0240\ d^2$ $(44 - 0.08d)$ | $0.0251\ d^2$ $(44 - 0.08d)$ |
| Break | $0.0223\ d^2$ $(44 - 0.08d)$ | $0.0249\ d^2$ $(44 - 0.08d)$ | $0.0274\ d^2$ $(44 - 0.08d)$ | $0.0304\ d^2$ $(44 - 0.08d)$ | $0.0320\ d^2$ $(44 - 0.08d)$ |
| ***Test Load, in kN*** | ***Grade R3 Studless*** | ***Grade R3S Studless*** | ***Grade R4 Studless*** | ***Grade R4S Studless*** | ***Grade R5 Studless*** |
| Proof | $0.0148\ d^2$ $(44 - 0.08d)$ | $0.0174\ d^2$ $(44 - 0.08d)$ | $0.0192\ d^2$ $(44 - 0.08d)$ | $0.0213\ d^2$ $(44 - 0.08d)$ | $0.0223\ d^2$ $(44 - 0.08d)$ |
| Break | $0.0223\ d^2$ $(44 - 0.08d)$ | $0.0249\ d^2$ $(44 - 0.08d)$ | $0.0274\ d^2$ $(44 - 0.08d)$ | $0.0304\ d^2$ $(44 - 0.08d)$ | $0.0320\ d^2$ $(44 - 0.08d)$ |
| Chain Weight, in kg/m | Stud link = $0.0219d^2$ | | | | |
| Chain Weight, in kg/m | Studless chain<br>Weight calculations for each design are to be submitted. | | | | |
| Pitch Length | Five Link Measure | | | | |
| Minimum | $22d$ | | | | |
| Maximum | $22.55d$ | | | | |

**W22**
**(cont)**

### 3.2.9 Dimensions and dimensional tolerances

3.2.9.1 The shape and proportion of links and accessories must conform to ISO 1704:1991 or the designs specially approved.

3.2.9.2 The following tolerances are applicable to links:

a) Diameter measured at the crown:

| | |
|---|---|
| up to 40 mm nominal diameter | : - 1 mm |
| over 40 up to 84 mm nominal diameter | : - 2 mm |
| over 84 up to 122 mm nominal diameter | : - 3 mm |
| over 122 up to 152 mm nominal diameter | : - 4 mm |
| over 152 up to 184 mm nominal diameter | : - 6 mm |
| over 184 up to 210 mm nominal diameter | : - 7.5 mm |

Note: The plus tolerance may be up to 5 percent of the nominal diameter. The cross sectional area at the crown must have no negative tolerance.

b) Diameter measured at locations other than the crown:

The diameter is to have no negative tolerance. The plus tolerance may be up to 5 percent of the nominal diameter. The approved manufacturer's specification is applicable to the plus tolerance of the diameter at the flash butt weld.

c) The allowable manufacturing tolerance on a length of five links is + 2.5 percent, but may not be negative.

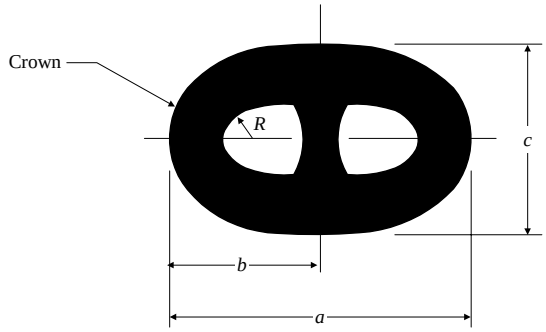
d) All other dimensions are subject to a manufacturing tolerance of ± 2.5 percent, provided always that all parts fit together properly.

e) The tolerances for stud link and studless common links are to be measured in accordance with Figure 4.

f) For stud link chains studs must be located in the links centrally and at right angles to the sides of the link. The following tolerances in Figure 4 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link:

**W22**
**(cont)**

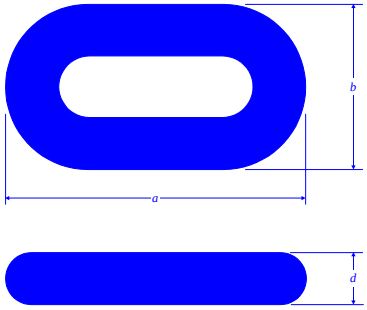
**(a) Stud link** - The internal link radii (R) and external radii should be uniform




| *Designation* (1) | *Description* | *Nominal Dimension of the Link* | *Minus Tolerance* | *Plus Tolerance* |
|---|---|---|---|---|
| *a* | Link Length | 6*d* | 0.15*d* | 0.15*d* |
| *b* | Link Half Length | *a**/2 | 0.1*d* | 0.1*d* |
| *c* | Link Width | 3.6*d* | 0.09*d* | 0.09*d* |
| *e* | Stud Angular Misalignment | 0 degrees | 4 degrees | 4 degrees |
| *R* | Inner Radius | 0.65*d* | 0 | ----- |

Notes: 1 Dimension designation is shown in above figure
d = Nominal diameter of chain, a* = Actual link length

**(b) Studless** - The internal link radii (R) and external radii should be uniform.




| *Designation* (1) | *Description* | *Nominal Dimension of the Link* | *Minus Tolerance* | *Plus Tolerance* |
|---|---|---|---|---|
| *a* | Link Length | 6*d* | 0.15*d* | 0.15*d* |
| *b* | Link Width | 3.35*d* | 0.09*d* | 0.09*d* |
| *R* | Inner Radius | 0.60*d* | 0 | ----- |

Notes: 1 Dimension designation is shown in above figure.
d = Nominal diameter of chain
2 Other dimension ratios are subject to special approval.

**Figure 4 Stud link and studless common link, proportions dimensions and tolerances**

W22
(cont)

### 3.2.10 Stud link chain - welding of studs

3.2.10.1 A welded stud may be accepted for grade R3 and R3S chains. Welding of studs in grades R4, R4S and R5 chain is not permitted unless specially approved.

3.2.10.2 Where studs are welded into the links this is to be completed before the chain is heat treated.

3.2.10.3 The stud ends must be a good fit inside the link and the weld is to be confined to the stud end opposite to the flash butt weld. The full periphery of the stud end is to be welded unless otherwise approved.

3.2.10.4 Welding of studs both ends is not permitted unless specially approved.

3.2.10.5 The welds are to be made by qualified welders using an approved procedure and low-hydrogen approved consumables.

3.2.10.6 The size of the fillet weld shall as a minimum be as per API Specification 2F.

3.2.10.7 The welds are to be of good quality and free from defects such as cracks, lack of fusion, gross porosity and undercuts exceeding 1 mm.

3.2.10.8 All stud welds shall be visually examined. At least 10 per cent of all stud welds within each length of chain shall be examined by dye penetrant or magnetic particles after proof testing. If cracks or lack of fusion are found, all stud welds in that length are to be examined.

### 3.2.11 Connecting common links (splice links)

3.2.11.1 Single links to substitute for test links or defective links without the necessity for re-heat treatment of the whole length are to be made in accordance with an approved procedure. Separate approvals are required for each grade of chain and the tests are to be made on the maximum size of chain for which approval is sought.

3.2.11.2 Manufacture and heat treatment of connecting common link is not to affect the properties of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.2.11.3 Each link is to be subjected to the appropriate proof load and non-destructive examination as detailed in Table 3 and Section 4.5. A second link shall be made identical to the connecting common link; the link shall be tested and inspected per Section 4.4 and 4.5.

3.2.11.4 Each connecting common link is to be marked either; on the stud for stud link chain or, on the outer straight length on the side opposite the flash butt weld for Studless chain. This marking is to be in accordance with Section 4.7 plus a unique number for the link. The adjoining links are also to be marked on the studs or straight length as above.

## 4 TESTING AND INSPECTION OF FINISHED CHAIN

### 4.1 General

4.1.1 This section applies to but is not limited to finished chain cable such as common stud and studless links, end links, enlarged end links and connecting common links (splice links).

4.1.2 All chain is to be subjected to proof load tests, sample break load tests and sample mechanical tests after final heat treatment in the presence of a Surveyor. Where the

**W22 (cont)**

manufacturer has a procedure to record proof loads and the Surveyor is satisfied with the adequacy of the recording system, he need not witness all proof load tests. The Surveyor is to satisfy himself that the testing machines are calibrated and maintained in a satisfactory condition. Prior to testing and inspection the chain is to be free from scale, paint or other coating. The chain shall be sand- or shot blasted to meet this requirement.

**4.2 Proof and break load tests**

4.2.1 The entire length of chain shall withstand the proof load specified in Table 3 without fracture and shall not crack in the flash weld. The load applied shall not exceed the proof load by more than 10% when stretching the chain. Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests.

4.2.2 A break-test specimen consisting of at least 3 links is to be either taken from the chain or produced at the same time and in the same manner as the chain. The test frequency is to be based on tests at sampling intervals according to Table 4 provided that every cast is represented. Each specimen shall be capable of withstanding the break load specified without fracture and shall not crack in the flash weld. It shall be considered acceptable if the specimen is loaded to the specified value and maintained at that load for 30 seconds.

4.2.3 For chain diameters over 100mm, alternative break-test proposals to the above break-test will be considered whereby a one link specimen is used. Alternatives are to be approved by the Classification Society, every heat is to be represented, the test frequency is to be in accordance with Table 4, and it is to be demonstrated and proven that the alternative test represents an equivalent load application to the three link test.

4.2.4 If the loading capacity of the testing machine is insufficient, another equivalent method shall be agreed with the Society.

**Table 4 Frequency of break and mechanical tests**

| Nominal chain diameter (mm) | Maximum sampling interval (m) |
|---|---|
| Min - 48 | 91 |
| 49 - 60 | 110 |
| 61 - 73 | 131 |
| 74 - 85 | 152 |
| 86 - 98 | 175 |
| 99 - 111 | 198 |
| 112 - 124 | 222 |
| 125 - 137 | 250 |
| 138 - 149 | 274 |
| 150 - 162 | 297 |
| 163 - 175 | 322 |
| 176 – 186 | 346 |
| 187 – 199 | 370 |
| 199 - 210 | 395 |

**W22 (cont)**

### 4.3 Dimensions and dimensional tolerances

4.3.1 After proof load testing measurements are to be taken on at least 5 per cent of the links in accordance with Section 3.2.9.

4.3.2 The entire chain is to be checked for the length, five links at a time. By the five link check the first five links shall be measured. From the next set of five links, at least two links from the previous five links set shall be included. This procedure is to be followed for the entire chain length. The measurements are to be taken preferably while the chain is loaded to 5 - 10 % of the minimum proof load. The links held in the end blocks may be excluded from this measurement.

### 4.4 Mechanical tests

4.4.1 Links of samples detached from finished, heat treated chain shall be sectioned for determination of mechanical properties. A test unit shall consist of one tensile and nine impact specimens. The tensile specimen shall be taken in the side opposite the flash weld. Three impact specimens shall be taken across the flash weld with the notch centred in the middle. Three impact specimens shall be taken across the unwelded side and three impact specimens shall be taken from the bend region.

4.4.2 The test frequency is to be based on tests at sampling intervals according to Table 4 provided that every cast is represented. Mechanical properties shall be as specified in Table 1.

4.4.3 The frequency of impact testing in the bend may be reduced at the discretion of the Society provided it is verified by statistical means that the required toughness is consistently achieved.

### 4.5 Non-destructive examination

4.5.1 After proof testing, all surfaces of every link shall be visually examined. Burrs, irregularities and rough edges shall be contour ground. Links shall be free from mill defects, surface cracks, dents and cuts, especially in the vicinity where gripped by clamping dies during flash welding. Studs shall be securely fastened. Chain is to be positioned in order to have good access to all surfaces.

4.5.2 Testing is to be performed in accordance with a recognized Standard and the procedures, together with acceptance/rejection criteria are to be submitted to the Classification Society for review. Operators are to be appropriately qualified, in the method of inspection, to at least level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program.

4.5.3 Magnetic particles shall be employed to examine the flash welded area including the area gripped by the clamping dies. Procedures and equipment in accordance with those approved shall be used. Frequency of examination shall be every link. Additionally, 10% of links are to be tested on all accessible surfaces. Link surfaces and the surface at the flash weld shall be free from cracks, lack of fusion and gross porosity.

4.5.4 Ultrasonics shall be employed to examine the flash weld fusion. Procedures and equipment in accordance with those approved shall be used. On-site calibration standards for chain configurations shall be approved. Frequency of examination shall be every link. The flash weld shall be free from defects causing ultrasonic back reflections equal to or greater than the calibration standard.

**W22 (cont)**

**4.6 Retest, rejection and repair criteria**

4.6.1 If the length over 5 links is short, the chain may be stretched by loading above the proof test load specified provided that the applied load is not greater than that approved and that only random lengths of the chain need stretching. If the length exceeds the specified tolerance, the over length chain links shall be cut out and 4.6.2 shall apply.

4.6.2 If single links are found to be defective or to not meet other applicable requirements, defective links may be cut out and a connecting common link inserted in their place. The individual heat treatment and inspection procedure of connecting common links is subject to the Society's approval. Other methods for repair are subject to the written approval of the Society and the end purchaser.

4.6.3 If a crack, cut or defect in the flash weld is found by visual or magnetic particle examination, it shall be ground down no more than 5% of the link diameter in depth and streamlined to provide no sharp contours. The final dimensions must still conform to the agreed standard.

4.6.4 If indications of interior of flash weld defects, in reference to the accepted calibration standards are detected during ultrasonic examination, 4.6.2 shall apply.

4.6.5 If link diameter, length, width and stud alignment do not conform to the required dimensions, these shall be compared to the dimensions of 40 more links; 20 on each side of the affected link. If a single particular dimension fails to meet the required dimensional tolerance in more than 2 of the sample links, all links shall be examined. Sec. 4.6.2 shall apply.

4.6.6 If a break load test fails, a thorough examination with the Surveyor informed in a timely manner is to be carried out to identify the cause of failure. Two additional break test specimens representing the same sampling length of chain are to be subjected to the break load test. Based upon satisfactory results of the additional tests and the results of the failure investigation, it will be decided what lengths of chain can be accepted. Failure of either or both additional tests will result in rejection of the sampling length of chain represented and 4.6.2 shall apply.

4.6.7 If a link fails during proof load testing, a thorough examination with the Surveyor informed in a timely manner is to be carried out to identify the probable cause of failure of the proof test. In the event that two or more links in the proof loaded length fail, that length is to be rejected. The above failure investigation is to be carried out especially with regard to the presence in other lengths of factors or conditions thought to be causal to failure.

4.6.8 In addition to the above failure investigation, a break test specimen is to be taken from each side of the one failed link, and subjected to the breaking test. Based upon satisfactory results of both break tests and the results of the failure investigation, it will be decided what length of chain can be considered for acceptance. Failure of either or both breaking tests will result in rejection of the same proof loaded length. Replacement of defective links is to be in accordance with 4.6.2.

4.6.9 Re-test requirements for tensile tests are to be in accordance with UR W2. Failure to meet the specified requirements of either or both additional tests will result in rejection of the sampling length of chain represented and 4.6.2 shall apply.

4.6.10 Re-test requirements for Charpy impact tests are to be in accordance with UR W2. Failure to meet the requirements will result in rejection of the sampling length represented and 4.6.2 shall apply.

**W22 (cont)**

### 4.7 Marking

4.7.1 The chain shall be marked at the following places:

- At each end.
- At intervals not exceeding 100 m.
- On connecting common links.
- On links next to shackles or connecting common links.

4.7.2 All marked links shall be stated on the certificate, and the marking shall make it possible to recognize leading and tail end of the chain. In addition to the above required marking, the first and last common link of each individual charge used in the continuous length shall be traceable and adequately marked.

The marking shall be permanent and legible throughout the expected lifetime of the chain.

4.7.3 The chain shall be marked on the studs as follows:

- Chain grade
- Certificate No.
- Society's stamp

4.7.4 The Certificate number may be exchanged against an abbreviation or equivalent. If so, this shall be stated in the certificate.

4.7.5 The chain certificate shall contain information on number and location of connecting common links. The certificate number and replacement link number may be exchanged against an abbreviation or equivalent. If so, this shall be stated in the certificate.

### 4.8 Documentation

4.8.1 A complete Chain Inspection and Testing Report in booklet form shall be provided by the chain manufacturer for each continuous chain length. This booklet shall include all dimensional checks, test and inspection reports, NDT reports, process records, photographs as well as any nonconformity, corrective action and repair work.

4.8.2 Individual certificates are to be issued for each continuous single length of chain.

4.8.3 All accompanying documents, appendices and reports shall carry reference to the original certificate number.

4.8.4 The manufacturer will be responsible for storing, in a safe and retrievable manner, all documentation produced for a period of at least 10 years.

## 5 TESTING AND INSPECTION OF ACCESSORIES

### 5.1 General

5.1.1 This section applies to but is not limited to mooring equipment accessories such as detachable connecting links (shackles), detachable connecting plates (triplates), end shackles, swivels and swivel shackles.

5.1.2 All accessories are to be subjected to proof load tests, sample break load tests and sample mechanical tests after final heat treatment in the presence of a Surveyor. Where the manufacturer has a procedure to record proof loads and the Surveyor is satisfied with the

**W22 (cont)**

adequacy of the recording system, he need not witness all proof load tests. The Surveyor is to satisfy himself that the testing machines are calibrated and maintained in a satisfactory condition. Prior to testing and inspection the chain accessories are to be free from scale, paint or other coating.

**5.2 Proof and break load tests**

5.2.1 All accessories are to be subjected to the proof load specified for the corresponding stud link chain.

5.2.2 Chain accessories are to be tested at the break load prescribed for the grade and size of chain for which they are intended. At least one accessory out of every batch or every 25 accessories, whichever is less, is to be tested. For individually produced accessories or accessories produced in small batches (less than 5), alternative testing will be subject to special consideration. Alternative testing is to be approved by the Classification society.

5.2.3 A batch is defined as accessories that originate from the same heat treatment charge and the same heat of steel. Reference sections 2.3 and 2.4.

5.2.4 The accessories which have been subjected to the break load test are to be destroyed and not used as part of an outfit, with the exceptions given in 5.2.5.

5.2.5 Where the accessories are of increased dimension or alternatively a material with higher strength characteristics is used, they may be included in the outfit at the discretion of the Classification Society, provided that;

(a) the accessories are successfully tested at the prescribed breaking load appropriate to the chain for which they are intended, and

(b) it is verified by procedure tests that such accessories are so designed that the breaking strength is not less than 1.4 times the prescribed breaking load of the chain for which they are intended.

**5.3 Dimensions and dimensional tolerances**

5.3.1 At least one accessory (of the same type, size and nominal strength) out of 25 is to be checked for dimensions after proof load testing. The manufacturer is to provide a statement indicating compliance with the purchaser's requirements.

5.3.2 The following tolerances are applicable to accessories:

a) Nominal diameter: + 5 percent, - 0 percent
b) Other dimensions: ± 2½ percent

These tolerances do not apply to machined surfaces.

**5.4 Mechanical tests**

5.4.1 Accessories are to be subjected to mechanical testing as described in Section 2.3 and 2.4. Mechanical tests are to be taken from proof loaded full size accessories that have been heat treated with the production accessories they represent. The use of separate representative coupons is not permitted except as indicated in 5.4.4 below.

5.4.2 Test location of forged shackles. Forged shackle bodies and forged Kenter shackles are to have a set of three impact tests and a tensile test taken from the crown of the shackle.

**W22 (cont)**

Tensile tests on smaller diameter shackles can be taken from the straight part of the shackle, where the geometry does not permit a tensile specimen from the crown. The tensile properties and impact values are to meet the requirements of Table 1 in the locations specified in Figure 2, with the Charpy pieces on the outside radius.

5.4.3 The locations of mechanical tests of cast shackles and cast Kenter shackles can be taken from the straight part of the accessory. The tensile properties and impact values are to meet the requirements of Table 1 in the locations specified in Figure 2.

5.4.4 The locations of mechanical tests of other accessories with complex geometries are to be agreed with the Classification Society.

5.4.5 For individually produced accessories or accessories produced in small batches, (less than 5), alternative testing can be proposed to the Classification Society.
Each proposal for alternative testing is to be detailed by the manufacturer in a written procedure and submitted to the Classification Society.

5.4.6 A batch is defined as accessories that originate from the same heat treatment charge and the same heat of steel. Reference sections 2.3 and 2.4.

5.4.7 Mechanical tests of pins are to be taken as per Figure 2 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter dimension which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin as per Figure 5.

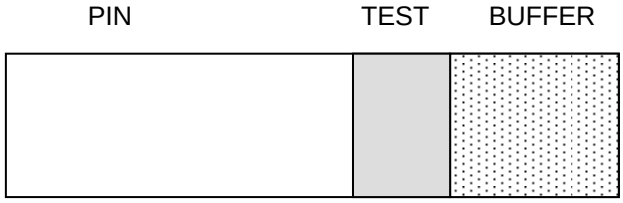



**Figure 5 Buffer and test piece location**

### 5.5 Non-destructive examination

5.5.1 After proof load testing all chain accessories are to be subjected to a close visual examination. Special attention is to be paid to machined surfaces and high stress regions. All non-machined surfaces are to be sand or shot blasted to permit a thorough examination. All accessories are to be checked by magnetic particles or dye penetrant.

5.5.2 Testing is to be performed in accordance with a recognized Standard and the procedures, together with acceptance/rejection criteria are to be submitted to the Classification Society for review. Operators are to be appropriately qualified, in the method of inspection, to at least level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program.

5.5.3 The manufacturer is to provide a statement that non destructive examination has been carried out with satisfactory results. This statement should include a brief reference to the techniques and to the operator's qualification.

**W22**
**(cont)**

### 5.6 Test failures

5.6.1 In the event of a failure of any test the entire batch represented is to be rejected unless the cause of failure has been determined and it can be demonstrated to the Surveyor's satisfaction that the condition causing the failure is not present in any of the remaining accessories.

### 5.7 Marking

5.7.1 Each accessory is to be marked as follows:

- Chain grade

5.7.2 The Certificate number may be exchanged against an abbreviation or equivalent. If so, this shall be stated in the certificate.

### 5.8 Documentation

5.8.1 A complete Inspection and Testing Report in booklet form shall be provided by the manufacturer for each order. This booklet shall include all dimensional checks, test and inspection reports, NDT reports, process records as well as any nonconformity, corrective action and repair work.

5.8.2 Each type of accessory shall be covered by separate certificates.

5.8.3 All accompanying documents, appendices and reports shall carry reference to the original certificate number.

5.8.4 The manufacturer will be responsible for storing, in a safe and retrievable manner, all documentation produced for a period of at least 10 years.

**W22 (cont)**

# Appendix A - Chafing Chain for Single Point Mooring arrangements

## A.1. Scope

These requirements apply to short lengths (approximately 8m) of 76mm diameter chain to be connected to hawsers for the tethering of oil carriers to single point moorings, FPSO's and similar uses.

## A.2. Approval of Manufacturing

A.2.1 The chafing chain is to be manufactured by works approved by the Society according to W22.1.3.

## A.3. Materials

A.3.1 The materials used for the manufacture of the chafing chain are to satisfy the requirements of W22.2.

## A.4. Design, manufacturing, testing and certification

A.4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with W22.3, W22.4 and W22.5, except that batch heat treatment is permitted.

A.4.2 The arrangement of the end connections is to be of an approved type.

A.4.3 The common link is to be of the stud link type – Grade R3 or R4.

A.4.4 The chafing chain is to be capable of withstanding the breaking test loads of 4884kN (Grade R3) and 6001kN (Grade R4). See Note 1.

A.4.5 The chain lengths shall be proof load tested in accordance with W22.4.2. The test load for Grade R3 is 3242kN and for Grade R4 is 4731kN.

Note 1: Documented evidence of satisfactory testing of similar diameter mooring chain in the prior 6 month period may be used in lieu of break testing subject to agreement with classification society.

End of Document

# W23 Approval of Welding Consumables for High Strength Quenched and Tempered Steels for Welded Structures

(1995)
(Rev 1
1997)

## 1. General

### 1.1 Scope

1.1.1 These requirements supplements the UR W17 and give the conditions of approval and inspection of welding consumables used for high strength quenched and tempered or TMCP steels for welded structures according to UR W16 with yield strength levels from 420 N/mm$^2$ up to 690 N/mm$^2$ and impact grades A, D, E and F.
Where no special requirements are given, those of UR W17 apply in analogous manner.

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

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

### 1.2 Grading, Designation

1.2.1 Based on the yield strength of the weld metal, the welding consumables concerned are divided into six (yield) strength groups :

- Y42 - for welding steels with minimum yield strength 420 N/mm$^2$
- Y46 - for welding steels with minimum yield strength 460 N/mm$^2$
- Y50 - for welding steels with minimum yield strength 500 N/mm$^2$
- Y55 - for welding steels with minimum yield strength 550 N/mm$^2$
- Y62 - for welding steels with minimum yield strength 620 N/mm$^2$
- Y69 - for welding steels with minimum yield strength 690 N/mm$^2$

*) Wire-flux combinations for single or two-run technique are subject to special consideration of the Classification Society.

1.2.2 Each of the six (yield) strength groups is further divided into three main grades in respect of charpy V-notch impact test requirements (test temperatures):

- Grade 3, test temperature -20$^o$C
- Grade 4, test temperature -40$^o$C
- Grade 5, test temperature -60$^o$C

1.2.3 Analagously to the designation scheme used in UR W17 the welding consumables for high strength quenched and tempered steels are subject to classification designation and approval as follows:

▶

**W23**
cont'd

- According to 1.2.2 with the quality grades **3,4 or 5**
- With the added symbol Y and an appended code number designating the minimum yield strength of the weld metal corresponding 1.2.1: Y42, Y46, Y50, Y55, Y62 and Y69.
- With the added symbol H10 (HH) or H5 (HHH) for controlled hydrogen content of the weld metal,
- With the added symbol **S** (= semi-automatic) for semi-mechanised welding,
- With the added symbol **M** designating multirun technique *) (and is applicable only to welding consumables for fully mechanised welding),

*) see footnote on page 2

1.2.4 Each higher quality grade includes the one (or those) below Grade A... and D... steels acc. to UR W16 are to be welded using welding consumables of at least quality grade 3, grade E... steels using at least quality grade 4 and grade F... steels using at least quality grade 5., see the following table :

| Consumable Grade | Steel Grades covered |
|---|---|
| 3Y..<br>4Y..<br>5Y.. | D.. and A..<br>E..,D.. and A..<br>F..,E..,D.. and A.. |

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

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

1.3 Manufacture, testing and approval procedure

1.3.1 Manufacturer's plant, production methods and quality control measures shall be such as to ensure reasonable uniformity in manufacture, see also UR W17.

1.3.2 Testing and approval procedure shall be in accordance with UR W17, sections 2 and 3 and as required in UR W17 for the individual categories (types) of welding consumables mentioned in 1.1.2 above.

◀

**2. Testing of the weld metal**

2.1 For testing the deposited weld metal, test pieces analogous to those called for in UR W17, sections 4.2, 5.2, 6.2 or 6.3 respectively shall be prepared, depending on the type of the welding consumables (and according to the welding process). the base metal used shall be a fine-grained structural steel compatible with the properties of the weld metal, or the side walls of the weld shall be buttered with a weld metal of the same composition.

▶

**W23**
cont'd

2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in UR W17, section 4.2.2. The results of the analysis shall not exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

2.3 Depending on the type of the welding consumables (and according to the welding process), the test specimens prescribed in UR W17, sections 3.1 and 4.2, 5.2, 6.2 or 6.3 respectively shall be taken from the weld metal test pieces in a similar manner.

2.4 The mechanical properties must meet the requirements stated in Tables 1 and 2. The provisions of UR W17 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperature in the notched bar impact test and the carrying out of results.

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

| Quality grade | Test temperature [°C] | Minimum notch impact energy [J] 1) |
|---|---|---|
| 3 | - 20 | Y42: ≥ 47<br>Y46: ≥ 47<br>Y50: ≥ 50<br>Y55: ≥ 55<br>Y62: ≥ 62<br>Y69: ≥ 69 |
| 4 | - 40 | |
| 5 | - 60 | |

1) Charpy V-notch impact test specimen, mean value of three specimens; for requirements regarding minimum individual values and retests, see UR W17, section 3.3.2

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

| Symbols added to quality grade | Minimum yield strength or 0.2% proof stress [N/mm²] | Tensile Strength 1) [N/mm²] | Minimum elongation [%] |
|---|---|---|---|
| Y42 | 420 | 530-680 | 20 |
| Y46 | 460 | 570-720 | 20 |
| Y50 | 500 | 610-770 | 18 |
| Y55 | 550 | 670-830 | 18 |
| Y62 | 620 | 720-890 | 18 |
| Y69 | 690 | 770-940 | 17 |

1) The tensile strength of the weld metal may be up to 10% below the requirements, provided that the results obtained with the transverse tensile specimens taken from the welded joints meet the minimum tensile strength requirements stated in Table 3. The elongation is to be stated in the test report.

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

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**W23**
cont'd

### 3. Testing on welded joints

3.1 Depending on the type of the welding consumables (and according to the welding process), the testing on the welded joints shall be performed on butt-weld test pieces in analogous manner to UR W17, sections 4.3, 5.2, 6.2, 6.3, or 6.4 respectively.

3.2 Depending on the type of the welding consumables (and according to the welding process), the butt-weld test pieces called for in para. 3.1 shall be welded in a manner analogous to that prescribed in UR W17. The base metal used shall be a high-strength fine-grained structural steel with an appropriate minimum yield strength and tensile strength and compatible with the added symbol for which application is made.

3.3 Depending on the type of the welding consumables (and according to the welding process), the test specimens described in UR W17 shall be taken from the butt-weld test pieces.

3.4 The mechanical properties must meet the requirements stated in Table 3. The provisions of UR W17 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperatures in the notched bar impact test and the requirements regarding the retest specimens.

**Table 3 Required properties of welded joints**

| Quality grade | Added symbol | Minimum tensile strength [N/mm$^2$] | Minimum notch impact energy, test temperature | Minimum bending angle [1)] | Bend ratio D/t [2)] |
|---|---|---|---|---|---|
| 3 to 5 accordance with Table 1 | Y42 | 530 | Depending on the quality grade & yield strength in accordance Table 1 | 120° | 4 |
| | Y46 | 570 | | | 4 |
| | Y50 | 610 | | | 4 |
| | Y55 | 670 | | | 5 |
| | Y62 | 720 | | | 5 |
| | Y69 | 770 | | | 5 |

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

2) D = Mandrel diameter, t = specimen thickness

3.5 Where the bending angle required in Table 3 is not achieved, the specimen may be considered as fulfilling the requirements, if the bending elongation on a gauge length length Lo fulfills the minimum elongation requirements stated in Table 2. The gauge length Lo = Ls + t (Ls = width of weld, t = specimen thickness), see sketch below.

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**W23**
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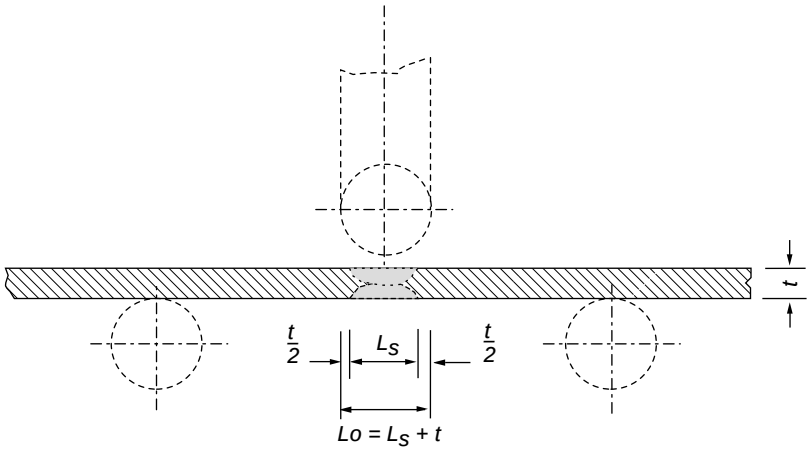


**4. Hydrogen test**

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

4.2 The diffusible hydrogen content of the weld metal determined in accordance with the provisions of UR W17, section 4.5 shall not exceed the limits given in table 4.

**Table 4 Allowable diffusible hydrogen content**

| Yield strength group | Hydrogen symbol | Maximum hydrogen content [$cm^3$/100 g deposited weld metal] |
|---|---|---|
| Y42<br>Y46<br>Y50 | H 10 (HH) | 10 |
| Y55<br>Y62<br>Y69 | H 5 (HHH) | 5 |

◀

5. **Annual repeat test**

The annual repeat tests specified in UR W 17 shall entail the preparation and testing of weld metal test pieces as prescribed under 2. In special cases, the Society may require more extensive repeat tests.

◀◀

# W24 Cast Copper Alloy Propellers

(1996) (Rev.1 1997) (Rev.2 May 2004) (Rev.3 May 2012)

## 1. Scope

These unified requirements are applicable to the moulding, casting, inspection and repair procedures of new cast copper alloy propellers, blades and bosses. Upon special consideration of the individual Classification Society these requirements may also be applied for the repair and inspection of propellers becoming damaged during service.

Note:

These requirements supersede the IACS unified requirements nos. K1 and K2 as well as the IACS Recommendation no. 4.

## 2. Foundry approval

2.1 Approval

All propellers and propeller components are to be cast by foundries approved by the classification society. For this purpose, the foundries have to demonstrate that they have available the necessary facilities and skilled personnel to enable proper manufacture of propellers which will satisfy these rules.

2.2 Application for approval

The approval is to be applied for at the classification society. The applications are to be accompanied by specifications of the propeller materials, manufacturing procedures, repair, NDT inspection procedures and a description of the foundry facilities, including the maximum capacity of the ladles.

2.3 Scope of the approval test

The scope of the approval test is to be agreed with the Classification Society. This should include the presentation of cast test coupons of the propeller materials in question for approval testing in order to verify that the chemical composition and the mechanical properties of these materials comply with these rules.

2.4 Inspection facilities

The foundry is to have an adequately equipped laboratory, manned by experienced personnel, for the testing of moulding materials chemical analyses, mechanical testing and microstructural testing of metallic materials. Provision is also to be made for NDT inspection. If these test facilities are not available at the foundry, details are to be provided of an approved local laboratory which will provide such services.

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Notes:

1. Rev.3 of this UR is applicable to the moulding, casting, inspection and repair procedures of cast copper alloy propellers, blades and bosses from 1 July 2013.

**W24 (cont)**

## 3. Moulding and casting

3.1 Pouring

The pouring must be carried out into dried moulds using degassed liquid metal. The pouring is to be controlled as to avoid turbulences of flow. Special devices and/or procedures must prevent slag flowing into the mould.

3.2 Stress relieving

Subsequent stress relieving heat treatment may be performed to reduce the residual stresses. For this purpose, the manufacturer shall submit a specification containing the details of the heat treatment to the society for approval. For stress relieving temperatures and holding times see tables 4 and 5.

## 4. General characteristics of castings

4.1 Freedom from defects

All castings must have a workman like finish and must be free from defects liable to impair their use. Minor casting defects which may still be visible after machining such as small sand and slag inclusions, small cold shuts and scabs shall be trimmed off by the manufacturer, cf. para 14.

4.2 Removal of defects

Casting defects which may impair the serviceability of the castings, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks, are not permitted. They may be removed by one of the methods described in para 14 and repaired within the limits and restrictions for the severity zones. Full description and documentation must be available for the surveyor.

## 5. Dimensions, dimensional and geometrical tolerances

5.1 The dimensions and the dimensional and geometrical tolerances are governed by the data contained in the approval drawings or order documents. These shall be submitted to the Surveyor at the time of the test.
The accuracy and verification of the dimensions are the responsibility of the manufacturer, unless otherwise agreed.

5.2 Statik balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamik balancing is necessary for propellers running above 500 rpm.

## 6. Chemical composition and structure characteristics

6.1 Chemical composition

Typical copper propeller alloys are grouped into the four types CU 1, CU 2, CU 3 and CU 4 depending on their chemical composition as given in table 1. Copper alloys whose chemical composition deviate from the typical values of Table 1 must be specially approved by the Society.

**W24**
**(cont)**

**Table 1 Typical chemical compositions of cast copper alloys for propellers**

| Alloy type | Chemical Composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Cu** | **Al** | **Mn** | **Zn** | **Fe** | **Ni** | **Sn** | **Pb** |
| **CU1** | 52-62 | 0,5-3,0 | 0,5-4,0 | 35-40 | 0,5-2,5 | max 1,0 | max 1,5 | max 0,5 |
| **CU2** | 50-57 | 0,5-2.0 | 1,0-4,0 | 33-38 | 0,5-2,5 | 3,0-8,0 | max 1,5 | max 0,5 |
| **CU3** | 77-82 | 7,0-11,0 | 0,5-4,0 | max 1,0 | 2,0-6,0 | 3,0-6,0 | max 0,1 | max 0,03 |
| **CU4** | 70-80 | 6,5-9,0 | 8,0-20,0 | max 6,0 | 2,0-5,0 | 1,5-3,0 | max 1,0 | max 0,05 |

6.2 Metallurgical characteristics

Note:

"The main constituents of the microstructure in the copper-based alloys categories CU 1 and CU 2 are alpha and beta phase.
Important properties such as ductility and resistance to corrosion fatigue are strongly influenced by the relative proportion of beta phase (too high a percentage of beta phase having a negative effect on these properties). To ensure adequate cold ductility and corrosion fatigue resistance, the proportion of beta phase is to be kept low. The concept of the zinc equivalent should be used as control since it summarizes the effect of the tendency of various chemical elements to produce beta phase in the structure."
The structure of CU 1 and CU 2 type alloys must contain an alpha phase component of at least 25 % as measured on a test bar by the manufacturer. To ensure adequate ductility and corrosion fatigue resistance, the proportion of beta phase is to be kept low. For this purpose, the zinc equivalent defined by the following formula shall not exceed a value of 45 %:

$$\textit{Zinc}\ \text{equivalent}\ (\%) = 100 - \frac{100.\%\ \text{Cu}}{100 + A}$$

In which A is the algebraic sum of the following values:

1 . % Sn
5 . % Al
-0,5 . % Mn
-0,1 . % Fe
-2,3 . % Ni

Note:

The negative sign in front of the elements Mn, Fe and Ni signifies that these elements tend to reduce the proportion of beta phase.

**W24**
**(cont)**

## 7. Mechanical characteristics

7.1 Standardized alloys

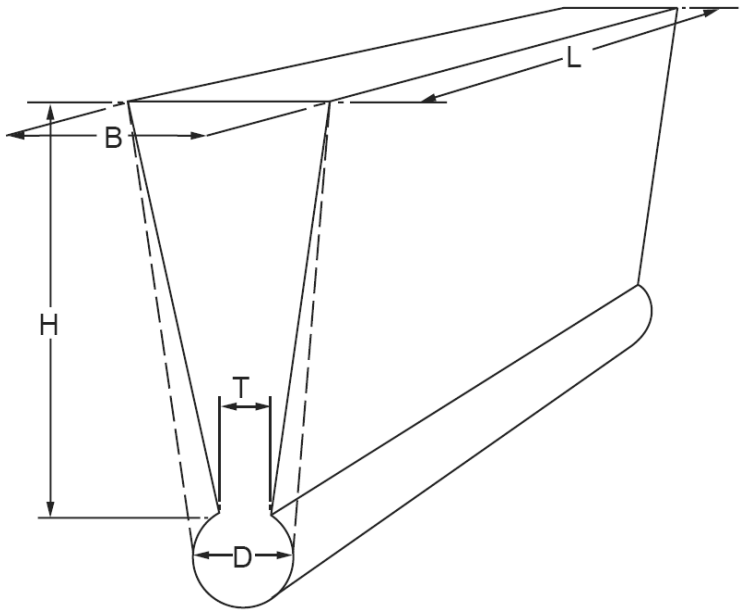
The mechanical characteristics must conform to the values shown in table 2. These values are applicable to test specimens taken from separately cast samples in accordance with Fig. 1, or with any other recognized national standard.

Note:

These properties are a measure of the mechanical quality of the metal in each heat; and they are generally not representative of the mechanical properties of the propeller casting itself, which may be up to 30 % lower than that of a separately cast test coupon.
For integrally cast test specimens the requirements are specially to be agreed with the Society.

**Table 2 Mechanical characteristics of cast copper alloys for propellers (separately cast text coupons)**

| Alloy type | Proof stress $R_p$ 0,2 [N/mm$^2$] min. | Tensile strength $R_m$ [N/mm$^2$] min. | Elongation $A_5$ [%] min. |
|---|---|---|---|
| **CU1** | 175 | 440 | 20 |
| **CU2** | 175 | 440 | 20 |
| **CU3** | 245 | 590 | 16 |
| **CU4** | 275 | 630 | 18 |




H = 100 mm
B = 50 mm
L > 150 mm
T = 15 mm
D = 25 mm

**Fig.1 Test sample casting**

**W24 (cont)**

7.2 Other alloys

The mechanical characteristics of alloys not meeting the limiting values of Table 2 must be in accordance with a specification approved by the Society.

## 8 Inspection and tests

The following tests and inspections are to be performed. For test specimen's dimensions and testing procedures reference is made to UR-W2.

8.1 Chemical composition

The manufacturer shall furnish proof of the composition of each ladle.

8.2 Tensile test

8.2.1 The tensile strength, 0,2 % proof stress and elongation shall be determined by tensile test. For this purpose, at least one tensile test specimen shall be taken from each ladle.

8.2.2 Generally, the specimens shall be taken from separately cast sample pieces, see 7.1. The test samples shall be cast in moulds made of the same material as the mould for the propeller and they must be cooled down under the same conditions as the propeller.

8.2.3 If propellers are subjected to a heat treatment the test samples are to be heat treated together with them.

8.2.4 Where test specimens are to be taken from integrally cast test samples, this shall be the subject of special agreement with the Society. Wherever possible, the test samples shall be located on the blades in an area lying between 0,5 to 0,6 R, where R is the radius of the propeller. The test sample material must be removed from the casting by non thermal procedures.

8.3 Micrographic examination

The micro structure of alloy types CU 1 and CU 2 shall be verified by determining the proportion of alpha phase. For this purpose, at least one specimen shall be taken from each heat. The proportion of alpha phase shall be determined as the average value of 5 counts. The requirements of para 6.2 are to be fulfilled.

8.4 Surface quality and dimensions

8.4.1 Propeller castings should be visually inspected at all stages of manufacture and the whole surface is to be subjected to a comprehensive visual inspection in the finished condition by the Surveyor. This has to include the bore.

8.4.2 The dimensions are to be checked by the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence.

8.4.3 The Surveyor may be require areas to be etched (e.g. by iron chloride) for the purpose of investigating weld repairs.

**W24 (cont)**

## 9. Non-destructive inspections

9.1 Dye penetrant inspection

9.1.1 The severity zones "A" (see para 12) are to be subjected to a dye penetrant inspection in the presence of the Surveyor. For the inspection and acceptance standard see para 13. In zones "B" and "C" the dye penetrant inspection is to be performed by the manufacturer and may be witnessed by the Surveyor upon his request.

9.1.2 If repairs have been made either by grinding or by welding the repaired areas are additionally to be subjected to the dye penetrant inspection independent of their location and/or severity zone.

9.2 Radiographic and ultrasonic inspection

Where serious doubts exist that the castings are not free from internal defects further non-destructive inspections are to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic tests. For this purpose, the following is to be observed: The acceptance criteria are to be agreed between the manufacturer and the classification Society in accordance with a recognized standard.

Footnote for Guidance

The absorption of the X-rays and gamma-rays is stronger in copper-based alloys than in steel. For propeller bronzes, 300 kV X-rays can normally be used up to 50 mm and Co60 gamma-rays up to 160 mm thickness. Due to the limited thicknesses that can be radiographed as well as for other practical reasons radiography is generally not a realistic method for checking of the thickest parts of large propellers.
As a general rule, ultrasonic testing of CU 1 and CU 2 is not feasible due to the high damping capacity of these materials. For CU 3 and CU 4, ultrasonic inspection of subsurface defects is possible.

9.3 Documentation of defects and inspections

All defects requiring welding repair on the castings are to be documented preferably on drawings or special sketches showing their dimensions and locations. Furthermore, the inspection procedure is to be reported. The documentation is to be presented to the Surveyor prior to any repair weldings will be carried out.

## 10. Identification and marking

10.1 Identifications

The manufacturer must employ a monitoring system which enables all castings to be traced back to their heats. On request, the Surveyor shall be given proof of this.

10.2 Marking

Prior to final inspection by the Surveyor each casting shall be marked by the manufacturer at least with the following symbols:

a) Grade of cast material or corresponding abbreviated designation

b) Manufacturer’s mark

**W24 (cont)**

c) Heat number, casting number or another mark enabling the manufacturing process to be traced back

d) Specimen number

e) Date of final inspection

f) Number of the Society's test certificate

g) Ice class symbol, where applicable

h) Skew angle for high skew propellers.

**11. Manufacturer's certificates**

For each propeller the manufacturer must supply to the Surveyor a certificate containing the following details:

a) Purchaser and order number

b) Shipbuilding project number, if known

c) Description of the casting with drawing number

d) Diameter, number of blades, pitch, direction of turning

e) Grade of alloy and chemical composition of each heat

f) Heat or casting number

g) Final weight

h) Results of non-destructive tests and details of test procedure where applicable

i) Portion of alpha-structure for CU 1 and CU 2 alloys

k) Results of the mechanical tests

l) Casting identification No.

m) Skew angle for high skew propellers, see 12.1

**12. Definition of skew, severity zones**

12.1 Definition of skew

The skew of a propeller is defined as follows:

The maximum skew angle of a propeller blade id defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade section, see Fig 2.
High skew propellers have a skew angle greater than 25°, low skew propellers a skew angle of up to 25°.

# W24
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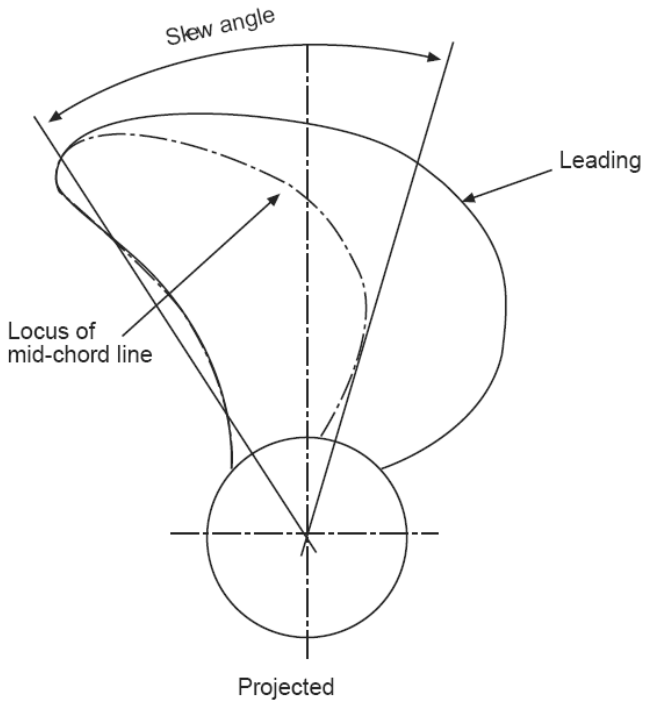


**Fig.2 Definition of skew angle**

12.2 Severity zones

In order to relate the degree of inspection to the criticality of defects in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into the three zones designated A, B and C.

Zone A is the region carrying the highest operating stresses and which, therefore, requires the highest degree of inspection. Generally, the blade thicknesses are greatest in this area giving the greatest degree of restraint in repair welds and this in turn leads to the highest residual stresses in and around any repair welds. High residual tensile stresses frequently lead to fatigue cracking during subsequent service so that relief of these stresses by heat treatment is essential for any welds made in this zone. Welding is generally not permitted in Zone A and will only be allowed after special consideration by the Classification Society. Every effort should be made to rectify a propeller which is either defective or damaged in this area without recourse to welding even to the extent of reducing the scantlings, if this is acceptable. If a repair using welding is agreed, postweld stress relief heat treatment is mandatory.

Zone B is a region where the operation stresses may be high. Welding should preferably be avoided but generally is allowed subject to prior approval from the Classification Society. Complete details of the defect / damage and the intended repair procedure are to be submitted for each instance in order to obtain such approval.

Zone C is a region in which the operation stresses are low and where the blade thicknesses are relatively small so that repair welding is safer and, if made in accordance with an approved procedure is freely permitted.

**W24**
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12.2.1 Low-skew propellers

Zone A is in the area on the pressure side of the blade, from and including the fillet to 0,4R, and bounded on either side by lines at a distance 0,15 times the chord length $C_r$ from the leading edge and 0,2 times $C_r$ from the trailing edge, respectively (see Fig. 3).
Where the hub radius ($R_b$) exceeds 0,27R, the other boundary of zone A is to be increased to $1,5R_b$.

Zone A also includes the parts of the separate cast propeller hub which lie in the area of the windows as described in Fig. 5 and the flange and fillet area of controllable pitch and built-up propeller blades as described in Fig. 6.

Zone B is on the pressure side the remaining area up to 0,7R and on the suction side the area from the fillet to 0,7R (see Fig. 2).

Zone C is the area outside 0,7R on both sides of the blade. It also includes the surface of the hub of a monobloc propeller and all the surfaces of the hub of a controllable pitch propeller other than those designated Zone A above.

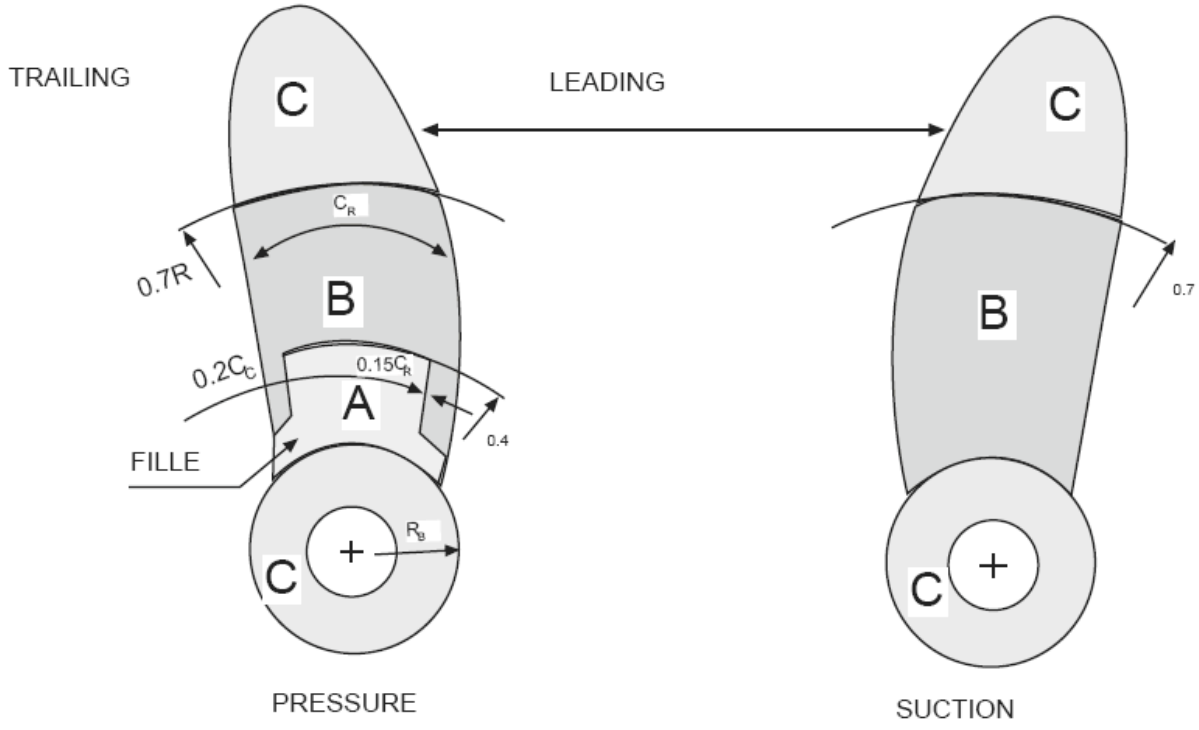


**Fig.3 Severity zones for integrally cast low skew propellers**

**W24**
**(cont)**

12.2.2 High-skew propellers

Zone A is the area on the pressure face contained within the blade root-fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0.9 R and at passing through the mid-point of the blade chord at 0.7 R and a point situated at 0.3 of the chord length from the leading edge at 0.4 R. It also includes an area along the trailing edge on the suction side of the blade from the root to 0.9 R and with its inner boundary at 0.15 of the chord lengths from the trailing edge.

Zone B constitutes the whole of the remaining blade surfaces.

Zone A and B are illustrated in Fig. 4.

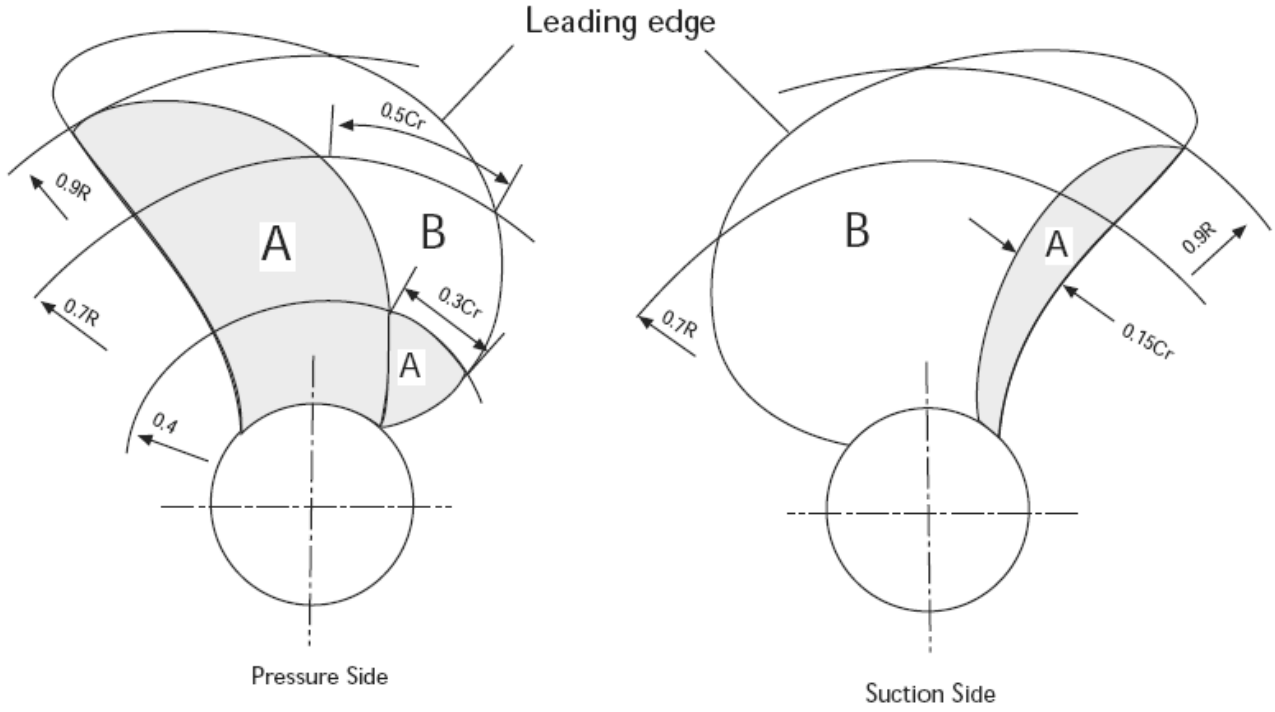


**Fig.4 Severity zones in blades with skew angles greater than 25°**

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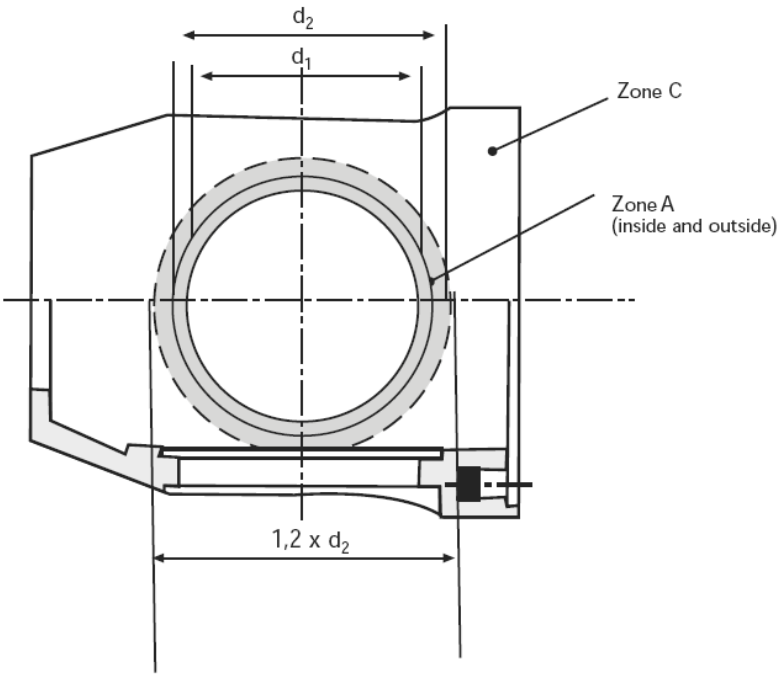


**Fig.5 Severity zones for controllable pitch propeller boss**

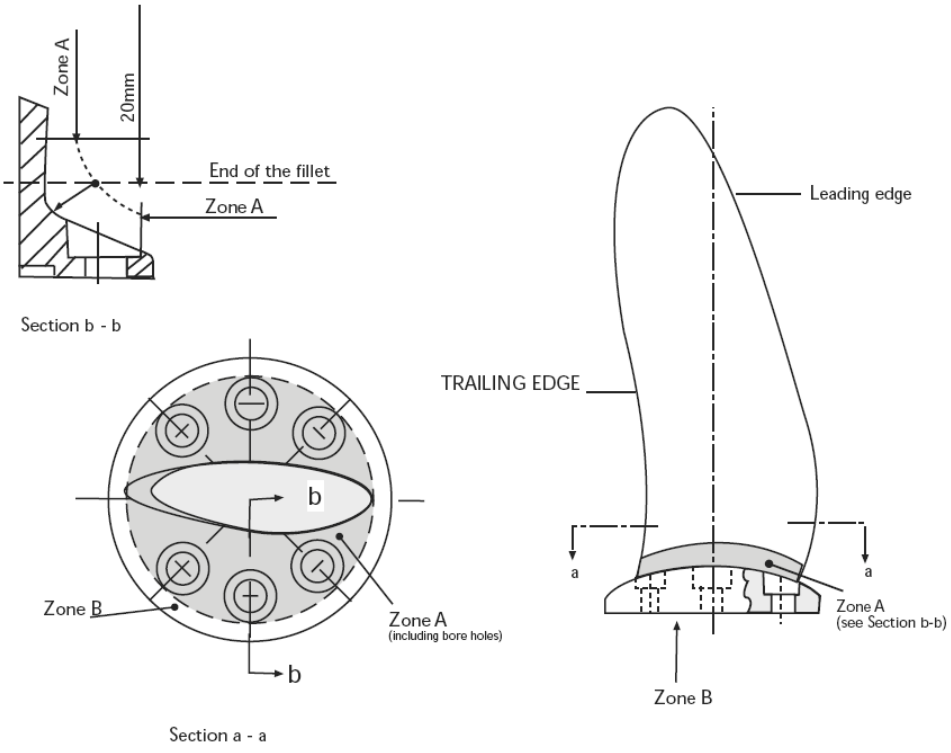


**Fig.6 Severity zones for controllable pitch and built-up propeller**

Note:

The remaining surface of the propeller blades are to be divided into the severity zones as given for solid cast propellers (cf. Fig. 3 and Fig. 4)

**W24 (cont)**

## 13. Acceptance criteria for dye penetrant inspection

13.1 Inspection procedure

The dye penetrant inspection is to be carried out in accordance with a standard or specification approved by the Society.

13.2 Definitions

Indication:

In the dye penetrant inspection an indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

Shape of indications:

A distinction is made between circular, linear and aligned indications, see Fig. 7.

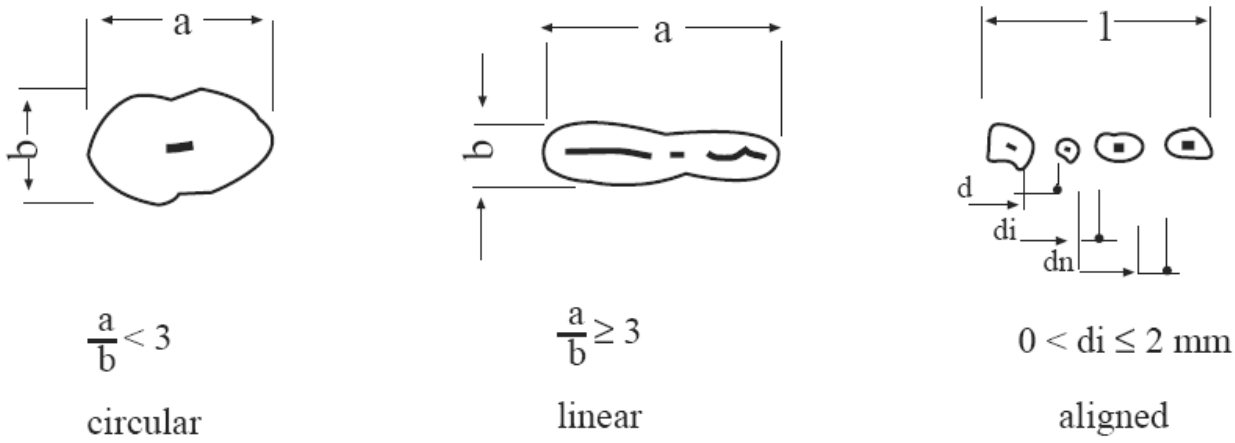


**Fig.7 Shape of indications**

Reference area:

The reference area is defined as an area of 100 $cm^2$ which may be square or rectangular with the major dimension not exceeding 250 mm.

13.3 Acceptance standard

13.3.1 For the judgement, the surface to be inspected is to be divided into reference areas of 100 $cm^2$ as given in the definitions, see para 13.2. The indications detected may, with respect to their size and number, not exceed the values given in the Table 3.
The area shall be taken in the most unfavourable location relative to the indication being evaluated.

13.3.2 Areas which are prepared for welding are independent of their location always to be assessed according to zone A. The same applies to the welded areas after being finished machined and/or grinded.

**W24 (cont)**

**Table 3 Allowable number and size of indications in a reference area of 100 cm$^2$, depending on severity zones**

| Severity zones | Max. total number of indications | Type of indication | Max. number of each type[1)2)] | Max. acceptable value for "a" or "l" of indications [mm] |
|---|---|---|---|---|
| **A** | 7 | Circular | 5 | 4 |
| | | Linear | 2 | 3 |
| | | Aligned | 2 | 3 |
| **B** | 14 | Circular | 10 | 6 |
| | | Linear | 4 | 6 |
| | | Aligned | 4 | 6 |
| **C** | 20 | Circular | 14 | 8 |
| | | Linear | 6 | 6 |
| | | Aligned | 6 | 6 |

Notes: 1) Singular circular indications less than 2 mm for zone A and less than 3 mm for the other zones may be disregarded.

2) The total number of circular indications may be increased to the max. total number, or part thereof, represented by the absence of linear/aligned indications.

**14. Repair of defects**

14.1 Definition

Indications exceeding the acceptance standard of Table 3, cracks, shrinkage cavities, sand, slag and other non-metallic inclusions, blow holes and other discontinuities which may impair the safe service of the propeller are defined as defects and must be repaired.

14.2 Repair procedures

14.2.1 In general the repairs shall be carried out by mechanical means, e. g. by grinding, chipping or milling. Welding may be applied subject to the agreement of the Society's Surveyor if the requirements of the paras 14.3, 14.4 and / or 14.5 will be complied with.

14.2.2 After milling or chipping grinding is to be applied for such defects which are not to be welded. Grinding is to be carried out in such a manner that the contour of the ground depression is as smooth as possible in order to avoid stress concentrations or to minimise cavitation corrosion.

14.2.3 Welding of areas less than 5 cm$^2$ is to be avoided.

**W24 (cont)**

14.3 Repair of defects in zone A

14.3.1 In zone A, repair welding will generally not be allowed unless specially approved by the Classification Society.

14.3.2 Grinding may be carried out to an extent which maintains the blade thickness of the approved drawing.

14.3.3 The possible repair of defects which are deeper than those referred to above is to be considered by the classification Society.

14.4 Repair of defects in zone B

14.4.1 Defects that are not deeper than dB = (t/40) mm (t = min. local thickness in mm according to the Rules) or 2 mm (whichever is greatest) below min. local thickness according to the Rules should be removed by grinding.

14.4.2 Those defects that are deeper than allowable for removal by grinding may be repaired by welding.

14.5 Repair of defects in zone C

In zone C, repair welds are generally permitted.

**15. Repair Welding**

15.1 General requirements

15.1.1 Companies wishing to carry out welding work on propellers must have at their disposal the necessary workshops, lifting gear, welding equipment, preheating and, where necessary, annealing facilities, testing devices as well as certified welders and expert welding supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

15.1.2 The company concerned shall prepare and submit to the classification Society a detailed welding specification covering the weld preparation, welding procedure, filler metals, preheating and post weld heat treatment and inspection procedures.

15.1.3 Before welding is started, Welding Procedure Qualification Test are to be carried out and witnessed by the Surveyors. Each welder / operator is to demonstrate his ability to carry out the proposed welding using the same process, consumable and position which are to be used in actual repair (the scope of tests is given in Appendix A).

15.2 Welding preparation

Defects to be repaired by welding are to be ground to sound material according to the requirements as given under para 14.2. To ensure complete removal of the defects the ground areas are to be examined by dye penetrant methods in the presence of the Surveyor. The welding grooves are to be prepared in such a manner which will allow a good fusion of the groove bottom.

15.3 Welding repair procedure

15.3.1 Metal arc welding is recommended for all types of repair on bronze propellers.

**W24 (cont)**

For material thickness less than 30 mm, gas welding may give a satisfactory weldment for CU 1 and CU 2 materials.
Arc welding with coated electrodes and gas-shielded metal arc process (GMAW) are generally to be applied. Argon-shielded tungsten welding (GTAW) should be used with care due to the higher specific heat input of this process.
Recommended filler metals, pre-heating and stress relieving temperatures are listed in Table 4.

15.3.2 Adequate pre-heating is to be carried out with care to avoid local overheating, c. f. Table 4.

15.3.3 All propeller alloys are generally to be welded in down-hand (flat) position. Where this cannot be done, gas-shielded metal arc welding should be carried out.
The section to be welded is to be clean and dry. Flux-coated electrodes are to be dried before welding according to the maker's instructions.
To minimize distortion and the risk of cracking, interpass temperatures are to be kept low. This is especially the case with CU 3 alloys.
Slag, undercuts and other defects are to be removed before depositing the next run.

15.3.4 All welding work is to be carried out preferably in the shop free from draughts and influence of the weather.

15.3.5 With the exception of alloy CU 3 (Ni-Al-bronze) all weld repairs are to be stress relief heat treated, in order to avoid stress corrosion cracking. However, stress relief heat treatment of alloy Cu 3 propeller castings may be required after major repairs in zone B (and specially approved welding in Zone A) or if a welding consumable susceptible to stress corrosion cracking is used. In such cases the propeller is to be either stress relief heat treated in the temperature 450 to 500°C or annealed in the temperature range 650-800°C, depending on the extent of repair, c. f. Table 4.

15.3.6 The soaking times for stress relief heat treatment of copper alloy propellers should be in accordance with Table 5. The heating and cooling is to be carried out slowly under controlled conditions. The cooling rate after any stress relieving heat treatment shall not exceed 50°C/h until the temperature of 200°C is reached.

**W24**
**(cont)**

**Table 4 Recommended filler metals and heat treatments**

| Alloy type | Filler metal | Preheat temperature °C [min] | Interpass temperature °C [max] | Stress relief temperature °C | Hot straightening temperature °C |
|---|---|---|---|---|---|
| **CU1** | Al-bronze[1)]<br>Mn-bronze | 150 | 300 | 350-500 | 500-800 |
| **CU2** | Al-bronze<br>Ni-Mn-bronze | 150 | 300 | 350-550 | 500-800 |
| **CU3** | Al-bronze<br>Ni-Al-bronze[2)]<br>Mn-Al-bronze | 50 | 250 | 450-500 | 700-900 |
| **CU4** | Mn-Al-bronze | 100 | 300 | 450-600 | 700-850 |

Notes: [1)] Ni-Al-bronze and Mn-Al-bronze are acceptable.

[2)] Stress relieving not required, if filler metal Ni-Al-bronze is used.

**Table 5 Soaking times for stress relief heat treatment of copper alloy propellers**

| Stress relief temperature [°C] | Alloy grade CU1 and CU2 | | Alloy grade CU3 and CU4 | |
|---|---|---|---|---|
| | Hours per 25 mm thickness | Max. recommended total time hours | Hours per 25 mm thickness | Max. recommended total time hours |
| **350** | 5 | 15 | - | - |
| **400** | 1 | 5 | - | - |
| **450** | 1/2 | 2 | 5 | 15 |
| **500** | 1/4 | 1 | 1 | 5 |
| **550** | 1/4 | 1/2 | 1/2[1)] | 2[1)] |
| **600** | - | - | 1/4[1)] | 1[1)] |

Note: [1)] 550°C and 600°C only applicable for CU 4 alloys.

**W24 (cont)**

## 16. Straightening

16.1 Application of load

For hot and cold straightening purposes, static loading only is to be used.

16.2 Hot straightening

Straightening of a bent propeller blade or a pitch modification should be carried out after heating the bent region and approximately 500 mm wide zones on either side of it to the suggested temperature range given in Table 4.
The heating should be slow and uniform and the concentrated flames such as oxy-acetylene and oxy-propane should not be used. Sufficient time should be allowed for the temperature to become fairly uniform through the full thickness of the blade section. The temperature must be maintained within the suggested range throughout the straightening operation. A thermocouple instrument or temperature indicating crayons should be used for measuring the temperature.

16.3 Cold straightening

Cold straightening should be used for minor repairs of tips and edges only. Cold straightening on Cu 1, Cu 2 and Cu 4 bronze should always be followed by a stress relieving heat treatment, see Table 4.

**W24**
**(cont)**

## Appendix A: Welding procedure and welder's qualification test

### 1 General

The qualification test is to be carried out with the same welding process filler metal, preheating and stress-relieving treatment as those intended applied by the actual repair work.

### 2 Test sample

A test sample of minimum 30 mm thickness is to be welded in down-hand (flat) position. The test specimens to be prepared and their dimensions are shown in Fig. 8.

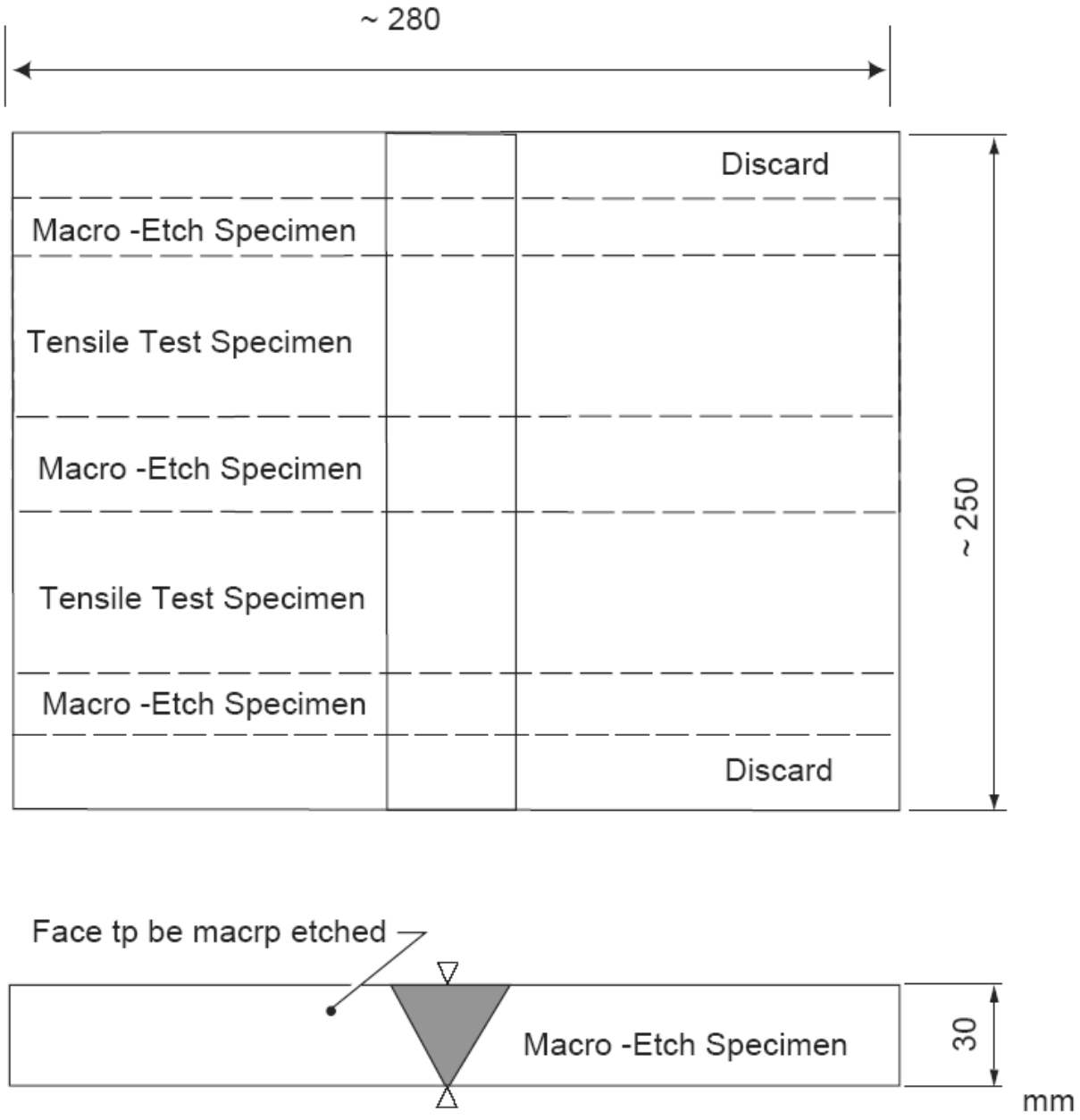


**Fig.8 Test Specimen**

**W24 (cont)**

## 3 Qualification testing

### 3.1 Non-destructive testing:

After completion, the weldment is to be 100% tested by a dye-penetrant method. No cracks are permitted.

### 3.2 Macro-etching:

Three macro-etch samples should be prepared (see Fig. 8). A suitable etchant for this purpose is:

5 g iron (III) chloride
30 ml hydrochloric acid (cone)
100 ml water.

Pores greater than 3 mm and cracks are not permitted.

### 3.3 Mechanical testing:

Two tensile tests should be prepared as shown in W2.4.2.8 b). The table requirements to the tensile strength, as given in Table 6, should be met. Alternatively tensile test specimens according to recognized standards may be used.

**Table 6 Required tensile strength values**

| Alloy Type | Tensile Strength, $N/mm^2$, min |
|---|---|
| **CU1** | 370 |
| **CU2** | 410 |
| **CU3** | 500 |
| **CU4** | 550 |

End of Document

# W25 Aluminium Alloys for Hull Construction and Marine Structure

(May 1998) (Rev.1 May 2004) (Rev.2 Dec 2004) (Rev.3 May 2006) (Rev.4 Dec 2011)

**TABLE OF CONTENTS**



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Note:

1. Rev.4 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2013 and when the application for certification of materials is dated on or after 1 January 2013.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR)No. 29.

**W25**
(cont'd)

## 1. SCOPE

1.1 These Requirements apply to wrought aluminium alloys used in the construction of hulls, superstructures and other marine structures.
They are not applicable to the use of aluminium alloys at low temperature for cryogenic applications.

1.2 These Requirements are applicable to wrought aluminium alloy products within a thickness range of 3 mm and 50 mm inclusive.
The application of aluminium alloys products outside this thickness range requires prior agreement of the Classification Society.

1.3 The numerical designation (grade) of aluminium alloys and the temper designation are based on those of the Aluminium Association.

1.4 Temper conditions (delivery heat treatment) are defined in the European Standard EN 515 or ANSI H35.1.

1.5 Consideration may be given to aluminium alloys not specified in these Requirements, and to alternative temper conditions, subject to prior agreement with the Classification Society further to a detailed study of their properties, including corrosion resistance, and of their conditions of use (in particular welding procedures).

## 2. APPROVAL

2.1 All materials, including semi finished products, are to be manufactured at works which are approved by the Classification Society for the grades of aluminium alloy supplied.

## 3. ALUMINIUM ALLOYS AND THEIR TEMPER CONDITIONS

3.1 Rolled products (sheets, strips and plates)
The following aluminium alloys are covered by these Requirements:

5083, 5086, 5383, 5059, 5754, 5456

with the hereunder temper conditions:

O, H111, H112, H116, H321

3.2 Extruded products (sections, shapes, bars and closed profiles)

The following aluminium alloys are covered by these Requirements:

5083, 5383, 5059, 5086

with the hereunder temper conditions:

O, H111, H112,

and:
6005A, 6061, 6082

with the hereunder temper conditions:

T5 or T6.

**W25**
(cont'd)

Note: The alloy grades 6005A, 6061 of the 6000 series should not be used in direct contact with sea water unless protected by anodes and/or paint system.

**4. CHEMICAL COMPOSITION**

4.1 The Manufacturer is to determine the chemical composition of each cast.

4.2 The chemical composition of aluminium alloys is to comply with the requirements given in Table 1.

4.3 The Manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyor; in particular, product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

4.4 When the aluminium alloys are not cast in the same works in which they are manufactured into semi finished products, the Society Surveyor shall be given a certificate issued by the works in question which indicates the reference numbers and chemical composition of the heats.

**5. MECHANICAL PROPERTIES**

5. 1 The mechanical properties are to comply with the requirements given in Tables 2 and 3.

Note: It should be recognized that the mechanical properties of the welded joint are lower for strain hardened or heat treated alloys, when compared with those of the base material, in general. For reference, see the UR for Aluminium Consumables.

**6. FREEDOM OF DEFECTS**

6.1 The finished material is to have a workmanlike finish and is to be free from internal and surface defects prejudicial to the use of the concerned material for the intended application.

6.2 Slight surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in Section 7.

**7. TOLERANCES**

7.1 The underthickness tolerances for rolled products given in Table 4 are minimum requirements.

7.2 The underthickness tolerances for extruded products are to be in accordance with the requirements of recognized international or national standards.

7.3 Dimensional tolerances other than underthickness tolerances are to comply with a recognized national or international standard.

**8. TESTING AND INSPECTION**

8.1 **Tensile test**
The test specimens and procedures are to be in accordance with UR W2.

**W25**
(cont'd)

8.2 **Non-destructive examination.**
In general, the non-destructive examination of material is not required for acceptance purposes.

Note: Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

8.3 **Dimensions**
It is the manufacturer's responsibility to check the materials for compliance with the tolerances given in Section 7.

8.4 **Verification of proper fusion of press welds for closed profiles.**

8.4.1 The Manufacturer has to demonstrate by macrosection tests or drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

8.4.2 Drift expansion tests

8.4.2.1 Every fifth profile shall be sampled after final heat treatment.
Batches of five profiles or less shall be sampled one profile.
Profiles with lengths exceeding 6 m shall be sampled every profile in the start of the production. The number of tests may be reduced to every fifth profile if the results from the first 3-5 profiles are found acceptable.

8.4.2.2 Each profile sampled will have two samples cut from the front and back end of the production profile.

8.4.2.3 The test specimens are to be cut with the ends perpendicular to the axis of the profile. The edges of the end may be rounded by filing.

8.4.2.4 The length of the specimen is to be in accordance with UR W2.

8.4.2.5 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the profile by means of a hardened conical steel mandrel having an included angle of at least 60°.

8.4.2.6 The sample is considered to be unacceptable if the sample fails with a clean split along the weld line which confirms lack of fusion.

**8.5 Corrosion testing**

8.5.1 Rolled 5xxx-alloys of type 5083, 5383, 5059, 5086 and 5456 in the H111, H112, H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

8.5.2 The manufacturers shall establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, under the conditions specified in ASTM B928, Section 9.4.1, shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than

**W25**
(cont'd)

15mg/cm$^2$, when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by the Classification Society. Production practices shall not be changed after approval of the reference micrographs.

Other test methods may also be accepted at the discretion of the Classification Society.

8.5.3 For batch acceptance of 5xxx-alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination, under the conditions specified in ASTM B928, Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation-corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 ASSET test, and the sample shall exhibit resistance to intergranular corrosion at a mass loss no greater than 15mg/cm$^2$ when subjected to ASTM G67 NAMLT test. If the results from testing satisfy the acceptance criteria stated in paragraph 8.5.2 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation-corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B928, or equivalent standards. If this alternative is used, then the results of the test must satisfy the acceptance criteria stated in paragraph 8.5.3.

## 9. TEST MATERIALS

9.1 Definition of batches
Each batch is made up of products:
- of the same alloy grade and from the same cast
- of the same product form and similar dimensions (for plates, the same thickness)
- manufactured by the same process
- having been submitted simultaneously to the same temper condition.

9.2 The test samples are to be taken
- at one third of the width from a longitudinal edge of rolled products.
- in the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.

9.3 Test samples are to be taken so that the orientation of test specimens is as follows:

a) Rolled products

Normally, tests in the transverse direction are required. If the width is insufficient to obtain transverse test specimen, or in the case of strain hardening alloys, tests in the longitudinal direction will be permitted.

**W25**
(cont'd)

b) Extruded products

The extruded products are tested in longitudinal direction.

9.4 After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

## 10. MECHANICAL TEST SPECIMENS

10.1 Type and location of tensile test specimen

The type and location of tensile test specimens are to be in accordance with UR W2.

## 11. NUMBER OF TEST SPECIMENS

### 11.1 Tensile test

a) Rolled products

One tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 kg, one extra tensile test specimen is to be taken from every 2000 kg of the product or fraction thereof, in each batch.

For single plates or for coils weighting more than 2000 kg each, only one tensile test specimen per plate or coil shall be taken.

b) Extruded products

For the products with a nominal weight of less than 1 kg/m, one tensile test specimen is to be taken from each 1000 kg, or fraction thereof, in each batch. For nominal weights between 1 and 5 kg/m, one tensile test specimen is to be taken from each 2000 kg or fraction hereof, in each batch. If the nominal weight exceeds 5 kg/m, one tensile test specimen is to be taken for each 3000 kg of the product or fraction thereof, in each batch.

### 11.2 Verification of proper fusion of press welds

For closed profiles, verification of proper fusion of press welds is to be performed on each batch as indicated in 8.4 above.

### 11.3 Corrosion tests

For rolled plates of grade 5083, 5383, 5059, 5086 and 5456 delivered in the tempers H116 or H321, one sample is to be tested per batch.

## 12. RETEST PROCEDURES

12.1 When the tensile test from the first piece selected in accordance with Section 11 fails to meet the requirements, two further tensile tests may be made from the same piece. If both of these additional tests are satisfactory, this piece and the remaining pieces from the same batch may be accepted.

12.2 If one or both the additional tests referred to above are unsatisfactory, the piece is to be rejected, but the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch selected in the same way, are

**W25**
(cont'd)

tested with satisfactory results. If unsatisfactory results are obtained from either of these two pieces then the batch of material is to be rejected.

12.3 In the event of any material bearing the Classification Society's brand failing to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

**13. BRANDING**

13.1 The manufacturer shall mark each product at least one place with the following details:

a) Manufacturer's mark
b) Abbreviated designation of aluminium alloy according to Section 3
c) Abbreviated designation of temper condition according to Section 3
d) Tempers that are corrosion tested in accordance with section 8.5 are to be marked "M" after the temper condition, e.g. 5083 H321 M.
e) Number of the manufacturing batch enabling the manufacturing process to be traced back.

13.2 The product is also to bear the Classification Society's brand.

13.3 When extruded products are bundled together or packed in crates for delivery, the marking specified in para 13.1 should be affixed by a securely fastened tag or label.

**14. DOCUMENTATION**

14.1 For each tested batch, the manufacturer must supply to the Classification Society's Surveyor a test certificate, or a shipping statement containing the following details :

a) Purchaser and order number
b) Construction project number, when known,
c) Number, dimensions and weight of the product
d) Designation of the aluminium alloy (grade) and of its temper condition (delivery heat treatment)
e) Chemical composition
f) Manufacturing batch number or identifying mark
g) Mechanical Test results
h) Corrosion Test results (if any).

**W25**
(cont'd)

**Table 1 Chemical composition [1)]**

| Grade | Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Other elements [2)] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Each | Total |
| 5083 | 0.40 | 0.40 | 0.10 | 0.40-1.0 | 4.0-4.9 | 0.05-0.25 | 0.25 | 0.15 | 0.05 | 0.15 |
| 5383 | 0.25 | 0.25 | 0.20 | 0.7-1.0 | 4.0-5.2 | 0.25 | 0.40 | 0.15 | 0.05 [5)] | 0.15 [5)] |
| 5059 | 0.45 | 0.50 | 0.25 | 0.6-1.2 | 5.0-6.0 | 0.25 | 0.40-0.90 | 0.20 | 0.05 [6)] | 0.15 [6)] |
| 5086 | 0.40 | 0.50 | 0.10 | 0.20-0.7 | 3.5-4.5 | 0.05-0.25 | 0.25 | 0.15 | 0.05 | 0.15 |
| 5754 | 0.40 | 0.40 | 0.10 | 0.50 [3)] | 2.6-3.6 | 0.30 [3)] | 0.20 | 0.15 | 0.05 | 0.15 |
| 5456 | 0.25 | 0.40 | 0.10 | 0.50-1.0 | 4.7-5.5 | 0.05-0.20 | 0.25 | 0.20 | 0.05 | 0.15 |
| 6005A | 0.50-0.9 | 0.35 | 0.30 | 0.50 [4)] | 0.40-0.7 | 0.30 [4)] | 0.20 | 0.10 | 0.05 | 0.15 |
| 6061 | 0.40-0.8 | 0.7 | 0.15-0.40 | 0.15 | 0.8-1.2 | 0.04-0.35 | 0.25 | 0.15 | 0.05 | 0.15 |
| 6082 | 0.7-1.3 | 0.50 | 0.10 | 0.40-1.0 | 0.6-1.2 | 0.25 | 0.20 | 0.10 | 0.05 | 0.15 |

Notes:
[1)] Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
[2)] Includes Ni, Ga, V and listed elements for which no specific limit is shown. Regular analysis need not be made.
[3)] Mn + Cr: 0.10-0.60
[4)] Mn + Cr: 0.12-0.50
[5)] Zr: maximum 0.20. The total for other elements does not include Zirconium.
[6)] Zr: 0.05-0.25. The total for other elements does not include Zirconium.

**W25** (cont'd)

**Table 2 Mechanical properties for rolled products, 3 mm ≤ t ≤ 50 mm**

| Grade | Temper condition[3] | Thickness, t | Yield Strength $R_{p0.2}$ min. or range N/mm$^2$ | Tensile Strength $R_m$ min. or range N/mm$^2$ | Elongation, % min. [1] | |
|---|---|---|---|---|---|---|
| | | | | | $A_{50\ mm}$ | $A_{5d}$ |
| 5083 | O | 3 ≤ t ≤ 50 mm | 125 | 275-350 | 16 | 14 |
| | H111 | 3 ≤ t ≤ 50 mm | 125 | 275-350 | 16 | 14 |
| | H112 | 3 ≤ t ≤ 50 mm | 125 | 275 | 12 | 10 |
| | H116 | 3 ≤ t ≤ 50 mm | 215 | 305 | 10 | 10 |
| | H321 | 3 ≤ t ≤ 50 mm | 215-295 | 305-385 | 12 | 10 |
| 5383 | O | 3 ≤ t ≤ 50 mm | 145 | 290 | - | 17 |
| | H111 | 3 ≤ t ≤ 50 mm | 145 | 290 | - | 17 |
| | H116 | 3 ≤ t ≤ 50 mm | 220 | 305 | 10 | 10 |
| | H321 | 3 ≤ t ≤ 50 mm | 220 | 305 | 10 | 10 |
| 5059 | O | 3 ≤ t ≤ 50 mm | 160 | 330 | 24 | 24 |
| | H111 | 3 ≤ t ≤ 50 mm | 160 | 330 | 24 | 24 |
| | H116 | 3 ≤ t ≤ 20 mm | 270 | 370 | 10 | 10 |
| | | 20 < t ≤ 50 mm | 260 | 360 | - | 10 |
| | H321 | 3 ≤ t ≤ 20 mm | 270 | 370 | 10 | 10 |
| | | 20 < t ≤ 50 mm | 260 | 360 | - | 10 |
| 5086 | O | 3 ≤ t ≤ 50 mm | 95 | 240-305 | 16 | 14 |
| | H111 | 3 ≤ t ≤ 50 mm | 95 | 240-305 | 16 | 14 |
| | H112 | 3 ≤ t ≤ 12.5 mm | 125 | 250 | 8 | - |
| | | 12.5 < t ≤ 50 mm | 105 | 240 | - | 9 |
| | H116 | 3 ≤ t ≤ 50 mm | 195 | 275 | 10[2] | 9 |
| 5754 | O | 3 ≤ t ≤ 50 mm | 80 | 190-240 | 18 | 17 |
| | H111 | 3 ≤ t ≤ 50 mm | 80 | 190-240 | 18 | 17 |
| 5456 | O | 3 ≤ t ≤ 6.3 mm | 130-205 | 290-365 | 16 | |
| | | 6.3 < t ≤ 50 mm | 125-205 | 285-360 | 16 | 14 |
| | H116 | 3 ≤ t ≤ 30 mm | 230 | 315 | 10 | 10 |
| | | 30 < t ≤ 40 mm | 215 | 305 | - | 10 |
| | | 40 < t ≤ 50 mm | 200 | 285 | - | 10 |
| | H321 | 3 ≤ t ≤ 12.5 mm | 230-315 | 315-405 | 12 | - |
| | | 12.5 < t ≤ 40 mm | 215-305 | 305-385 | - | 10 |
| | | 40 < t ≤ 50 mm | 200-295 | 285-370 | - | 10 |

Notes:

[1] Elongation in 50 mm apply for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

[2] 8 % for thicknesses up to and including 6.3 mm.

[3] The mechanical properties for the O and H111 tempers are the same. However, they are separated to discourage dual certification as these tempers represent different processing.

**W25** (cont'd)

**Table 3 Mechanical properties for extruded products, 3 mm ≤ t ≤ 50 mm**

| Grade | Temper | Thickness, t | Yield Strength $R_{p0.2}$ min. N/mm$^2$ | Tensile Strength $R_m$ min. or range N/mm$^2$ | Elongation, % min. [1)2)] | |
|---|---|---|---|---|---|---|
| | | | | | $A_{50\ mm}$ | $A_{5d}$ |
| 5083 | O | 3 ≤ t ≤ 50 mm | 110 | 270-350 | 14 | 12 |
| | H111 | 3 ≤ t ≤ 50 mm | 165 | 275 | 12 | 10 |
| | H112 | 3 ≤ t ≤ 50 mm | 110 | 270 | 12 | 10 |
| 5383 | O | 3 ≤ t ≤ 50 mm | 145 | 290 | 17 | 17 |
| | H111 | 3 ≤ t ≤ 50 mm | 145 | 290 | 17 | 17 |
| | H112 | 3 ≤ t ≤ 50 mm | 190 | 310 | | 13 |
| 5059 | H112 | 3 ≤ t ≤ 50 mm | 200 | 330 | | 10 |
| 5086 | O | 3 ≤ t ≤ 50 mm | 95 | 240-315 | 14 | 12 |
| | H111 | 3 ≤ t ≤ 50 mm | 145 | 250 | 12 | 10 |
| | H112 | 3 ≤ t ≤ 50 mm | 95 | 240 | 12 | 10 |
| 6005A | T5 | 3 ≤ t ≤ 50 mm | 215 | 260 | 9 | 8 |
| | T6 | 3 ≤ t ≤ 10 mm | 215 | 260 | 8 | 6 |
| | | 10 < t ≤ 50 mm | 200 | 250 | 8 | 6 |
| 6061 | T6 | 3 ≤ t ≤ 50 mm | 240 | 260 | 10 | 8 |
| 6082 | T5 | 3 ≤ t ≤ 50 mm | 230 | 270 | 8 | 6 |
| | T6 | 3 ≤ t ≤ 5 mm | 250 | 290 | 6 | |
| | | 5 < t ≤ 50 mm | 260 | 310 | 10 | 8 |

Notes:
1) The values are applicable for longitudinal and transverse tensile test specimens as well.
2) Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

**W25** (cont'd)

**Table 4 Underthickness tolerances for rolled products**

| Nominal thickness (t), mm | Thickness tolerances for nominal width (w), mm | | |
|---|---|---|---|
| | w ≤ 1500 | 1500 < w ≤ 2000 | 2000 < w ≤ 3500 |
| 3.0 ≤ t < 4.0 | 0.10 | 0.15 | 0.15 |
| 4.0 ≤ t < 8.0 | 0.20 | 0.20 | 0.25 |
| 8.0 ≤ t < 12.0 | 0.25 | 0.25 | 0.25 |
| 12.0 ≤ t < 20.0 | 0.35 | 0.40 | 0.50 |
| 20.0 ≤ t < 50.0 | 0.45 | 0.50 | 0.65 |

End of Document

# W26 Requirements for Welding Consumables for Aluminium Alloys

(July, 1999) (Rev.1 June 2005)

## 1. General

### 1.1 Scope

1.1.1 These requirements give the conditions of approval and inspection of welding consumables to be used for hull construction and marine structure aluminium alloys according to UR W 25. Where no special requirements are given herein, e.g. for the approval procedure or for the welding of test assemblies and testing, those of UR W 17 apply in analogous manner.

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

- **W** = **w**ire electrode - and **w**ire - gas combinations for metal-arc inert gas welding (MIG, 131 acc. to ISO 4063), tungsten inert gas arc welding (TIG, 141) or plasma arc welding (15)

- **R** = **r**od - gas combinations for tungsten inert gas arc welding (TIG, 141) or plasma arc welding (15)

### 1.2 Grading, Designation

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

**Table 1 Consumable grades and base materials for the approval test**

| Consumable quality grade (Symbol) | Base material for the tests | |
|---|---|---|
| | Alloy Designation | |
| | Numerical | Chem. symbol |
| R**A**/W**A** | **5754** | AlMg3 |
| R**B**/W**B** | **5086** | AlMg4 |
| R**C**/W**C** | **5083** | AlMg4.5Mn0,7 |
| | **5383** | AlMg4.5Mn0.9 |
| | **5456** | AlMg5 |
| | **5059** | - |
| R**D**/W**D** | **6005A** | AlSiMg(A) |
| | **6061** | AlMg1SiCu |
| | **6082** | AlSi1MgMn |
| Note: Approval on higher strength AlMg base materials covers also the lower strength AlMg grades and their combination with AlSi grades | | |

1.2.2. Approval of a wire or a rod will be granted in conjunction with a specific shielding gas acc. to Table 2 or defined in terms of composition and purity of “special” gas to be designated with group sign “S”. The composition of the shielding gas is to be reported. The approval of a wire or rod with any particular gas can be applied or transferred to any combination of the same wire or rod and any gas in the same numbered group as defined in Table 2, subject to the agreement of the Society.

**W26**
cont'd

**Table 2 Compositional limits of shielding gases and mixtures to be used**

| Group | Gas composition (Vol. %) [1] | |
|---|---|---|
| | **Argon** | **Helium** |
| **I - 1** | 100 | --- |
| **I - 2** | --- | 100 |
| **I - 3** | Rest | > 0 to 33 |
| **I - 4** | Rest | > 33 to 66 |
| **I - 5** | Rest | > 66 to 95 |
| **S** | Special gas, composition to be specified, see 1.2.2 | |

[1] Gases of other chemical composition (mixed gases) may be considered as „special gases" and covered by a separate test.

### 1.3 Manufacture, testing and approval procedure

1.3.1 Manufacturer's plant, production methods and quality control measures shall be such as to ensure reasonable uniformity in manufacture, see also UR W 17.

1.3.2 Testing and approval procedure shall be in accordance with UR W 17, sections 2 and 3 and as required in UR W 17 for the individual categories (types) of welding consumables, shielding gases and their mixtures mentioned in 1.1.2 above.

## 2. Testing, required properties

2.1 Testing of the deposited weld metal

2.1.1 For the testing of the chemical composition of the deposited weld metal, a test piece according to Figure 1 shall be prepared. The size depends on the type of the welding consumable (and on the welding process) and shall give a sufficient amount of pure weld metal for chemical analysis. The base metal used shall be compatible with the weld metal in respect of chemical composition.

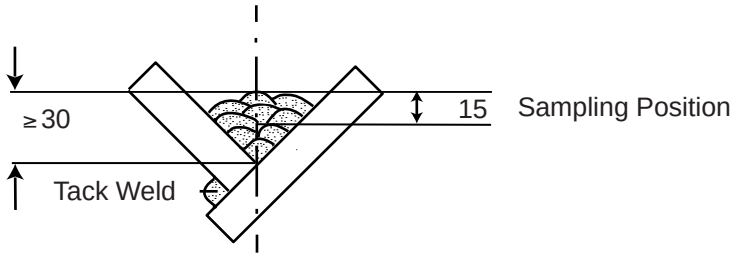



**Figure 1 Deposited weld metal test asembly**

**W26**
cont'd

2.1.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in UR W 17, section 6.2.3. The results of the analysis shall not exceed the limit values specified by the manufacturer.

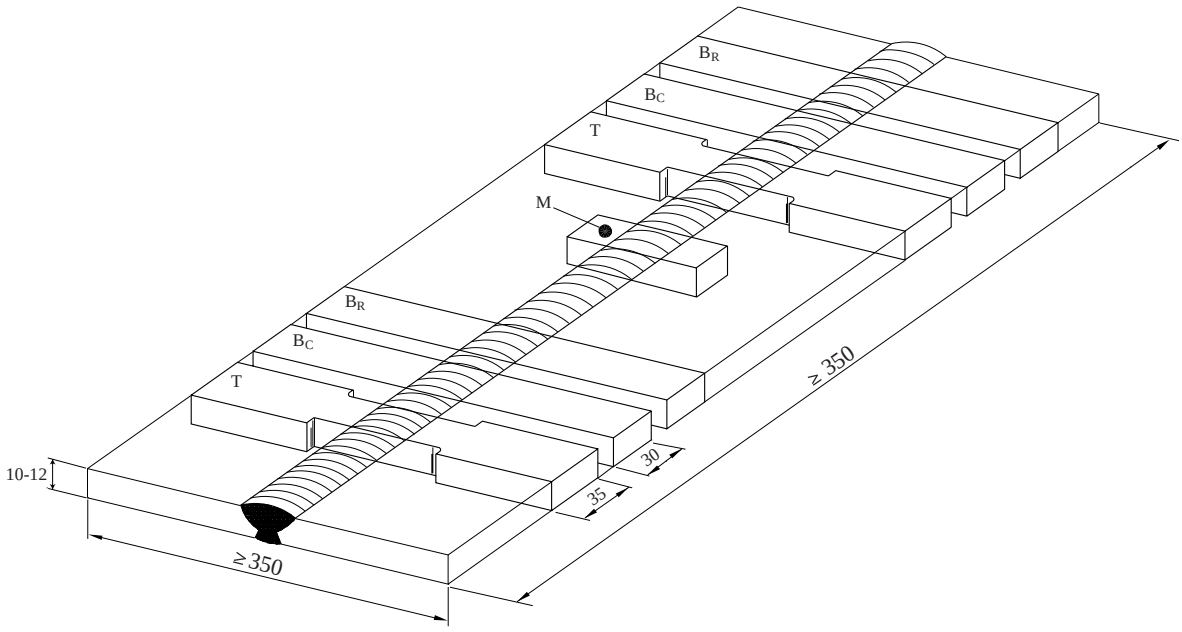
**2.2 Testing of butt weld assemblies**

2.2.1 The testing of the welded joints shall be performed on butt-weld test assemblies according to Figure 2 and Figure 3, made from materials as given in Table 1, in an analogous manner to UR W 17, sections 4.3, 6.2.5, 6.3.5 or 6.4.2 respectively.

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

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

T = Flat tensile test specimen
$B_C$ = Face bend test specimen
$B_R$ = Root bend test specimen
M = Macrographic section

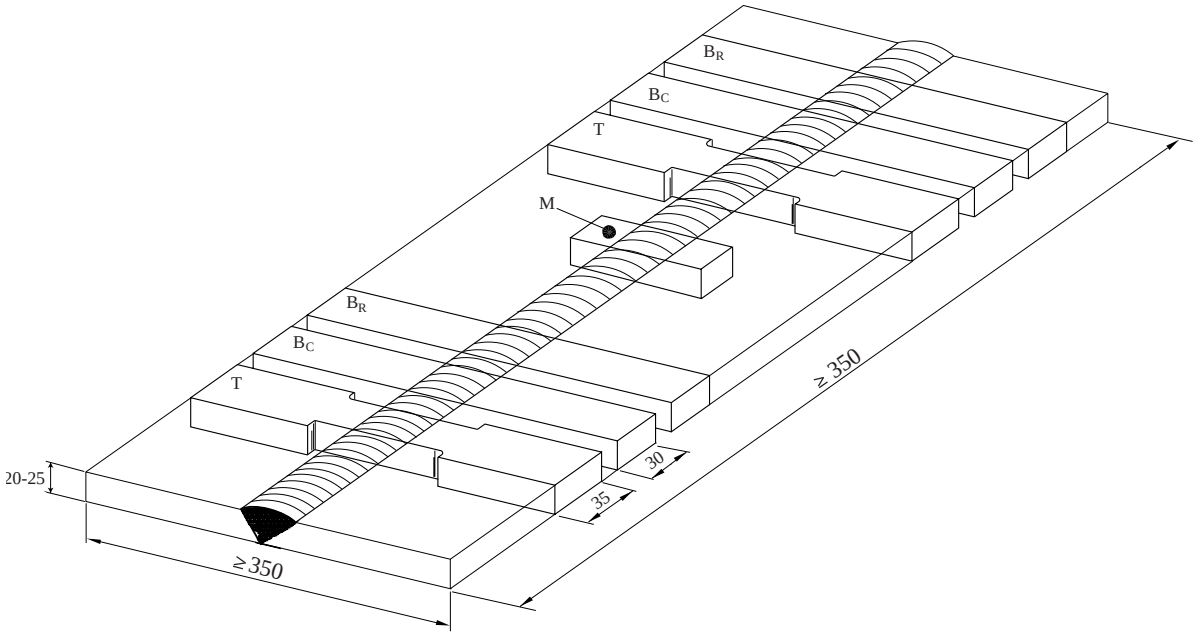



Notes: 1) Edge preparation is to be single V or double V with 70° angle.
2) Back sealing runs are allowed in single V weld assemblies.
3) In case of double V assembly both sides shall be welded in the same welding position.

**Figure 2 Butt weld test assembly for positional welding**

**W26**
cont'd

T = Flat tensile test specimen
$B_C$ = Face bend test specimen
$B_R$ = Root bend test specimen
M = Macrographic section




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

**Figure 3 Additional butt weld test assembly in downhand position**

**W26**
cont'd

2.2.4 On completion of welding, assemblies must be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens must not be subjected to any heat treatment.

Grade D assemblies should be allowed to naturally ageing for a minimum period of 72 hours from the completion of welding before testing is carried out.

2.2.5 The test specimens shown in Figure 2 and Figure 3 and described in UR W 17 shall be taken from the butt weld test assemblies.

2.2.6 The mechanical properties must meet the requirements stated in Table 3. The provisions of UR W 17 apply in analogous manner to the performance of the tests, including the requirements regarding the annual repeat tests and retesting. The position of the fractures is to be stated in the report. The macrographic specimen shall be examined for imperfections such as lack of fusion, cavities, inclusions, pores or cracks.

**Table 3 Requirements for the transverse tensile and bend tests**

**Table 3 Requirements for the transverse tensile and bend tests**

| Grade | Base material used for the test | Tensile strength $R_m$ [N/mm$^2$] min. | Former diameter | Bending angle[1)] [°] min. |
|---|---|---|---|---|
| R**A**/W**A** | 5754 | 190 | 3t | 180 |
| R**B**/W**B** | 5086 | 240 | 6t | |
| R**C**/W**C** | 5083 | 275 | 6t | |
| | 5383 or 5456 | 290 | 6t | |
| | 5059 | 330 | 6t | |
| R**D**/W**D** | 6061. 6005A or 6082 | 170 | 6t | |

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

## 3. Annual repeat tests

3.1 The annual repeat tests shall entail the preparation and testing of the deposited weld metal test assembly as prescribed under 2.1.1 (Figure 1) and of the downhand butt weld test assembly according to 2.2.2 (Figure 2).

END

# W27 Cast Steel Propellers

(May 2000) (Rev.1 May 2004)

## 1. Scope

1.1 These unified requirements are applicable to the manufacture of cast steel propellers, blades and bosses.

1.2 Where the use of alternative alloys is proposed, particulars of chemical composition, mechanical properties and heat treatment are to be submitted for approval.

1.3 These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Classification Society.

## 2. Foundry approval

All propellers, blades and bosses are to be manufactured by foundries approved by the Classification Society. The scope of the procedure tests involved in the approval is to be agreed.

## 3. General characteristics of castings

All castings are to have a workmanlike finish and are to be free from imperfections that could be considered to impair in-service performance.

## 4. Chemical composition

Typical cast steel propeller alloys are grouped into four types depending on their chemical composition as given in Table 1.

## 5. Heat treatment

Martensitic castings are to be austenitized and tempered. Austenitic castings should be solution treated.

## 6. Mechanical properties

6.1 The mechanical properties are to meet the requirements in Table 2. These values refer to the test specimens machined from integrally cast test bars attached to the hub or on the blade.

6.2 Where possible, the test bars attached on blades are to be located in an area between 0.5 to 0.6R, where R is the radius of the propeller.

6.3 The test bars are not to be detached from the casting until the final heat treatment has been carried out. Removal is to be by non-thermal procedures.

6.4 Separately cast test bars may be used subject to prior approval of the Classification Society. The test bars are to be cast from the same heat as the castings represented and heat treated with the castings represented.

6.5 At least one set of mechanical tests is to be made on material representing each casting in accordance with UR W2.

6.6 As an alternative to 6.5, where a number of small propellers of about the same size, and less than 1m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

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# W27

## 7. Visual inspection

7.1 All finished castings are to be 100% visually inspected by the Surveyor. The Surveyor may require areas to be etched for the purpose of investigating weld repairs.

7.2 Castings are to be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings.

## 8. Dimensions, dimensional and geometrical tolerances

8.1 The dimensions are the responsibility of the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence.

8.2 Static balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamic balancing may be necessary for propellers running above 500 rpm.

## 9. Non-destructive testing

**9.1** All finished castings are subject to non-destructive testing in accordance with the requirements given in 9.2 to 9.9.

**9.2** In order to relate the degree of non-destructive testing to the criticality of imperfections, propeller blades are divided into three severity Zones designated A, B and C. Further, a distinction is made between low skew and high skew propellers. IACS UR W24 refers.

**9.3** For all propellers, separately cast blades and hubs, the surfaces covered by severity Zones A, B and C are to be liquid penetrant tested. Testing of Zone A is to be undertaken in the presence of the Surveyor, whilst testing of Zone B and C may be witnessed by the Surveyor upon his request.

**9.4** If repairs have been made either by grinding or by welding, the repaired areas are additionally to be subjected to the liquid penetrant testing independent of their location and/or severity Zone. Weld repairs are, independent of their location, always to be assessed according to Zone A.

**9.5** The following definitions relevant to liquid penetrant indications apply**:**

*Indication*: the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied;

*Linear indication*: an indication in which the length is at least three times the width;

*Nonlinear indication*: an indication of circular or elliptical shape with a length less than three times the width;

*Aligned indication*: three or more indications in a line, separated by 2mm or less edge-to-edge;

*Open indication:* an indication that can be detected by the use of contrast dye penetrant;

*Non-open indication*: an indication that cannot be detected by the use of contrast dye penetrant,

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**W27**

*Relevant indication:* an indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5mm shall be considered relevant.

**9.6** For the purpose of evaluating indications, the surface is to be divided into reference areas of 100cm$^2$, which may be square or rectangular with the major dimension not exceeding 250mm. The area shall be taken in the most unfavorable location relative to the indication being evaluated.

**9.7** The indications detected may, with respect to their size and number, not exceed the values given in the Table 3.

**9.8** Where serious doubt exists that the castings are not free from internal defects, further non-destructive inspections are to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic tests. The acceptance criteria are then to be agreed between the manufacturer and the Classification Society.

**9.9** The foundry is to maintain records of inspections traceable to each casting. These records are to be reviewed by the Surveyor. The foundry is also to provide the Surveyor with a statement confirming that non-destructive tests have been carried out with satisfactory results.

## 10. Repair

**10.1** Defective castings are to be repaired in accordance with the requirements given in 10.2 to 10.7 and, where applicable, the requirements of Section 11.

**10.2** In general the repairs are to be carried out by mechanical means, e.g. by grinding or milling. The resulting grooves are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by liquid penetrant testing.

**10.3** Weld repairs are to be undertaken only when they are considered to be necessary and have prior approval of the Surveyor. All weld repairs are to be documented by means of sketches or photographs showing the location and major dimensions of the grooves prepared for welding. The documentation is to be presented to the Surveyor prior to repair welding.

**10.4** The excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by liquid penetrant testing. Welds having an area less than 5cm$^2$ are to be avoided.

**10.5** Grinding in severity Zone A may be carried out to an extent that maintains the blade thickness. Repair welding is generally not permitted in severity Zone A and will only be allowed after special consideration by the Classification Society.

**10.6** Defects in severity Zone B that are not deeper than t/40 mm ("t" is the minimum local thickness according to the Rules) or 2mm, whichever is greatest, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval from the Classification Society.

**10.7** Repair welding is generally permitted in severity Zone C.

## 11. Weld repair procedure

11.1 The scope of the procedure tests involved in the qualification is given in Appendix A. ▶

**W27** Before welding is started, a detailed welding procedure specification is to be submitted covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures.

**11.2** All weld repairs are to be made by qualified welders using qualified procedures.

**11.3** Welding is to be done under controlled conditions free from draughts and adverse weather.

**11.4** Metal arc welding with electrodes or filler wire used in the procedure tests is to be used. The welding consumables are to be stored and handled in accordance with the manufacturer s recommendations.

**11.5** Slag, undercuts and other imperfections are to be removed before depositing the next run.

**11.6** The martensitic steels are to be furnace re-tempered after weld repair. Subject to prior approval, however, local stress relieving may be considered for minor repairs.

**11.7** On completion of heat treatment the weld repairs and adjacent material are to be ground smooth. All weld repairs are to be liquid penetrant tested.

**11.8** The foundry is to maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. These records are to be reviewed by the Surveyor.

### 12. Identification

**12.1** Prior to final inspection by the surveyor, each casting is to be suitably identified by the manufacturer with the following:

a) Heat number or other marking which will enable the full history of the casting to be traced;

b) The Society s certificate number;

c) Ice class symbol, where applicable;

d) Skew angle for high skew propellers,

e) Date of final inspection.

**12.2** The Society s stamp is to be put on when the casting has been accepted.

### 13. Certification

13.1 The manufacturer is to provide the Surveyor with an inspection certificate giving the following particulars for each casting which has been accepted:

a) Purchaser s name and order number;

b) Vessel identification, where known;

c) Description of the casting with drawing number;

d) Diameter, number of blades, pitch, direction of turning;

e) Skew angle for high skew propellers;

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**W27**

f) Final mass;

g) Alloy type, heat number and chemical composition;

h) Casting identification number;

i) Details of time and temperature of heat treatment,

j) Results of the mechanical tests.

**13.2** The manufacturer is to provide a statement regarding non-destructive tests as required by 9.9 and, where applicable, records of weld repairs as required by 11.8.

Table 1 - Typical chemical composition for steel propeller castings

| Alloy type | C Max. (%) | Mn Max. (%) | Cr (%) | Mo[1)] Max. (%) | Ni (%) |
|---|---|---|---|---|---|
| Martensitic (12 Cr 1 Ni) | 0,15 | 2,0 | 11,5-17,0 | 0,5 | Max. 2,0 |
| Martensitic (13 Cr 4 Ni) | 0,06 | 2,0 | 11,5-17,0 | 1,0 | 3,5-5,0 |
| Martensitic (16 Cr 5 Ni) | 0,06 | 2,0 | 15,0-17,5 | 1,5 | 3,5-6,0 |
| Austenitic (19 Cr 1 1 Ni) | 0,12 | 1,6 | 16,0-21,0 | 4,0 | 8,0-13,0 |

Note: 1) Minimum values are to be in accordance with recognised national or international standards

# W27

Table 2 - Mechanical Properties for steel propeller castings

| Alloy type | Proof stress $R_{p0.2}$ min. ($N/mm^2$) | Tensile strength $R_m$ min. ($N/mm^2$) | Elongation $A_5$ min. (%) | Red. of area Z min. (%) | Charpy V-notch[1] Energy min. (J) |
|---|---|---|---|---|---|
| 12 Cr 1Ni | 440 | 590 | 15 | 30 | 20 |
| 13 Cr 4Ni | 550 | 750 | 15 | 35 | 30 |
| 16 Cr 5Ni | 540 | 760 | 15 | 35 | 30 |
| 19 Cr 11Ni | 180[2] | 440 | 30 | 40 | - |

1) Not required for general service and the lowest Ice class notations. For other Ice class notations, tests are to be made $-10^0$C.

2) $R_{p1,0}$ value is 205 $N/mm^2$.

# W27 Table 3 - Allowable number and size of indications depending on severity zones

| Severity zone | Max. total number of indications | Indication type | Max. number for each type 1) 2) | Max. dimension of indication (mm) |
|---|---|---|---|---|
| A | 7 | Non-linear | 5 | 4 |
| | | Linear | 2 | 3 |
| | | Aligned | 2 | 3 |
| B | 14 | Non-linear | 10 | 6 |
| | | Linear | 4 | 6 |
| | | Aligned | 4 | 6 |
| C | 20 | Non-linear | 14 | 8 |
| | | Linear | 6 | 6 |
| | | Aligned | 6 | 6 |

1) Single non-linear indications less than 2mm in Zone A and less than 3mm in other zones may be disregarded.

2) The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

# W27

## Appendix A

## Welding Procedure Qualification Test

### 1. Preparation of test assembly

A test assembly of minimum 30mm thickness is to be welded. The types of specimens to be prepared are shown in Fig. 1.

### 2. Non-destructive testing

Prior to sectioning, the test assembly is to be visually inspected and liquid penetrant tested. Imperfections shall be assessed in accordance with Section 9.

### 3. Macro-examination

Two macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. The sections are to be examined by eye (aided by low power hand lens if desired) for any imperfections present in the weld metal and HAZ. Cracks or crack-like imperfections, slag inclusions, and pores greater than 3mm are not permitted.

### 4. Tensile testing

Two flat transverse tensile test specimens shall be prepared. Testing procedures shall be in accordance with IACS UR W2.4.2.8 b).
The tensile strength shall meet the specified minimum value of the base material. The location of fracture is to be reported, i.e. weld metal, HAZ or base material.

### 5. Bend testing

Two transverse side bend test specimens shall be prepared in accordance with IACS UR W2. The former diameter shall be 4 x thickness except for austenitic steels, in which case the former diameter shall be 3 x thickness.
The test specimen, when visually inspected after bending, shall show no surface imperfections greater than 2mm in length.

### 6. Charpy V-notch testing

Impact test is not required, except where the base material is impact tested. Charpy V-notch test specimens shall be in accordance with IACS UR W2. Two sets shall be taken, one set with the notch positioned in the center of the weld and one set with the notch positioned in the fusion line, respectively.
The test temperature, and impact energy shall comply with the requirement specified for the base material.

### 7. Hardness testing

One of the macro-sections shall be used for HV5 hardness testing. Indentations shall traverse 2mm below the surface. At least three individual indentations are to be made in the weld metal, the HAZ (both sides) and in the base material (both sides). The values are to be reported for information.

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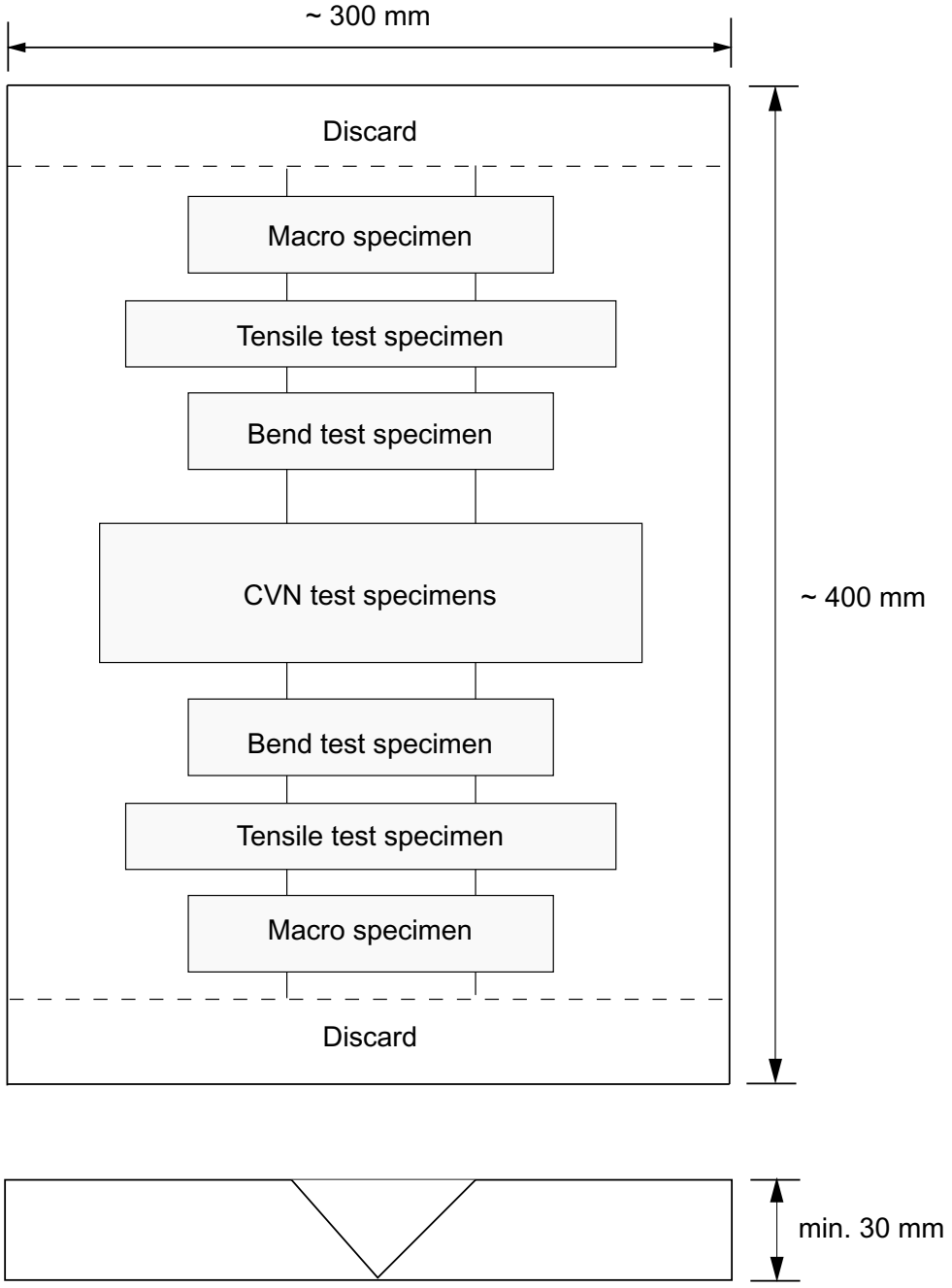


**Fig. 1 Weld test assembly**

# W28 Welding procedure qualification tests of steels for hull construction and marine structures

(June 2005) (Rev.1 Nov 2006) (Rev.2 Mar 2012)

## 1. Scope

1.1 This document gives requirements for qualification tests of welding procedures intended for the use of weldable steels as specified in UR W7, UR W8, UR W11 and UR W16 for hull construction and marine structures.

1.2 This document specifically excludes the welding procedure specified in UR W1.

1.3 All new welding procedure qualification tests are to be carried out in accordance with this document from 1 July 2007.

1.4 This document does not invalidate welding procedure qualification tests made and accepted by the Classification Society before 1 July 2007 provided the welding procedure qualification tests are considered by the Classification Society to meet the technical intent of this UR or have been qualified in accordance with the recognized standards such as ISO, EN, AWS, JIS or ASME.

## 2. General

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

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

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

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

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Note:

1. This UR is to be uniformly implemented by IACS Societies on ships contracted for construction from 1 January 2007 as well as the manufacturing of which is commenced on or after 1 January 2007.

2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

3. Rev.2 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2013.

**W28 (cont)**

## 3 Welding procedure specification

### 3.1 Preliminary welding procedure specification and welding procedure specification

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

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

3.1.3 The WPS is to be used as a basis for the production welds, and upon satisfactory completion of the tests based on the pWPS, the Society may approve it as a WPS. In case that a WPS is approved by the Society the approval range is to be in compliance with section 5.

## 4. Qualification of welding procedures

### 4.1 General

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

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

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

### 4.2 Butt weld

4.2.1 Assembly of test pieces

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

- manual or semi-automatic welding:

  width = 2a, a = 3 x t, min 150 mm
  length b = 6 x t, min 350 mm

- automatic welding:

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

# W28
**(cont)**

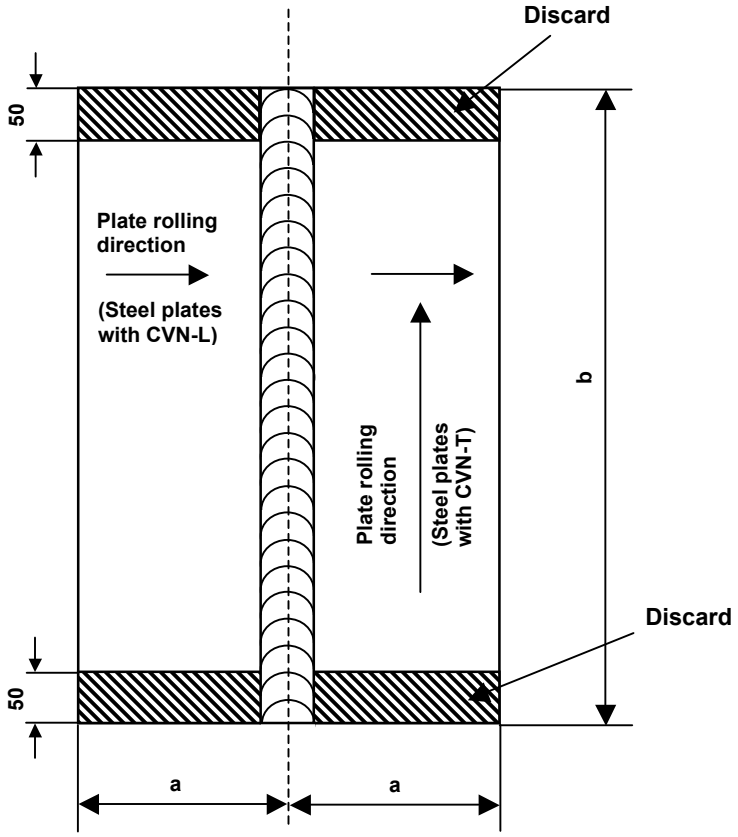



**Fig.1 Test assembly for butt weld**

For hull structural steel plates impact tested in the longitudinal direction (CVN-L) in UR W11, the butt weld of the test piece is perpendicular to the rolling direction of the two plates.

For high strength quenched and tempered steel plates impact tested in the transverse direction (CVN-T) in UR W16, the butt weld of the test piece is parallel to the rolling direction of the two plates.

4.2.2 Examinations and tests

Test assemblies are to be examined non-destructively and destructively in accordance with the following and Fig 2:

| | |
|---|---|
| - Visual testing | 100 % |
| - Surface crack detection | 100 %<br>(dye penetrant testing or magnetic particle testing) |
| - Radiographic or Ultrasonic testing | 100 % |
| - Transverse tensile test | two specimens as per 4.2.2.2 |
| - Longitudinal tensile test | required as per 4.2.2.3 |
| - Transverse bend test | four specimens as per 4.2.2.4 |
| - Charpy V-notch impact test | required as per 4.2.2.5 |
| - Macro examination | one specimen as per 4.2.2.6 |
| - Hardness test | required as per 4.2.2.7 |

# W28
**(cont)**

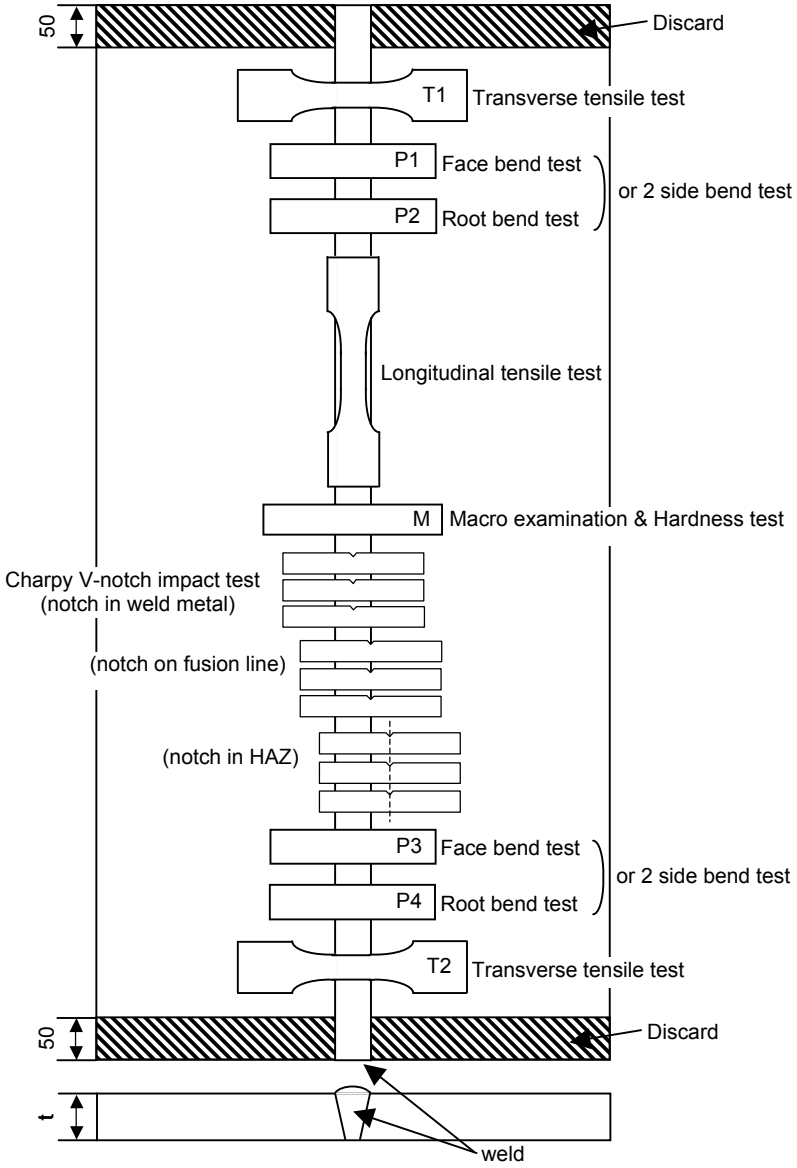



**Fig.2 Test sampling**

**W28 (cont)**

4.2.2.1 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified, non-destructive testing is to be performed after heat treatment. For steels according to UR W16 with specified minimum yield strength of 420 N/mm$^2$ and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with the Society.

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

4.2.2.2 Transverse tensile test

The testing is to be carried out in accordance with UR W2.4. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal.

When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength.

4.2.2.3 Longitudinal tensile test

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

The testing is to be carried out in accordance with UR W2.4. The tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the appropriate grade of consumable.

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

4.2.2.4 Bend test

Transverse bend tests for butt joints are to be in accordance with UR W2.6.

The mandrel diameter to thickness ratio (i.e. D/t) is to be that specified for the welding consumable (UR W17, UR W23) approvals + 1.

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

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

For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

**W28 (cont)**

4.2.2.5 Impact test

a) Normal and higher strength hull structural steels according to UR W11

The positions of specimens are to be in accordance with these requirements. Dimensions and testing are to be in accordance with the requirements of UR W2.7.

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

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

Test temperature and absorbed energy are to be in accordance with Table 1.

**Table 1 Impact test requirements for butt joints (t ≤ 50 mm)[(1),(2)]**

| Grade of steel | Testing Temperature ($C^o$) | Value of minimum average absorbed energy (J) | | |
|---|---|---|---|---|
| | | For manually or semi-automatically welded joints | | For automatically welded joints |
| | | Downhand, Horizontal, Overhead | Vertical upward, Vertical downward | |
| A[(3)] | 20 | 47 | 34 | 34 |
| B[(3)], D | 0 | | | |
| E | -20 | | | |
| A32, A36 | 20 | | | |
| D32, D36 | 0 | | | |
| E32, E36 | -20 | | | |
| F32, F36 | -40 | | | |
| A40 | 20 | | 39 | 39 |
| D40 | 0 | | | |
| E40 | -20 | | | |
| F40 | -40 | | | |

Note:

(1) For thickness above 50 mm impact test requirements are to be agreed by the Society.

(2) These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.

(3) For Grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be minimum 27 J.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

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

**W28 (cont)**

The testing of sub - size specimen is to be in accordance with UR W2.7.2

b) High strength quenched and tempered steels according to UR W16

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

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

Test temperature and absorbed energy are to be in accordance with the requirements of base metal as specified in UR W16.

c) Weldable C and C-Mn hull steel castings and forgings according to UR W7 and UR W8

For base metal with specified impact values test temperature and absorbed energy are to be in accordance with the requirements of the base metal to be welded.

4.2.2.6 Macro examination

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

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

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

4.2.2.7 Hardness test

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

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

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

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

**4.3 Fillet welds**

4.3.1 Assembly of test pieces

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig. 3 with the minimum dimensions:

- manual and semi-automatic welding:

  width a = 3 x t, min. 150 mm
  length b = 6 x t, min. 350 mm

**W28**
**(cont)**

- automatic welding:

  width a = 3 x t, min. 150 mm
  length b = 1000 mm

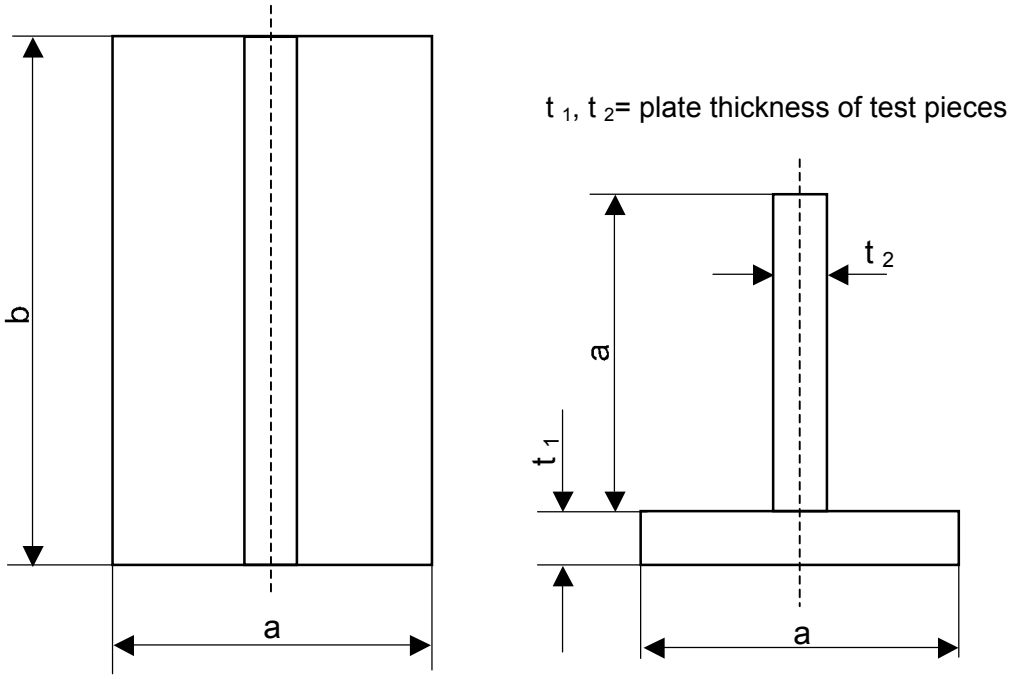



**Fig.3 Test assembly for fillet weld**

4.3.2 Welding of test pieces

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

4.3.3 Examinations and tests

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

| | |
|---|---|
| - Visual testing | 100 % |
| - Surface crack detection | 100 %<br>(dye penetrant testing or magnetic particle testing) |
| - Macro examination | two specimen as per 4.3.3.2 |
| - Hardness test | required as per 4.3.3.3 |
| - Fracture test | required as per 4.3.3.4 |

**W28 (cont)**

4.3.3.1 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified non-destructive testing is to be performed after heat treatment. For steels according to UR W16 with specified minimum yield strength of 420 N/mm$^2$ and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with the Society.

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

4.3.3.2 Macro examination

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

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

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

4.3.3.3 Hardness test

Hardness test is required for steels with a specified minimum yield strength of $R_{eH} \geq 355$ N/mm$^2$. The Vickers method HV 10 is normally to be used. The indentations are to be made in the weld metal, the heat affected zone and the base metal measuring and recording the hardness values. At least two rows of indentations are to be carried out in accordance with Fig. 3, 4a and 4b of Annex B.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zone (both sides) and the base metal (both sides). A typical example is shown in Annex B.

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

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

4.3.3.4 Fracture test

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

### 4.4 Re-testing

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

**W28 (cont)**

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

4.4.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with UR W 2.4.3.

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

4.4.5 The re-testing of Charpy impact specimens are to be carried out in accordance with UR W 2.7.4.

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

### 4.5 Test record

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

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

4.5.3 A statement that the test piece was made according to the particular welding procedure is to be signed by the Surveyor witnessing the test and is to include the Society´s identification.

## 5. Range of approval

### 5.1 General

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

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

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

### 5.2 Base metal

5.2.1 Normal and higher strength hull structural steels according to UR W11

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

**W28 (cont)**

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

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

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

5.2.2 High strength quenched and tempered steels according to UR W16

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

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

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

5.2.3 Weldable C and C-Mn hull steel forgings according to UR W7

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

b) The approval of quenched and tempered hull steel forgings does not quality other delivery conditions and vice versa.

5.2.4 Weldable C and C-Mn hull steel castings according to UR W8

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

b) The approval of quenched and tempered hull steel castings does not quality other delivery conditions and vice versa.

### 5.3 Thickness

5.3.1 The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in Table 2.

**Table 2 Approval range of thickness for butt and T-joint welds and fillet welds**

| Thickness of test piece T[(1)] (mm) | Range of approval | |
|---|---|---|
| | Butt and T-joint welds with single run or single run from both sides | Butt and T-joint welds with multi-run and fillet welds[(2)] |
| 3 < t ≤ 12 | 0.7 x t to 1.1 x t | 3 to 2 x t |
| 12 < t ≤ 100 | 0.7 x t to 1.1 x t[(3)] | 0.5 x t to 2 x t (Max. 150) |

**W28 (cont)**

Note:

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

(2) For fillet welds, the range of approval is to be applied to both base metals.

(3) For high heat input processes over 50kJ/cm, the upper limit of range of approval is to be 1.0 x t.

5.3.2 In addition to the requirements of Table 2, the range of approval of throat thickness “a” for fillet welds is to be as follows:

- Single run ; “0.75 x a” to “1.5 x a”

- Multi-run ; as for butt welds with multi-run (i.e. a=t)

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

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

5.3.5 Notwithstanding the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated 4.2.2.7 and 4.3.3.3.

**5.4 Welding position**

Approval for a test made in any position is restricted to that position (see Annex C). To qualify a range of positions, test assemblies are to be welded for highest heat input position and lowest heat input position and all applicable tests are to be made on those assemblies.

**5.5 Welding process**

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

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

**5.6 Welding consumable**

Except high heat input processes over 50kJ/cm, welding consumables cover other approved welding consumables having the same grade mark including all suffixes specified in UR W17 and UR W23 with the welding consumable tested.

**5.7 Heat input**

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

**W28 (cont)**

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

### 5.8 Preheating and interpass temperature

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

5.8.2 The maximum interpass temperature is not to be higher than that used in the qualification test.

### 5.9 Post-weld heat treatment

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

### 5.10 Type of joint

5.10.1 Range of approval depending on type of welded joints for test assembly is to be specified in Table 3.

5.10.2 A qualification test performed on a butt weld will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 5.3 above.

**Table 3 Range of approval for type of welded joint**

| Type of welded joint for test assembly | | | Range of approval | |
|---|---|---|---|---|
| Butt welding | One side | With backing | A | A, C |
| | | Without backing | B | A, B, C, D |
| | Both side | With gouging | C | C |
| | | Without gouging | D | C, D |

### 5.11 Other variables

The range of approval relating to other variables may be taken according to the Society requirements.

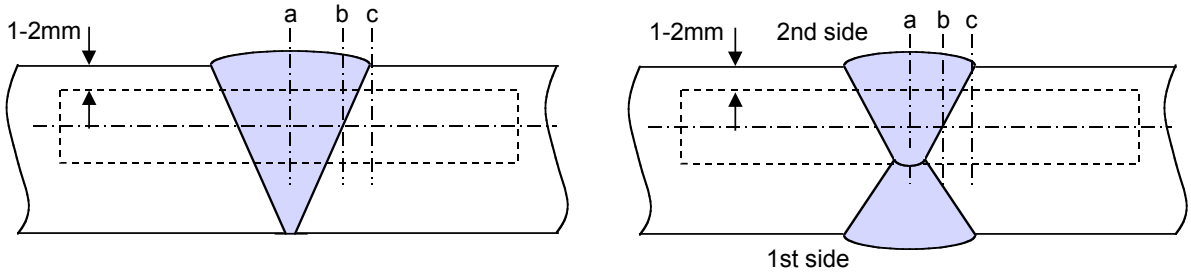
**W28**
**(cont)**

## Annex A

## Location of Charpy V-notch impact test

**W28**
**(cont)**

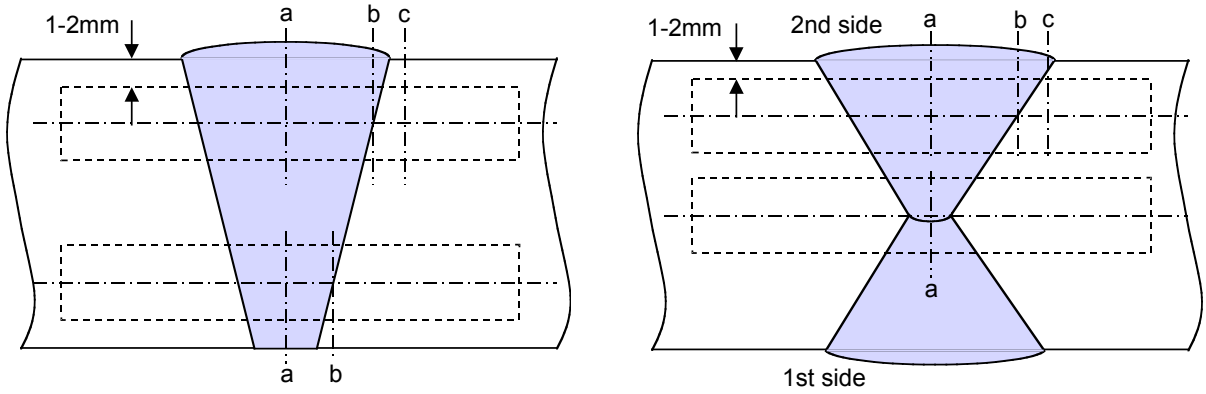
**a) t≤50mm(1)**




Note:

(1) For one side single run welding over 20mm notch location “a” is to be added on root side.

**b) t>50mm**

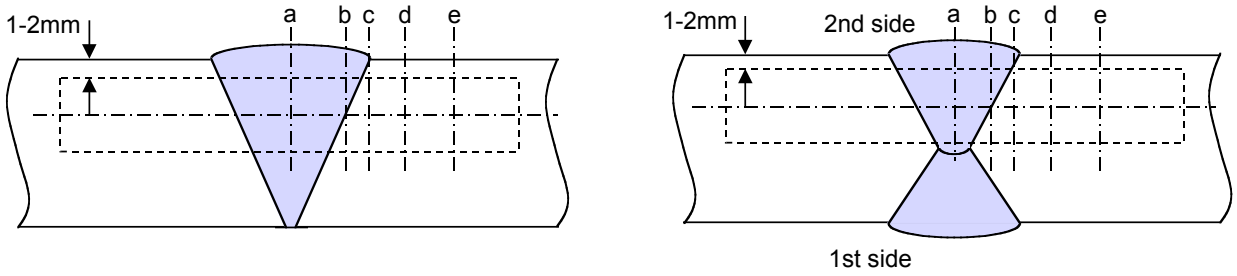



Notch locations:
a : center of weld “WM”
b : on fusion line “FL”
c : in HAZ, 2mm from fusion line

**Fig. 1 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)**

**W28**
**(cont)**

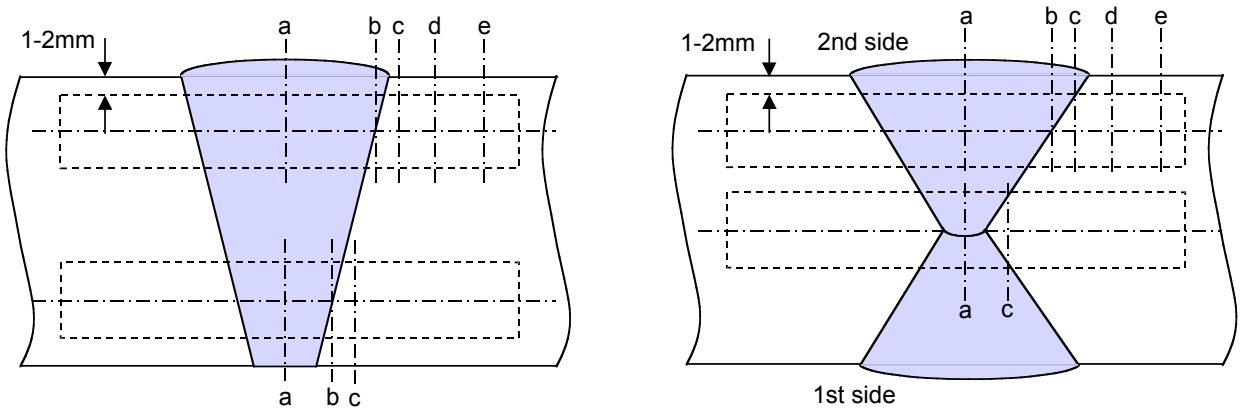
**a) t≤50mm(1)**




Note:

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

**b) t>50mm**




Notch locations:
a : center of weld “WM”
b : on fusion line “FL”
c : in HAZ, 2mm from fusion line
d : in HAZ, 5mm from fusion line
e : in HAZ, 10mm from fusion line in case of heat input > 200kJ/cm

**Fig. 2 Locations of V-notch for butt weld of high heat input (heat input > 50kJ/cm)**

**W28**
**(cont)**

## Annex B

## Hardness test

*(Typical examples of hardness test)*

# W28
**(cont)**

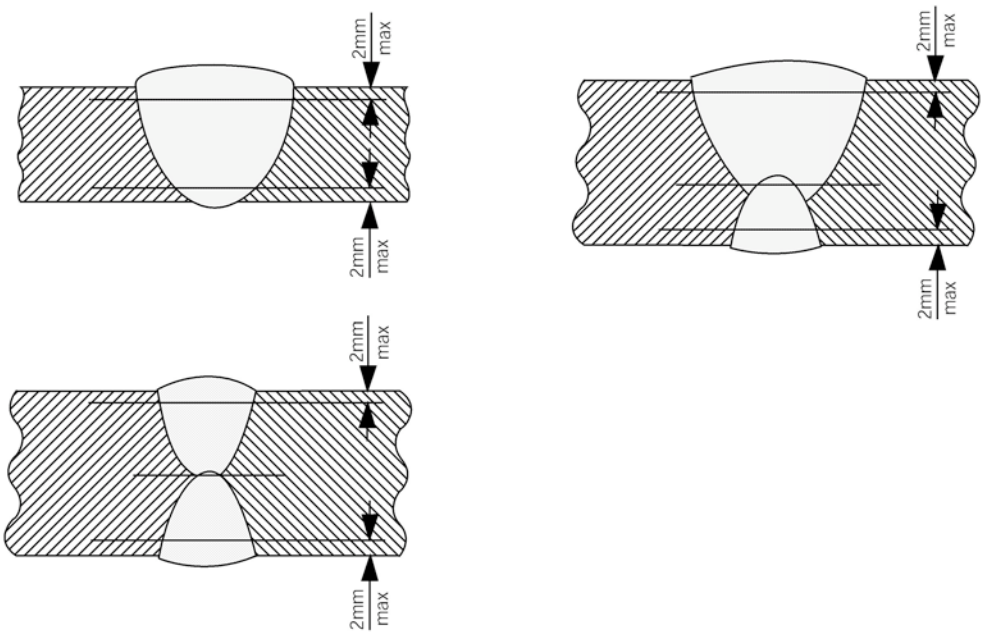



**Fig. 1 Examples of hardness test with rows of indentations (R) in butt welds**

**Table 1 Recommended distances *l* between indentations for hardness test in the heat affected zone**

| Vickers hardness Symbol | Distance between indentations *l* (mm) |
|---|---|
| HV 10 | 1 |

The distance of any indentation from the previous indentation is not to be less than the value allowed for the previous indentation by ISO 6507/1.

**W28**
**(cont)**

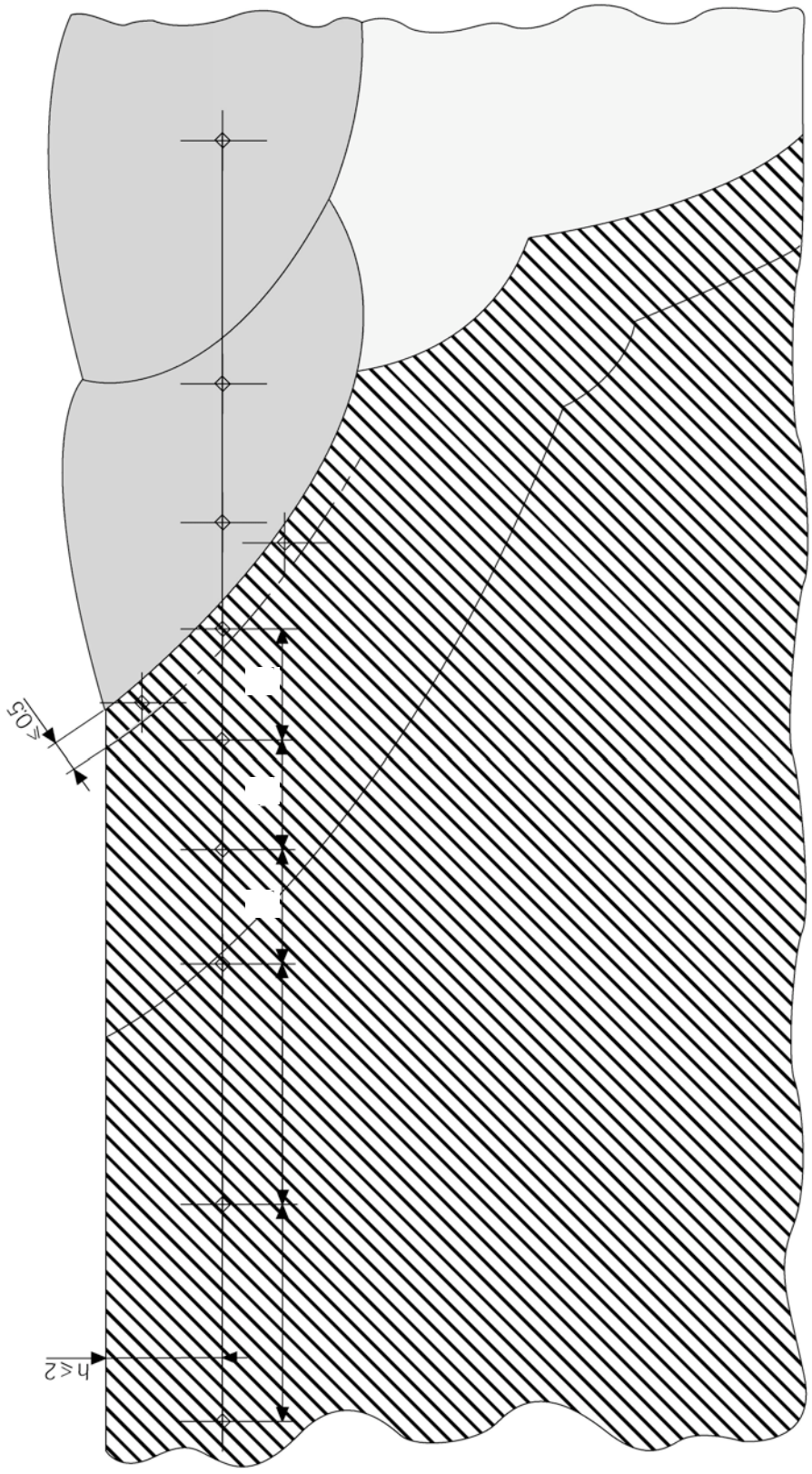
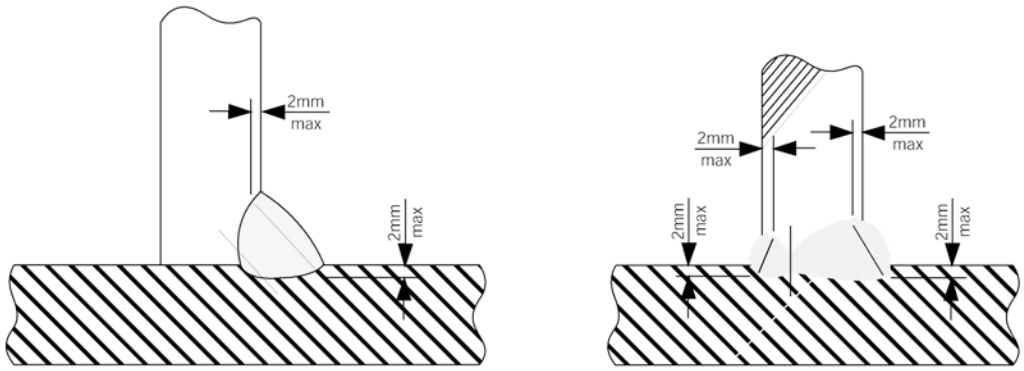



**Fig. 2 Example showing the position of the indentations for hardness test in the weld metal, the heat affected zone and the base metal of a butt weld (dimensions in mm)**

# W28
(cont)




a) Fillet weld b) T-joint weld

**Fig. 3 Examples of hardness test with row indentation (R) in fillet welds and in T-joint welds**

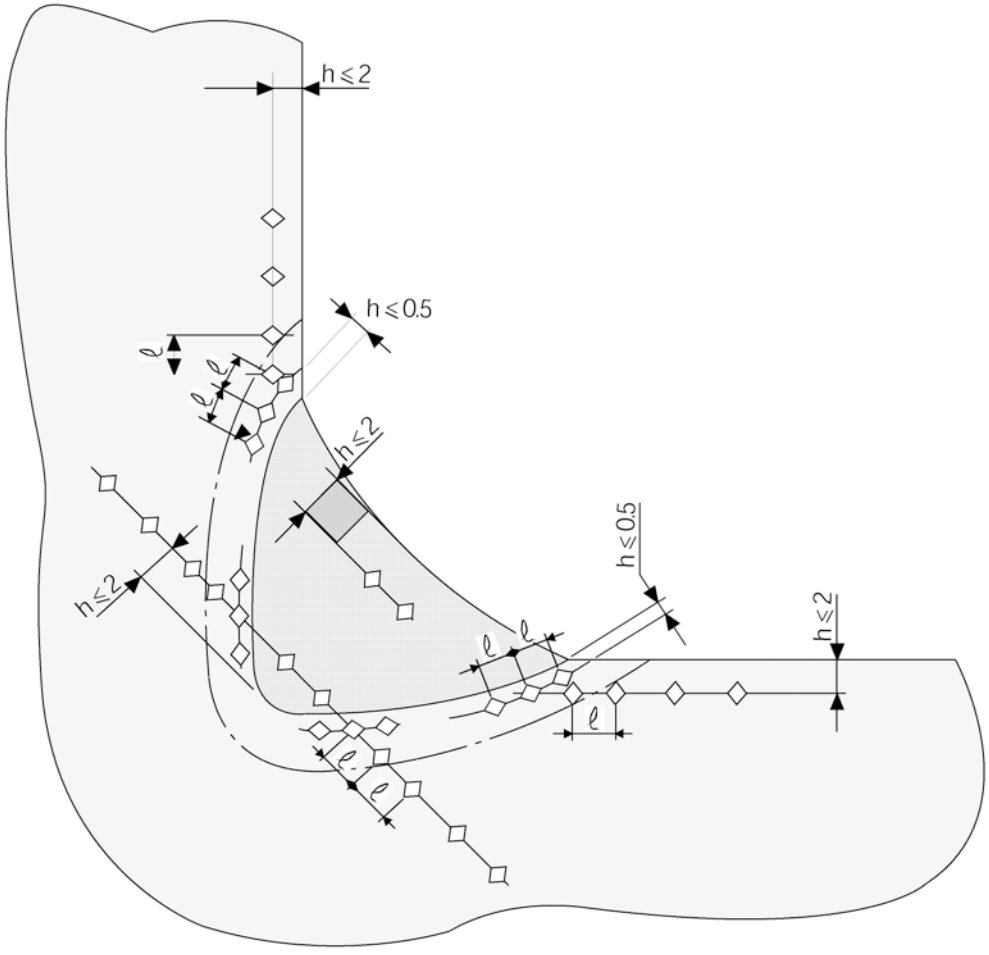



**Fig. 4a Example showing the position of the indentations for hardness test in the weld metal, the heat affected zone and the base metal of a fillet weld (dimensions in mm)**

# W28
**(cont)**

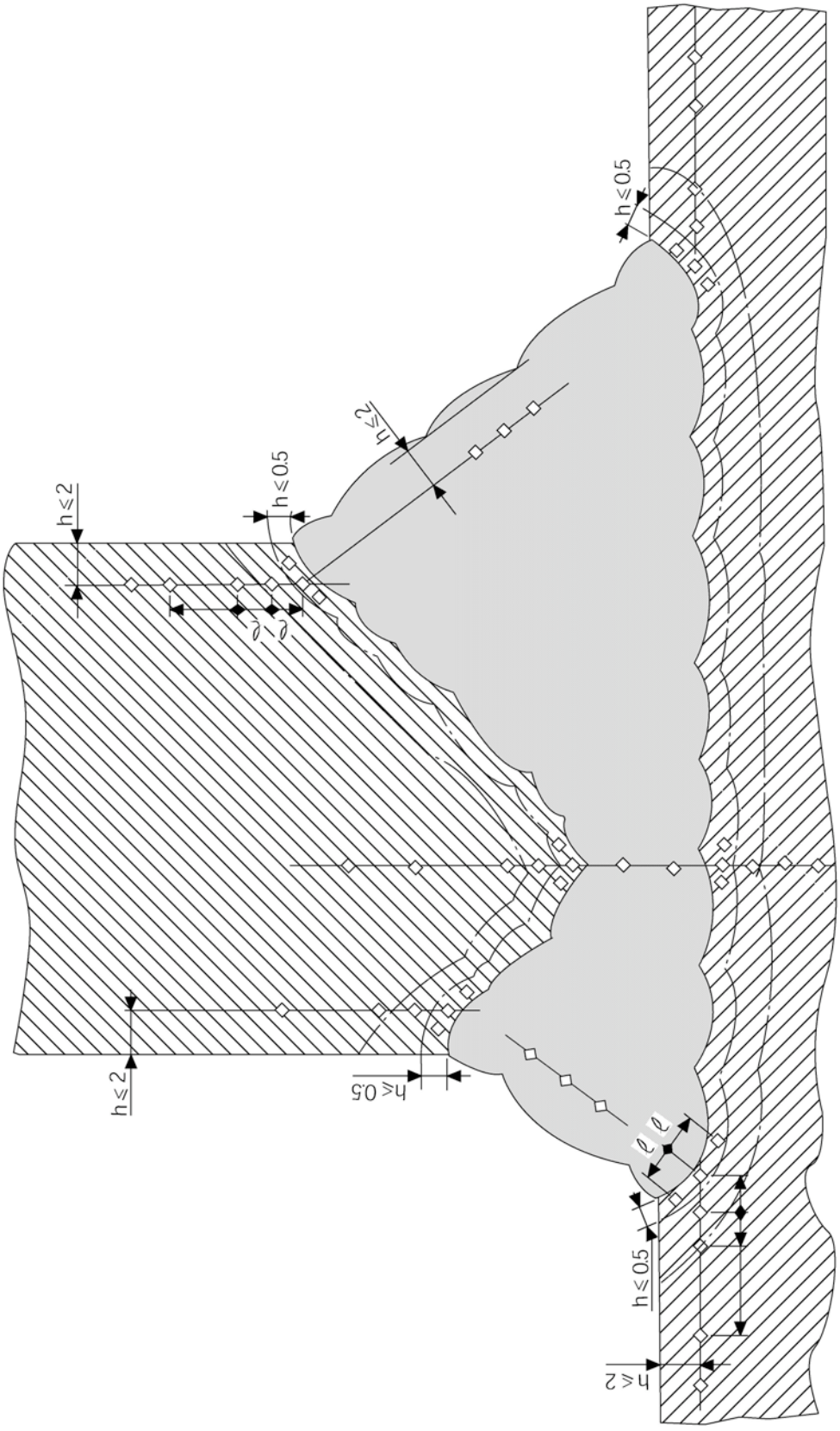



**Fig. 4b Example showing the position of the indentations for hardness test on the weld metal, the heat affect zone and the base metal of a T-joint weld (dimensions in mm)**

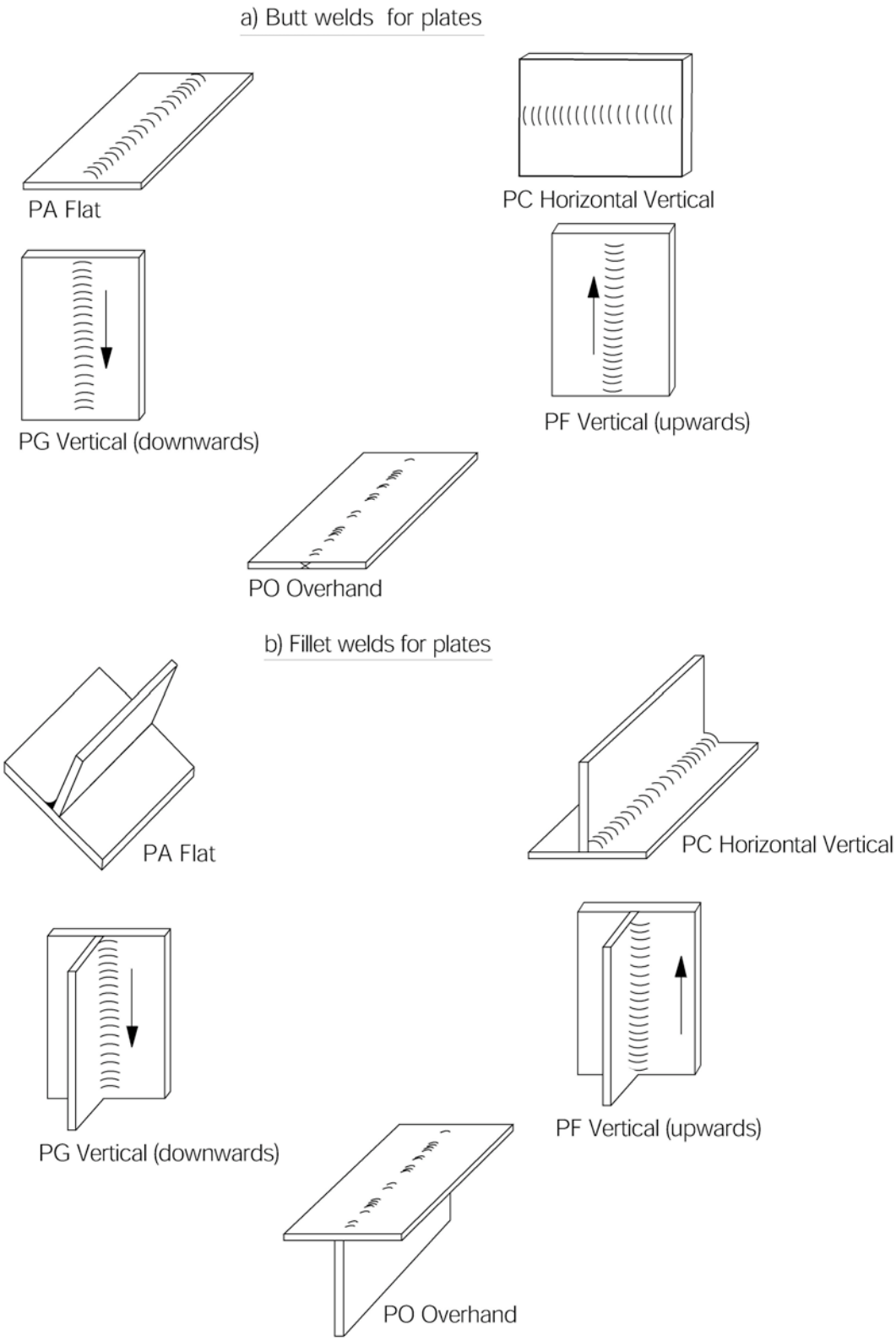
# W28 (cont)

## Annex C

## Welding positions

**W28**
**(cont)**

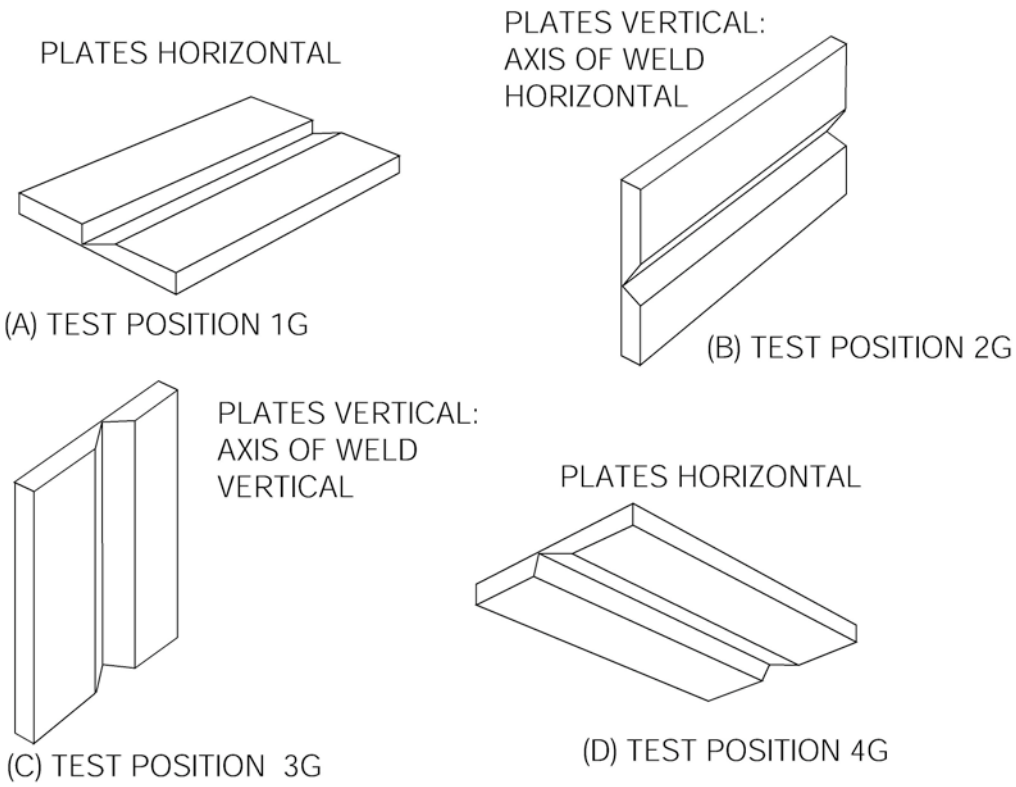
**Annex C.1: Welding positions according to ISO Standard**



**W28**
**(cont)**

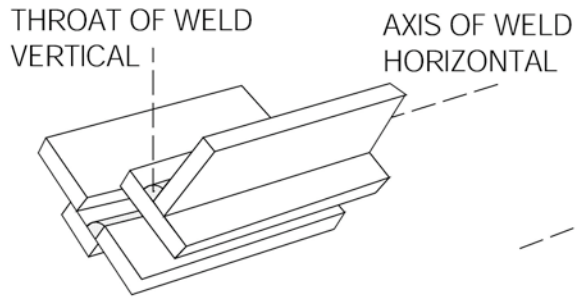
**Annex C.2: Welding positions according to AWS-Code**

a) Butt weld for plates

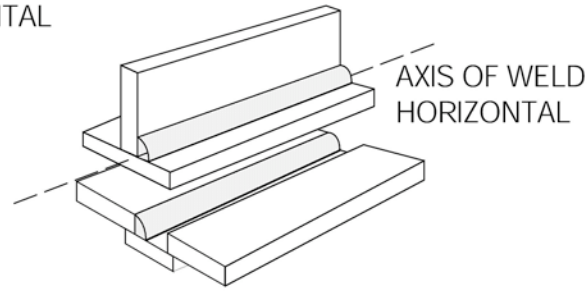


# W28
**(cont)**

b) Fillet welds for plates

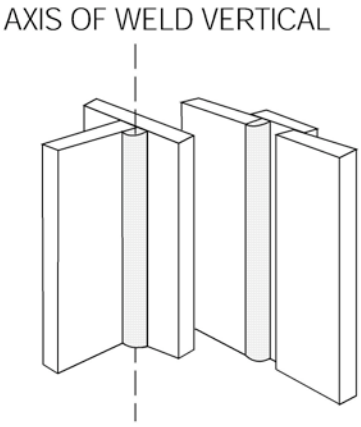



(A) FLAT POSITION 1F

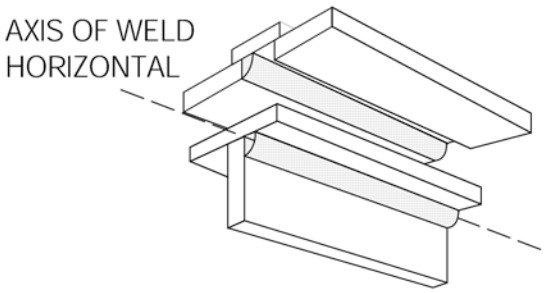



Note: One plate must be horizontal

(B) HORIZONTAL POSITION 2F




(C) VERTICAL POSITION 3F




Note: One plate must be horizontal

(D) OVERHEAD POSITION 4F

End of Document

# W29 Requirements for manufacture of anchors

(June 2005)

## 1. General requirements

### 1.1 Scope

These Rules apply to the materials, manufacture and testing, and certification of anchors, shanks and anchor shackles produced from cast or forged steel, or fabricated by welded rolled steel plate and bars. Frequent reference is made to UR A1.

With regard to holding power tests at sea for high holding power (HHP) and super high holding power (SHHP) anchors, refer to UR A1.

### 1.2 Types of anchor

The types of anchor covered include:

a) Ordinary anchors. Refer to UR A1.4.1.1
   i) Stockless anchors
   ii) Stocked anchors

b) HHP anchors. Refer to UR A1.4.1.2

c) SHHP anchors, not exceeding 1500kg in mass. Refer to UR A1.4.1.3

Any changes to the design made during manufacture are to have prior written agreement from the Classification Society.

## 2. Materials

### 2.1 Materials for anchors

All anchors are to be manufactured from materials meeting the requirements of the UR Ws as indicted below:

a) Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of UR W8 and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with Aluminium. If test programme B is selected in Section 4.2 then Charpy V notch (CVN) impact testing of cast material is required. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

b) Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of UR W7. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

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Note: This UR is to be uniformly implemented by IACS Societies in respect of anchors, the manufacturing of which is commenced on or after 1 January 2007.

c) Rolled billets, plate and bar for fabricated steel anchors are to be manufactured and tested in accordance with the requirements of UR W11.

d) Rolled bar intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements of UR W7 or UR W11.

### 2.2 Materials for SHHP anchors

In addition to the requirements of 2.1 above, SHHP anchors are to be produced in accordance with the material toughness requirements of UR A1.4.4.

## 3. Manufacture of anchors

### 3.1 Tolerance

If not otherwise specified on standards or on drawings demonstrated to be appropriate, the following assembly and fitting tolerance are to be applied.

The clearance either side of the shank within the shackle jaws is to be no more than 3mm for small anchors up to 3 tonnes weight, 4mm for anchors up to 5 tonnes weight, 6mm for anchors up to 7 tonnes weight and is not to exceed 12 mm for larger anchors.

The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0.5mm for pins up to 57mm and 1.0mm for pins of larger diameter.

The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3 degrees, see Figure 1.

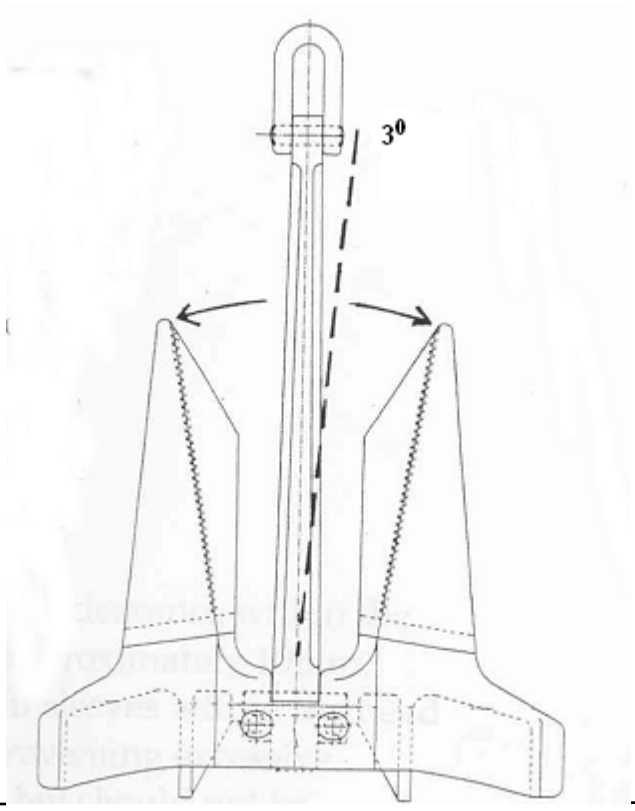

Figure 1 Allowable lateral movement of shank

### 3.2 Welding of anchors

Welded construction of fabricated anchors is to be done in accordance with procedures approved by the Classification Society. Welding is to be carried out by qualified welders, following the approved welding procedures qualified in accordance with UR W28, using consumables manufactured in accordance with the requirements of UR W17. NDE is to be carried in accordance with the requirements of 4.2 Product tests.

### 3.3 Heat treatment

Components for cast or forged anchors are to properly heat treated; fully annealed; normalised or normalised and tempered in accordance with UR W7 and UR W8.

Fabricated anchors may require stress relief after welding depending upon weld thickness. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

### 3.4 Freedom from defects

All parts are to have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects that would impair the performance of the product.

### 3.5 Repairs

Any necessary repairs to forged and cast anchors are to be agreed by the Surveyor and carried out in accordance with the repair criteria indicated in UR W7 and UR W8. Repairs to fabricated anchors are to be agreed by the Surveyor and carried out in accordance with qualified weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

### 3.6 Anchor assembly

Assembly and fitting are to be done in accordance with the design details.

Securing of the anchor pin, shackle pin or swivel nut by welding is to be done in accordance with an approved procedure.

## 4. Testing and certification

### 4.1 Proof load test

Proof load tests are to be carried out by an approved testing facility.

Proof load testing for Ordinary, HHP and SHHP anchors is to be carried out in accordance with the pertinent requirements of UR A1.4.3.

### 4.2 Product tests

### 4.2.1 Product Test Programmes

The Classification Society can request that either programme A or programme B be applied.

**Table 1 Applicable programmes for each product form**

| Product test | Product form | | |
|---|---|---|---|
| | Cast components | Forged components | Fabricated/Welded components |
| Programme A | Applicable | Not applicable | Not applicable |
| Programme B | Applicable (1) | Applicable | Applicable |

Notes : (1) CVN impact tests are to be carried out to demonstrate at least 27 joules average at 0ºC. Refer to 2.1 a).

**Table 2 Product test requirements for programme A and B**

| **Programme A** | **Programme B** |
|---|---|
| Drop test | — |
| Hammering test | — |
| Visual inspection | Visual inspection |
| General NDE | General NDE |
| — | Extended NDE |

### 4.2.2 Drop test

Each anchor fluke and shank is individually raised to a height of 4m and dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

### 4.2.3 Hammering test

After the drop test, hammering tests are carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3kg mass is to be used.

### 4.2.4 Visual inspection

After proof loading visual inspection of all accessible surfaces is to be carried out.

### 4.2.5 General non-destructive examination

After proof loading general NDE is to be carried out as indicated in the following Tables 3 and 4.

**Table 3 General NDE for Ordinary and HHP anchors**

| Location | Method of NDE |
|---|---|
| Feeders of castings | PT or MT |
| Risers of castings | PT or MT |
| Weld repairs | PT or MT |
| Forged components | Not required |
| Fabrication welds | PT or MT |

**Table 4 General NDE for SHHP anchors**

| Location | Method of NDE |
|---|---|
| Feeders of castings | PT or MT and UT |
| Risers of castings | PT or MT and UT |
| All surfaces of castings | PT or MT |
| Weld repairs | PT or MT |
| Forged components | Not required |
| Fabrication welds | PT or MT |

IACS Recommendation No. 69 “Guidelines for non-destructive examination of marine steel castings” is regarded as an example of an acceptable standard for surface and volumetric examination.

### 4.2.6 Extended non-destructive examination

After proof loading general NDE is to be carried out as indicated in the following Table 5.

**Table 5 Extended NDE for Ordinary, HHP and SHHP anchors**

| Location | Method of NDE |
|---|---|
| Feeders of castings | PT or MT and UT |
| Risers of castings | PT or MT and UT |
| All surfaces of castings | PT or MT |
| Random areas of castings | UT |
| Weld repairs | PT or MT |
| Forged components | Not required |
| Fabrication welds | PT or MT |

IACS Recommendation No. 69 “Guidelines for non-destructive examination of marine steel castings” is regarded as an example of an acceptable standard for surface and volumetric examination.

### 4.2.7 Repair criteria

If defects are detected by NDE, repairs are to be carried out in accordance with 3.5. For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.

## 4.3 Mass and dimensional inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless this is an integral component.

## 4.4 Retests

Mechanical retest are permitted in accordance with the requirements of UR W2.

## 4.5 Marking

Anchors which meet the requirements are to be stamped on the shank and the fluke. The markings on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the center line of the crown on the right hand fluke looking from the crown towards the shank. The markings are to include:

- Mass of anchor
- Identification, e.g. test No. or certificate No.
- Society’s stamp
- Manufacturer’s mark

Additionally the unique cast identification is to be cast on the shank and the fluke.

### 4.6 Certification

Anchors which meet the requirements are to be certified by the Society at least with the following items:

- Manufacturer's name
- Type
- Mass
- Fluke and Shank identification numbers
- Grade of materials
- Proof test loads
- Heat treatment
- Marking applied to anchor

### 4.7 Painting

All types of anchor are not to be painted until all tests and inspections have been completed.

**END**