W2 Test specimens and mechanical testing procedures for materials

(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.

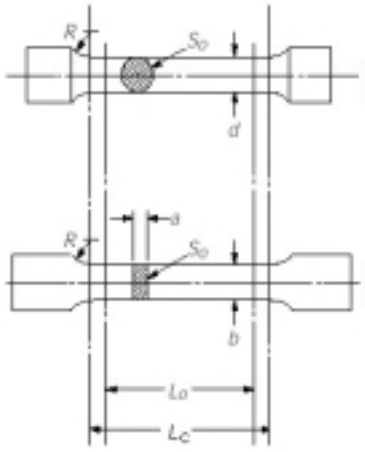
Tension/compression testing machines are to be calibrated in accordance with ISO 7500-1 or other recognised standard.

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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W2.4.2 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. ▶

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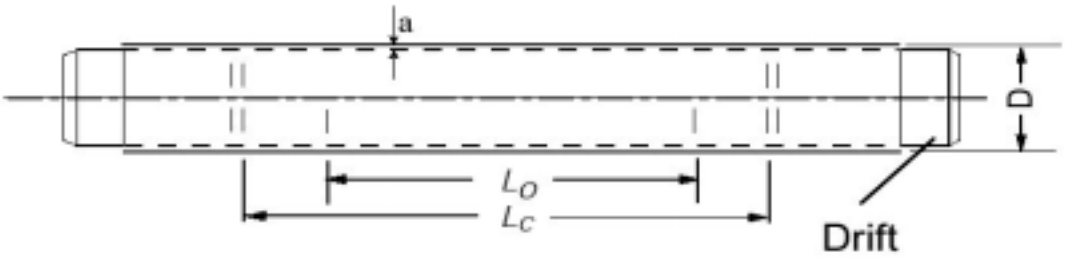
W2.4.2.5 Tubes

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.

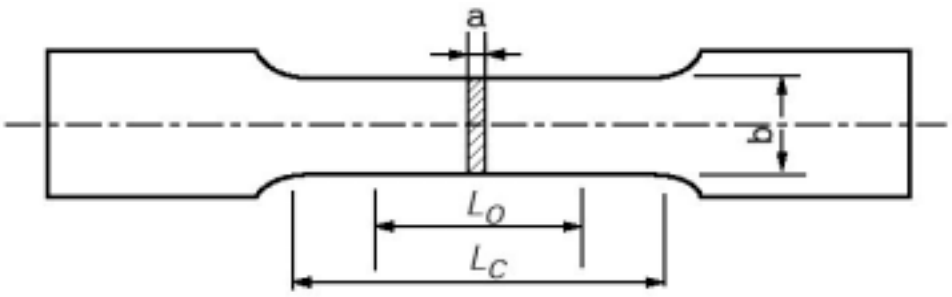


b) Strips cut longitudinally
a = t
b ≥ 12 mm

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

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.

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W2.4.2.6 Wires

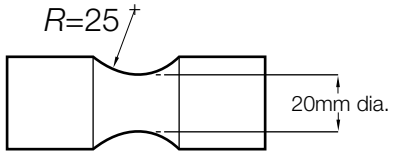
Full cross-section test specimen with the following dimension is to be used:

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 :

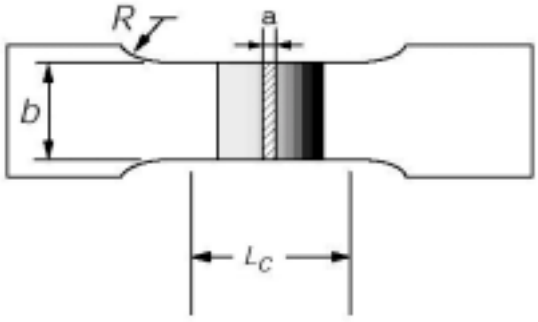
d = 10 mm
Lo = 50 mm
Lc ≥ 55 mm
R ≥ 10 mm

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



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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.

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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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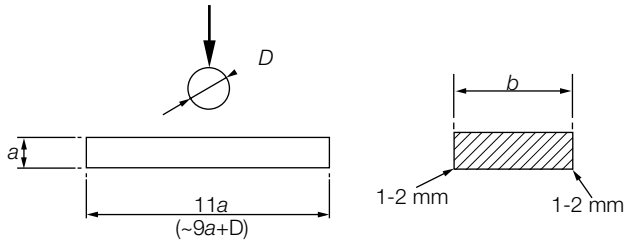
W2.6 Bend test specimen

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.

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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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W2.7.5 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

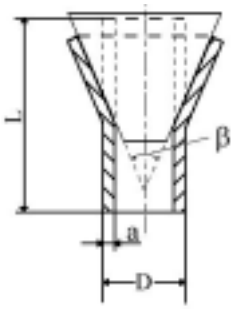
Length is to be from 10mm to 100mm. Plain and smoothed ends cut perpendicular to the tube axis. Reference is made to ISO 8492.

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.

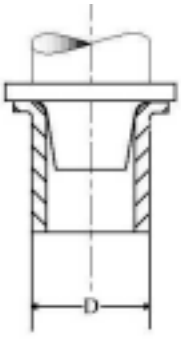
Metallic tubes: *L* equal to twice the external diameter *D* of the tube if the angle of the drift β is 30°, and *L* equal to 1.5*D* if the angle of the drift is 45° or 60°. The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5D.

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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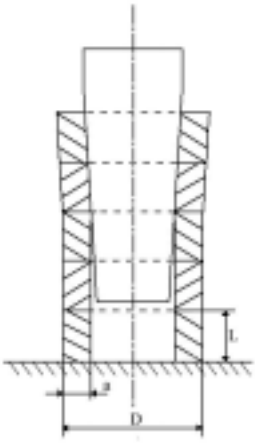
W2.8.4 Ring expanding test

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.

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 ▶

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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.

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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.

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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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W7
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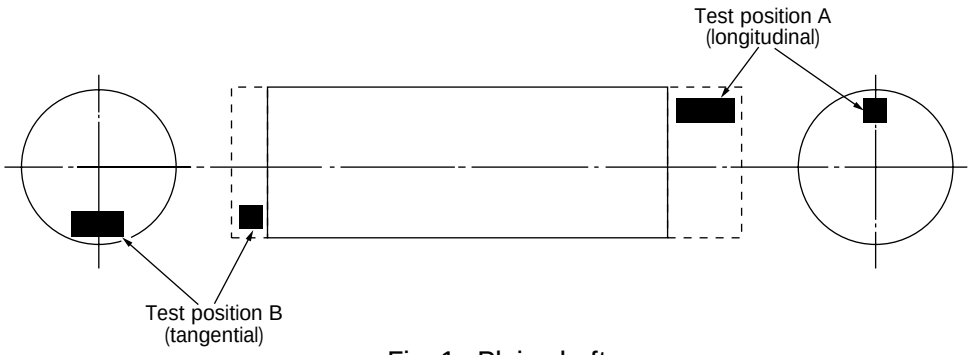

Fig. 1 Plain shaft

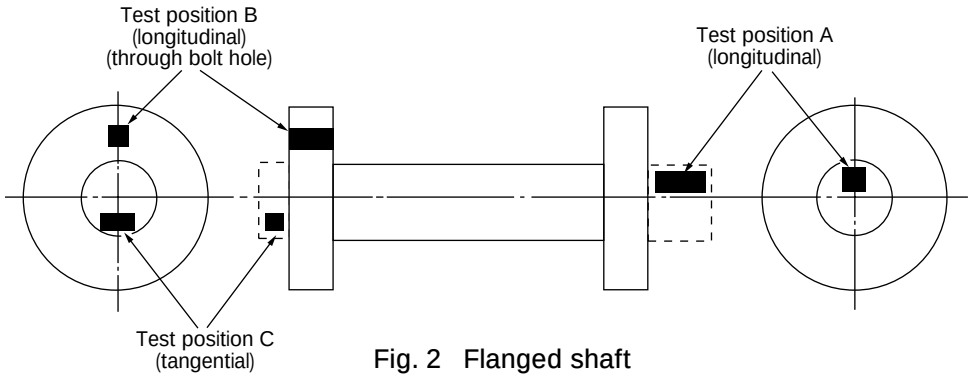

Fig. 2 Flanged shaft

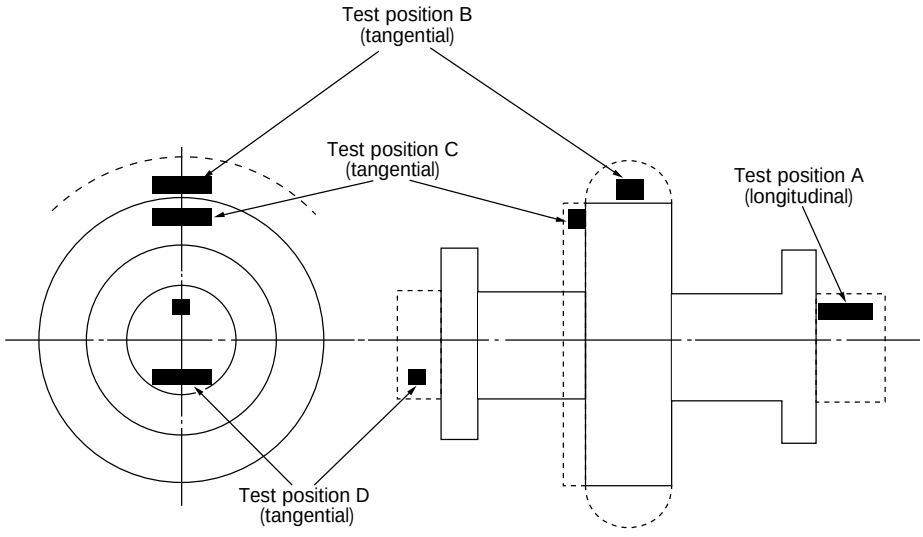

Fig. 3 Flanged shaft with collar

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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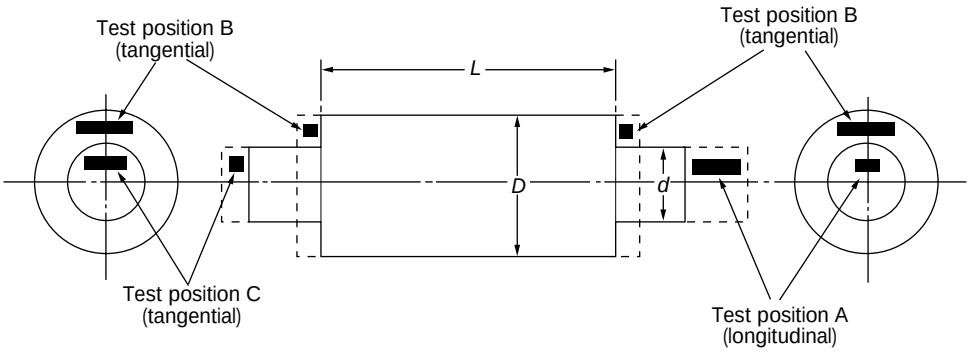

L = length of toothed portion
D = diameter of toothed portion
d = journal diameter

Fig. 4 Pinion

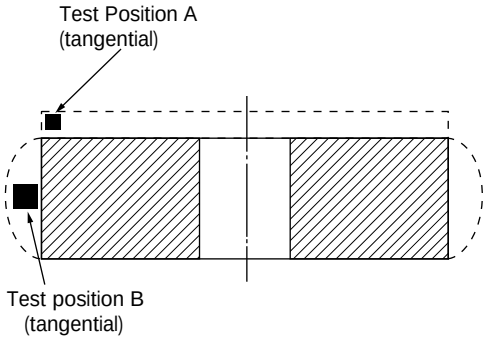

Fig. 5 Gear wheel

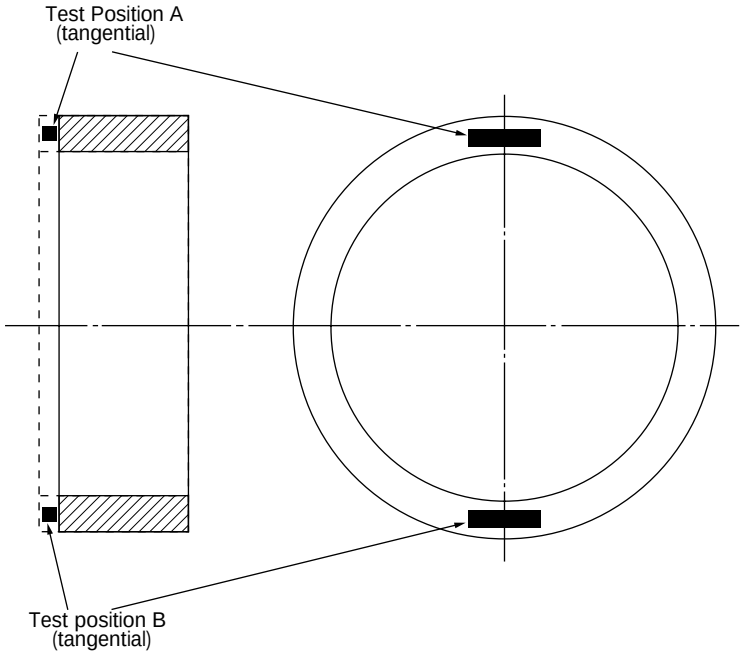

Fig. 6 Gear rim (made by expanding)

W7
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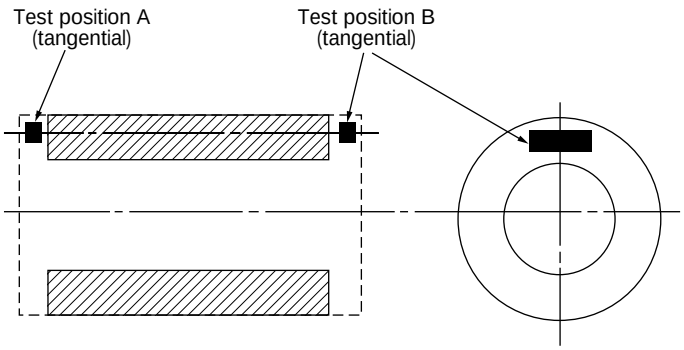

Fig. 7 Pinion sleeve

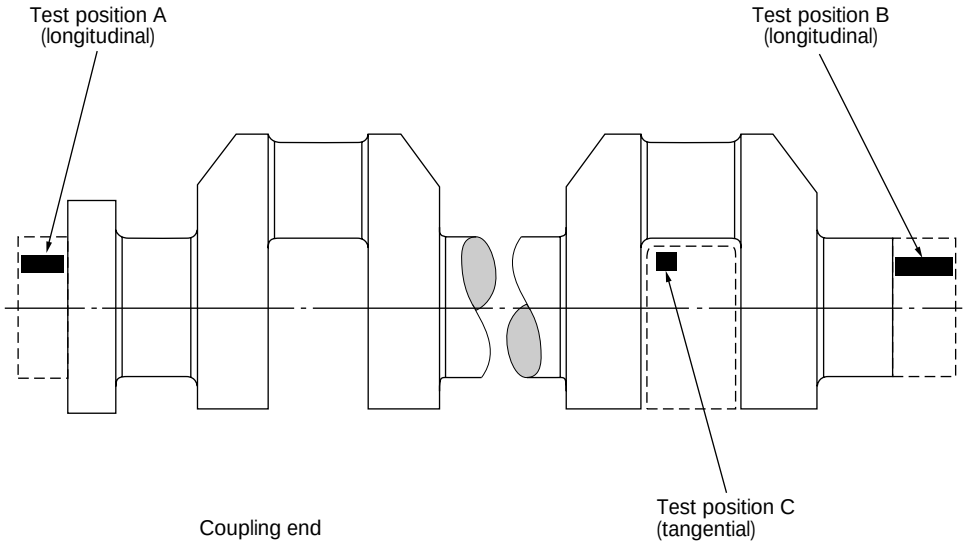

Fig. 8 Solid forged crankshaft

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
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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
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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
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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
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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
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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

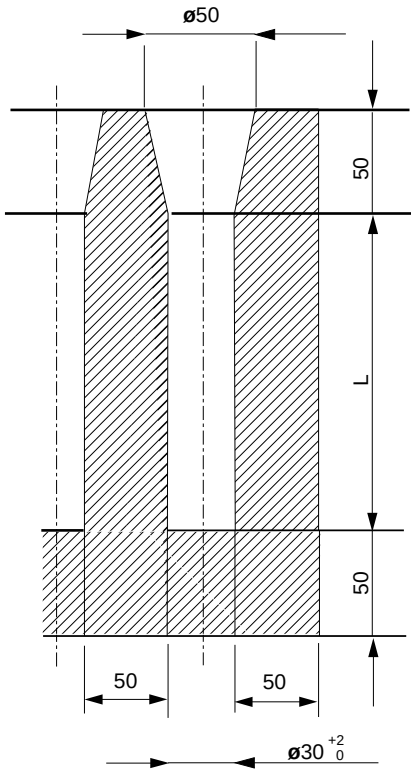
W9.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Classification Society.

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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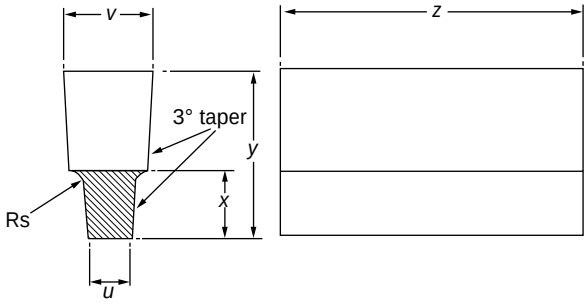

Fig. 1 Type A test samples (U-type)

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			

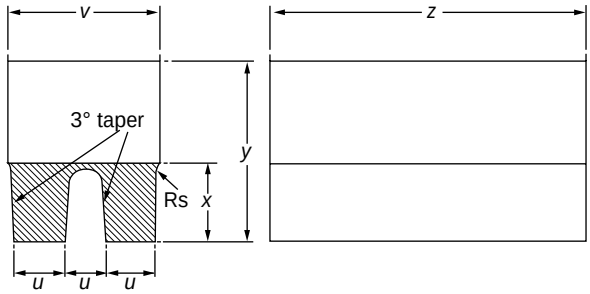

Fig. 2 Type B test samples (double U-type)

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

W10
cont'd

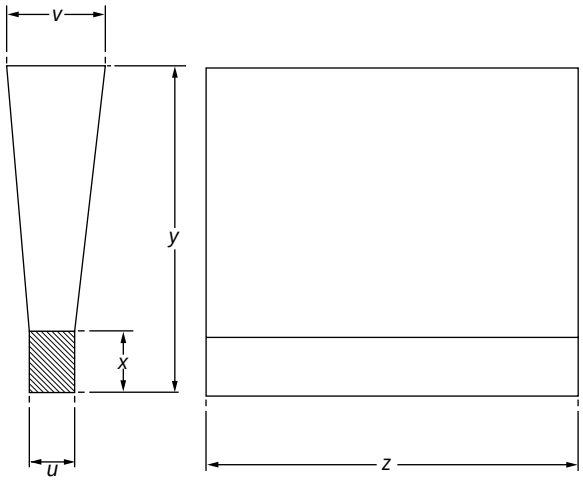

Fig. 3 Type C test samples (Y-type)

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 500	320	7	170-240	-	-	Ferrite/Perlite
qualities 600	370	3	190-270	-	-	Ferrite/Perlite
700	420	2	230-300	-	-	Perlite
800	480	2	250-350	-	-	Perlite or Tempered structure
Special 350	220	22(3)	110-170	+20	17(14)	Ferrite
qualities 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) (Rev.8 Apr 2014) (Rev.9 May 2017)

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.

Note:

1. Changes introduced in Rev.8 are to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 July 2015 and when the application for certification of steel plates is dated on or after 1 July 2015.

2. Changes introduced in Rev.9 are to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 July 2018, or when the application for certification of steel products is dated on or after 1 July 2018, or the application for certification of manufacturer approval is dated on or after 1 July 2018.

3. 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.

W11 (cont)

1.5 These requirements also apply to normal and higher strength Corrosion Resistant steels when such steel is used as the alternative means of corrosion protection for cargo oil tanks as specified in the performance standard MSC.289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention (Corrosion protection of cargo oil tanks of crude oil tankers). Corrosion Resistant steels as defined within this UR, are steels whose corrosion resistance performance in the bottom or top of the internal cargo oil tank is tested and approved to satisfy the requirements in MSC.289 (87) in addition to other relevant requirements for hull structural steels, structural strength and construction. It is not intended that such steels be used for corrosion resistant applications in other areas of a vessel that are outside of those specified in the performance standard MSC.289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention. These requirements apply to plates, wide flats, sections and bars in all grades up to a maximum thickness of 50 mm.

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. For steels intended for a corrosion resistant designation, the approval of the manufacturer is to additionally follow the scheme given in Appendix C.

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 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.

W11
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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 steel being cooled as it is rolled with no further heat treatment. 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 for a specific period of time, followed by air cooling. The process improves the mechanical properties of as rolled steel by refining the grain size and homogenising the microstructure.

(iii) Controlled Rolling, CR (Normalizing Rolling, NR):
A rolling procedure in which the final deformation is carried out in the normalising temperature range, allowed to cool in air, 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, held for a specific period of time, 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, maintained at that temperature for a specific period of time to restore toughness properties by improving the microstructure and reduce the residual stress caused by the quenching process.

(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. 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.

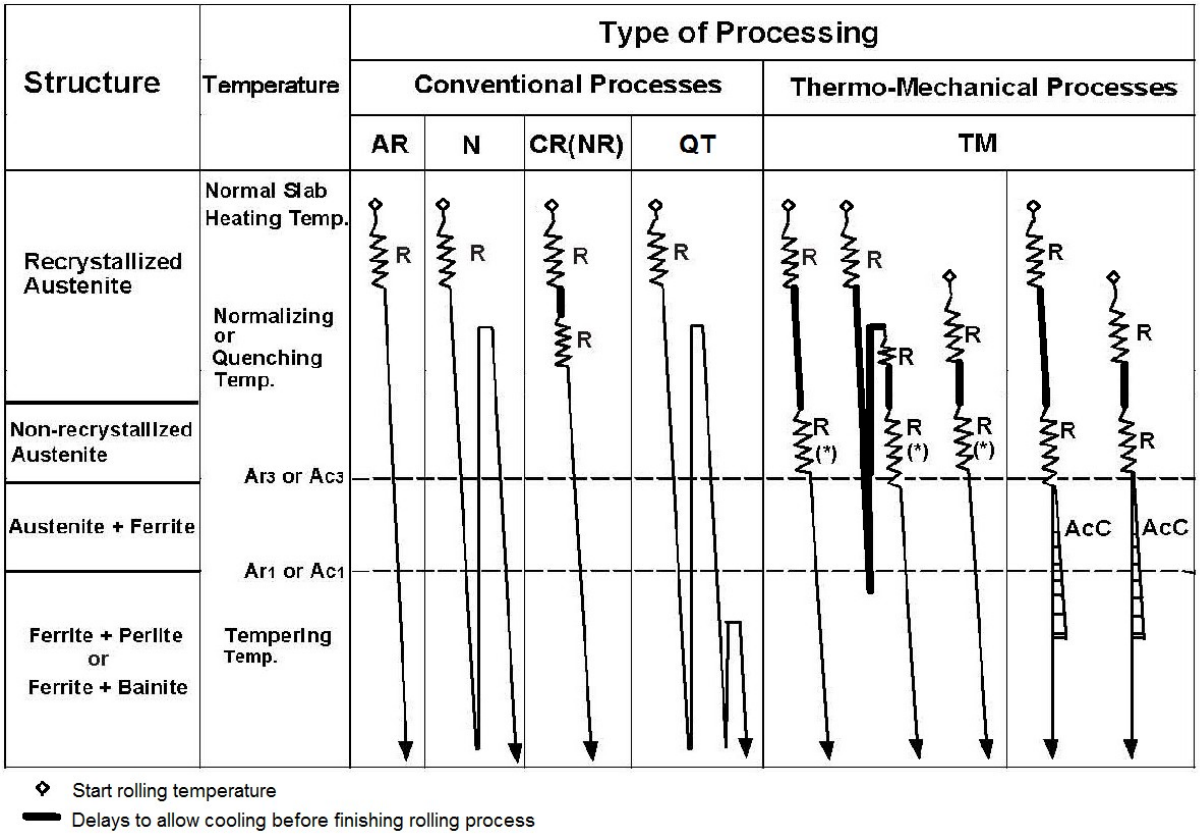
W11
(cont)

Where NR (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) For t > 50 mm Killed	For t ≤ 50 mm Any method except rimmed For t > 50 mm Killed	For t ≤ 25 mm Killed 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 A36 D36 E36 F36 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 W11.14.2 (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 W11.14.2 (ii) and W11.14.3 (iii) respectively.

W11
(cont)

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

Grades	Grain Refining Elements Used	Thickness	Condition of supply
A32 A36	Nb and/or V	≤ 12.5 mm	Any
		> 12.5 mm ≤ 100 mm	Normalized, controlled rolled or thermo-mechanically rolled (3)
	Al alone 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 D36	Nb and/or V	≤ 12.5 mm	Any
		> 12.5 mm ≤ 100 mm	Normalized, controlled rolled or thermo-mechanically rolled (3)
	Al alone 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 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 F36 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 W11.14.2 (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 W11.14.2 (ii) and W11.14.2 (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 W11.14.3 (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 W11.13.2). 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. Surface quality

7.1 The steel is to be free from surface defects prejudicial to the use of the material for the intended application.
The finished material is to have a surface quality in accordance with a recognized standard such as EN 10163 parts 1, 2 and 3, or an equivalent standard accepted by the Classification Society, unless otherwise specified in this section.

7.2 The responsibility for meeting the surface finish requirements rests with the manufacturer of the material, who is to take the necessary manufacturing precautions and is to inspect the products prior to delivery. At that stage, however, rolling or heat treatment scale may conceal surface discontinuities and defects. If, during the subsequent descaling or working operations, the material is found to be defective, the Classification Society may require materials to be repaired or rejected.

7.2.1 The surface quality inspection method shall be in accordance with recognized national or international standards agreed between purchaser and manufacturer, accepted by the Classification Society.

7.2.2 If agreed by the manufacturer and purchaser, steel may be ordered with improved surface finish over and above these requirements.

7.3 Acceptance Criteria

7.3.1 Imperfections

Imperfections of a harmless nature, for example pitting, rolled-in scale, indentations, roll marks, scratches and grooves, regarded as being inherent of the manufacturing process, are permissible irrespective of their number, provided the maximum permissible limits of Class A of EN 10163-2 or limits specified in a recognized equivalent standard accepted by the Classification Society, are not exceeded and the remaining plate or wide flat thickness remains within the average allowable minus thickness tolerance specified in UR W13.
Total affected area with imperfection not exceeding the specified limits are not to exceed 15 % of the total surface in question.

7.3.2 Defects

Affected areas with imperfections with a depth exceeding the limits of Class A of EN 10163-2 or the maximum permissible limits specified in a recognized equivalent standard accepted by the Classification Society, shall be repaired irrespective of their number.

Cracks, injurious surface flaws, shells (over lapping material with non-metallic inclusion), sand patches, laminations and sharp edged seams (elongated defects) visually evident on surface and/or edge of plate are considered defects, which would impair the end use of the product and which require rejection or repair, irrespective of their size and number.

7.4 Repair

7.4.1 Grinding repair

Grinding may be applied provided all the conditions below are adhered to:

W11 (cont)

(a) The nominal product thickness will not be reduced by more than 7% or 3 mm, whichever is the less.

(b) Each single ground area does not exceed 0,25 m^2.

(c) All ground areas do not exceed 2% of the total surface in question.

(d) Ground areas lying in a distance less than their average breadth to each other are to be regarded as one single area.

(e) Ground areas lying opposite each other on both surfaces shall not decrease the product thickness by values exceeding the limits as stated under (a).

Defects or unacceptable imperfections are to be completely removed by grinding and the remaining plate or wide flat thickness shall remain within the average allowable minus thickness tolerance specified in UR W13. The ground areas shall be a smooth transition to the surrounding surface of the product. Complete elimination of the defect is to be verified by magnetic particle or by liquid penetrant testing.

7.4.2 Welding repair

Weld repair procedures and the method are to be reported and be approved by the Classification Societies. Repair of defects such as unacceptable imperfections, cracks, shells or seams shall be followed by magnetic particle or liquid penetrant testing.

Local defects which cannot be repaired by grinding as stated in 7.4.1 may be repaired by welding with the agreement of the Classification Society subject to the following conditions:

(a) Any single welded area shall not exceed 0,125 m^2 and the sum of all areas shall not exceed 2% of the surface side in question.

(b) The distance between two welded areas shall not be less than their average width.

(c) The weld preparation shall not reduce the thickness of the product below 80% of the nominal thickness. For occasional defects with depths exceeding the 80% limit, special consideration at the Surveyor’s discretion will be necessary.

(d) If weld repair depth exceeds 3 mm, UT may be requested by the Classification Society. If required, UT shall be carried out in accordance with an approved procedure.

(e) The repair shall be carried out by qualified welders using an approved procedure for the appropriate steel grade. The electrodes shall be of low hydrogen type and shall be dried in accordance with the manufacturer’s requirements and protected against rehumidification before and during welding.

7.5 The surface quality and condition requirement herein are not applied to products in forms of bars and tubulars, which will be subject to manufacturers’ conformance standards.

8. Internal soundness

8.1 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.

W11 (cont)

8.2 Verification of internal soundness is the responsibility of the manufacturer. The acceptance of internal soundness by the Classification Society's surveyor shall not absolve the manufacturer from this responsibility.

9. Tolerances

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

10. Identification of Materials

10.1 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.

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

11. Testing and Inspection

11.1 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.

11.2 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.

11.3 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 Specified Minimum Through Thickness Properties ("Z" quality)" is to be carried out.

11.4 Dimensions

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.

12. Test Material

12.1 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.

W11
(cont)

12.2 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).

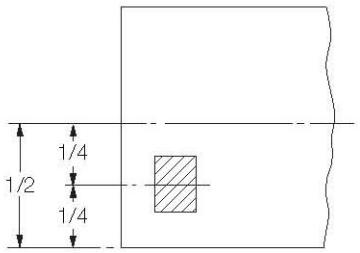


Fig. 1 Plates and flats

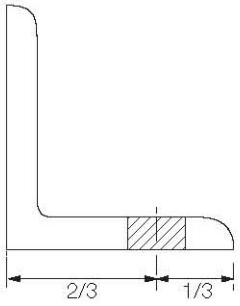


Fig. 2 Angles

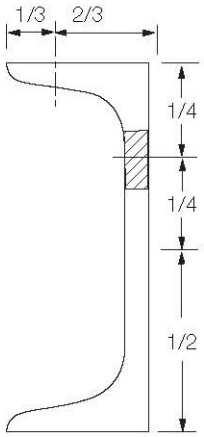


Fig. 3 Channel

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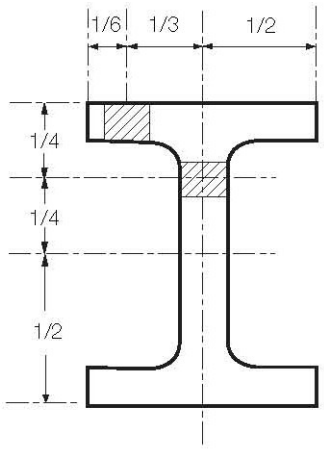

Fig. 4 H-sections

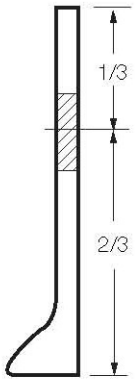

Fig. 5 Bulb flats

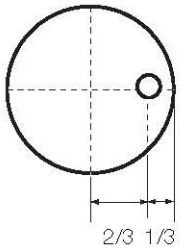

Fig. 6 Bars;

13. Mechanical Test specimens

13.1 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.

13.2 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.

14. Number of Test Specimens

14.1 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.

14.2 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.

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(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.

14.3 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.

15. Retest Procedures

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

15.2 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.

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

15.4 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.

15.5 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

W11 (cont)

length, the defective test piece may, at the Surveyors discretion, be disregarded and replayed by an additional test piece of the same type.

15.6 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.

15.7 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.

15.8 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.

16. Branding

16.1 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.

16.2 Steel plates that have complied with the requirements for corrosion resistant steel will be identified by adding a corrosion designation to the unified identification mark for the grade of steel.

The corrosion resistant steel is to be designated according to its area of application as follows:

- Lower surface of strength deck and surrounding structures; **RCU**
- Upper surface of inner bottom plating and surrounding structures; **RCB**
- For both strength deck and inner bottom plating; **RCW**

Example of designation:

A36 TM RCB Z35

16.3 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.

16.4 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.

W11 (cont)

16.5 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.

17. Documentation

17.1 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) For steel with a corrosion resistant steel designation the weight percentage of each element added or intentionally controlled for improving corrosion resistance.
(vii) Condition of supply when other than as rolled i.e. normalised, controlled rolled or thermomechanically rolled.
(viii) State if rimming steel has been supplied for grade A sections, up to 12.5 mm thick.
(ix) Test Results

17.2 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

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Deoxidation Practice</th><th rowspan="2">Products</th><th colspan="4">Condition of Supply (Batch for Impact Tests) (1)(2)</th></tr>
<tr><th colspan="4">Thickness (mm)
10 12.5 20 25 30 35 40 50 100</th></tr>
<tr><td rowspan="2">A</td><td>Rimmed</td><td>Sections</td><td>A(-)</td><td colspan="3">Not applicable</td></tr>
<tr><td>For t ≤ 50mm
Any method except rimmed
For t > 50mm
Killed</td><td>Plates</td><td colspan="2">A(-)</td><td>N(-)
TM(-) (3)
CR (50), AR* (50)</td></tr>
<tr><td></td><td></td><td>Sections</td><td colspan="2">A(-)</td><td>Not applicable</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">For t ≤ 50mm
Any method except rimmed
For t > 50mm
Killed</td><td>Plates</td><td>A(-)</td><td>A(50)</td><td>N(50)
TM(50)
CR (25), AR* (25)</td></tr>
<tr><td>Sections</td><td>A(-)</td><td>A(50)</td><td>Not applicable</td></tr>
<tr><td rowspan="4">D</td><td>Killed</td><td>Plates
Sections</td><td>A(50)</td><td colspan="2">Not applicable</td></tr>
<tr><td rowspan="2">Plates
Killed and fine grain treated</td><td>Plates</td><td colspan="2">A(50)</td><td>N(50)
CR(50)
TM(50)</td><td>N(50)
TM(50)
CR(25)</td></tr>
<tr><td>Sections</td><td colspan="2">A(50)</td><td>N(50)
CR(50)
TM(50)
AR*(25)</td><td>Not applicable</td></tr>
<tr><td rowspan="2">E</td><td rowspan="2">Killed and fine grain treated</td><td>Plates</td><td colspan="4">N(Each piece)
TM(Each piece)</td></tr>
<tr><td>Sections</td><td colspan="3">N(25)
TM(25)
AR* (15), CR*(15)</td><td>Not applicable</td></tr>
</table>

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.

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(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) / N(50), CR(50), TM (50)	Not applicable / 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

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(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.)

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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

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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.

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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.
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

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the caster shall be based on the technical characteristics of the casters to be evaluated on 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.

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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.

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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

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(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.

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l) 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 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:

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(cont)

- 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;
- 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 W11.12.1 (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 W11.12.2 (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.

W11 (cont)

Alternatively two round specimens with the axis located at one quarter and at mid-thickness can be taken.

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:

W11 (cont)

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

W11 (cont)

Appendix C Procedure for Approval of Corrosion resistant steels for cargo oil tanks

Approval Procedure for Corrosion Resistant Steel

1. Scope

1.1 This document specifies, as given in W11 2.1, the scheme for the approval of corrosion resistant steels based upon corrosion testing.

1.2 The corrosion testing is to be carried out in addition to the approval testing specified in Appendix A1 and A2 for the approval of normal and higher strength hull structural steels.

1.3 The corrosion tests and assessment criteria are to be in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).

2. Application for approval

2.1 The manufacturer is to submit to the Society a request for approval, which is to include the following:

(a) Corrosion test plan and details of equipment and test environments.

(b) Technical data related to product assessment criteria for confirming corrosion resistance.

(c) The technical background explaining how the variation in added and controlled elements improves corrosion resistance. The manufacturer will establish a relationship of all the chemical elements which affect the corrosion resistance. The chemical elements added or controlled to achieve the required level of corrosion resistance are to be specifically verified for acceptance. Verification is to be based on the ladle analysis of the steel.

(d) The grades, the brand name and maximum thickness of corrosion resistant steel to be approved. Designations for corrosion resistant steels are given in Table 2.1

(e) The welding processes and the brand name of the welding consumables to be used for approval.

Table 2.1 Designations for Corrosion Resistant Steels

Type of steel	Location where steel is effective	Corrosion Resistant Designation
Rolled steel for hull	For lower surface of strength deck and surrounding structures (ullage space)	RCU
	For upper surface of inner bottom plating and surrounding structures	RCB
	For both strength deck and inner bottom plating	RCW

W11 (cont)

3. Approval of test plan

3.1 The test program submitted by the manufacturer is to be reviewed by the Society, if found satisfactory, it will be approved and returned to the manufacturer for acceptance prior to tests being carried out. Tests that need to be witnessed by the society Surveyor will be identified.

3.2 Method for selection of test samples is to satisfy the following:

3.2.1 The numbers of test samples is to be in accordance with the requirements of the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).

3.2.2 The number of casts and test samples selected are to be sufficient to make it possible to confirm the validity of interaction effects and/or the control range (upper limit, lower limit) of the elements which are added or intentionally controlled, for improving the corrosion resistance. Where agreed, this may be supported with data submitted by the manufacturer.

3.2.3 Additional tests may be required by the Society when reviewing the test program against the paragraph 3.2.2

Remarks: Considerations for additional tests may include but not be limited to:

(a) When the Society determines that the control range is set by the theoretical analysis of each element based on existing data, the number of corrosion resistance tests conducted in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)) is too few to adequately confirm the validity of the control range of chemical composition;

(b) When the Society determines that the data of the corrosion resistance test result obtained for setting the control range of chemical composition varies too widely;

(c) When the Society determines that the validity of the corrosion resistance test result for setting the control range of chemical composition is insufficient, or has some flaws; and

(d) When the Society's surveyor has not attended the corrosion resistance tests for setting the control range of chemical composition, and the Society determines that additional testing is necessary in order to confirm the validity of the test result data.

Remarks: The chemical composition of the corrosion resistant steel is to be within the range specified for rolled steel for hull. Elements to be added for improving the corrosion resistance and for which content is not specified are to be generally within 1% in total.

4. Carrying out the approval test

4.1 The manufacturer is to carry out the approval test in accordance with the approved test plan.

5. Attendance of the Society's Surveyor for Test

5.1 The Society's Surveyor is to be present, as a rule, when the test samples for the approval test are being identified and for approval tests, see also 3.1.

W11
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6. Test Results

6.1 After completion of the approval test, the manufacturer is to produce the report of the approval test and submit it to the Society.

6.2 The Society will give approval for corrosion resistant steel where approval tests are considered by the society to have given satisfactory results based on the data submitted in accordance with the provisions of this Appendix.

6.3 The certificate is to contain the manufacturer's name, the period of validity of the certificate, the grades and thickness of the steel approved, welding methods and welding consumables approved.

7. Assessment Criteria for Results of Corrosion Resistance Tests of Welded Joint

7.1 The results will be assessed by the Classification Society in accordance with the acceptance criteria specified in the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)).

End of Document

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) (Corr.1 May 2012) (Rev.6 June 2018)

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 UR W11

(ii) High strength steels for welded structures 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 are to be in accordance with a national or international standard, e.g. Class B of ISO 7452. However, the minus tolerance shall not exceed 0.3mm.

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 lifting appliances which are subject to decision by the Classification Society.

W13.1.3 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.

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.

4. Rev.6 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 July 2019.

W13 (cont)

W13.1.4 Class C of ISO 7452-2013 or equivalent according to national or international standards may be applied in lieu of W13.3, in which case the requirements in W13.4 and W13.5 need not be applied.

Additionally, if Class C of ISO 7452-2013 is applied, it is required that the steel mill demonstrates 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.

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 fabricator 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 stated by the purchaser at the time of enquiry and order.

W13.3.2 The minus tolerance on nominal 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 Minus tolerances on nominal thickness for products for machinery structures

Nominal thickness (t) (mm)	Minus tolerance on nominal thickness (mm)
$3 \le t < 5$	-0.3
$5 \le t < 8$	-0.4
$8 \le t < 15$	-0.5
$15 \le t < 25$	-0.6
$25 \le t < 40$	-0.7
$40 \le t < 80$	-0.9
$80 \le t < 150$	-1.1
$150 \le t < 250$	-1.2
$t \ge 250$	-1.3

W13
(cont)

W13.3.4 The tolerances on nominal thickness are not applicable to areas repaired by grinding. For areas repaired by grinding the IACS UR W11 7.4.1 requirements are to be applied, unless stricter requirements as per a recognized standard are considered by the Classification Society or purchaser.

W13.3.5 The plus tolerances on nominal thickness are to be in accordance with a recognized national or international standard unless required otherwise by the Classification Society or purchaser.

W13.4 Average thickness

W13.4.1 The average thickness of 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 products in accordance with URs W11 or W16 is not to be less than the nominal thickness.

W13.5 Thickness measurements

W13.5.1 The thickness is to be measured at locations of 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

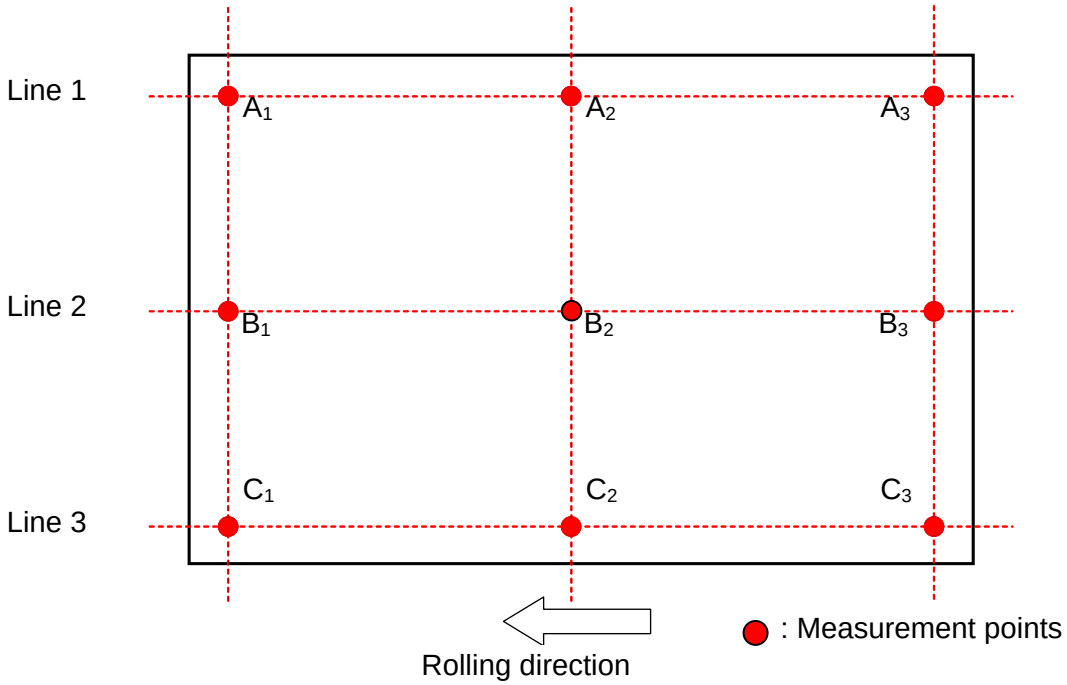
At least two lines among Line 1, Line 2 or Line 3 as shown in Figure A.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Figure A.1 are to be selected for thickness measurement. If more than three points are taken on each line the number 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.

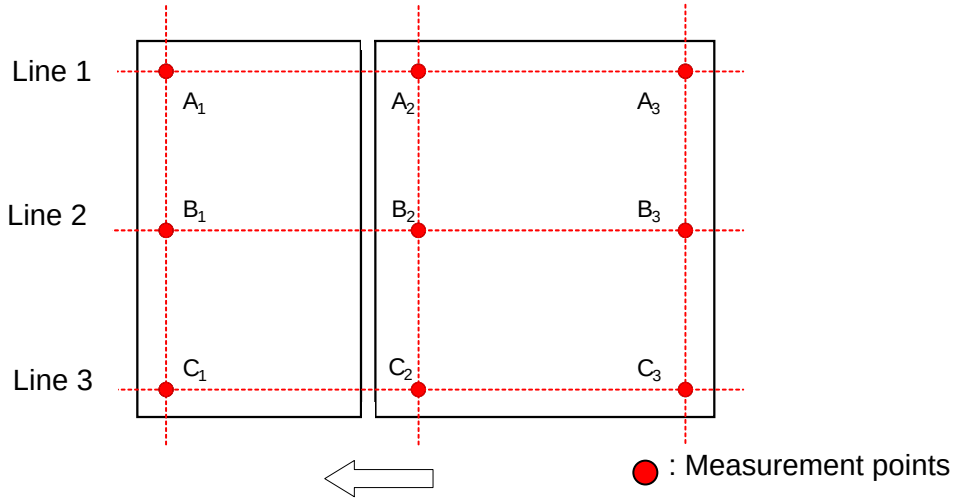
For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.

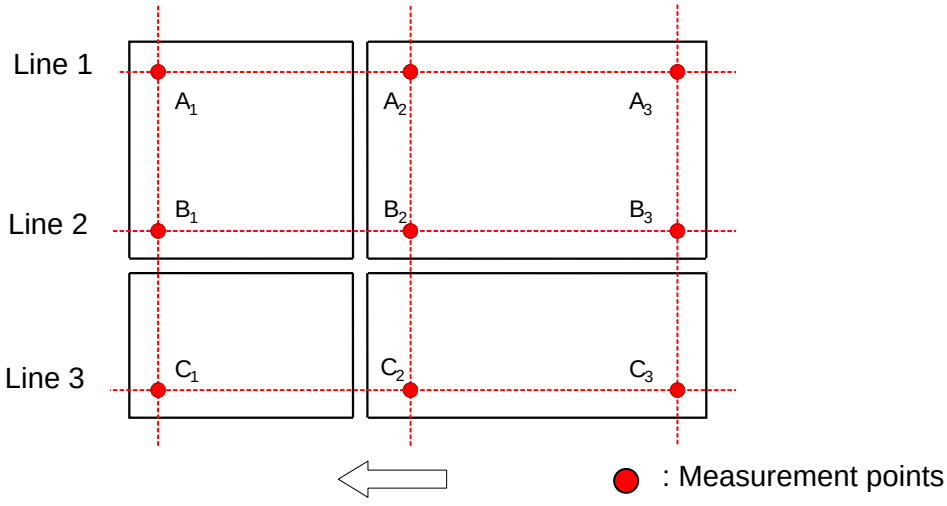
Figure A.1 - Locations of Thickness Measuring Points for the Original Steel Plates

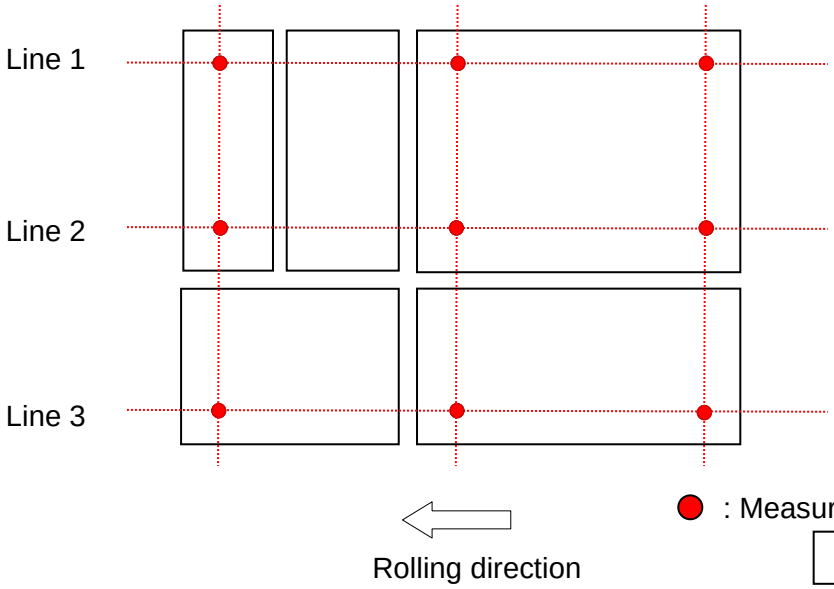


W13
(cont)

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.

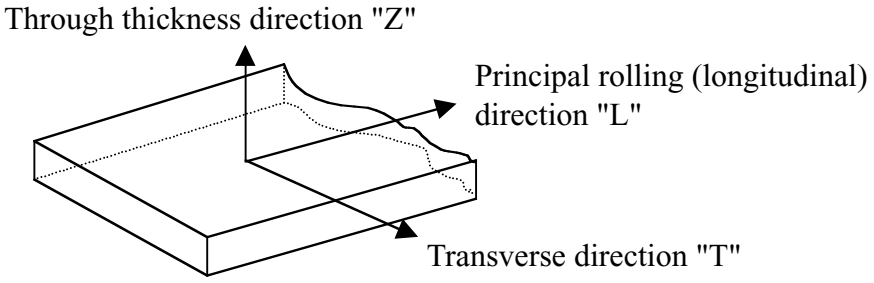

Figure 1 Schematic of testing directions

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.

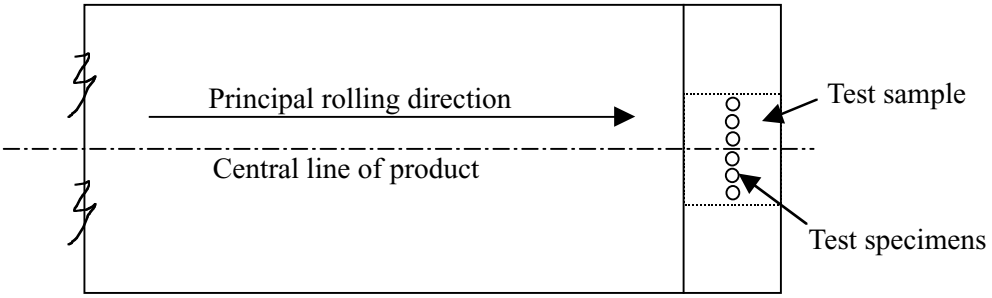

Figure 2 Plate and wide flat sampling position

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.

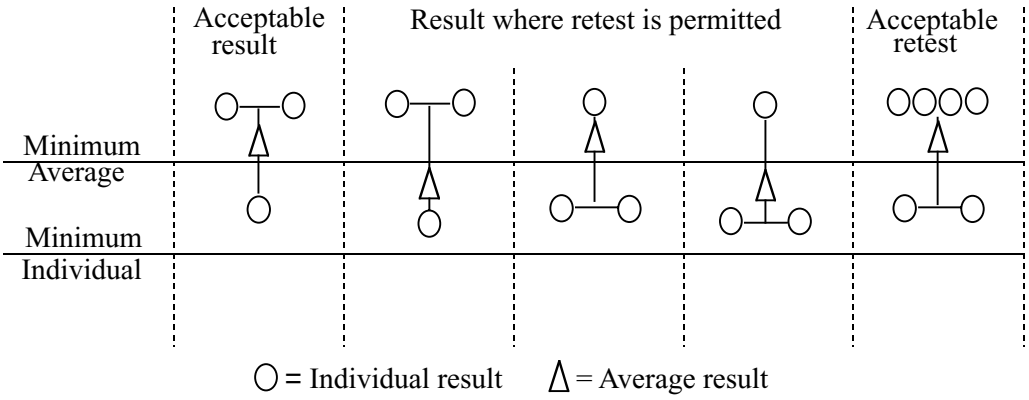

Figure 3 Diagram showing acceptance / rejection and retest criteria

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(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.

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) (Rev.5 June 2014)

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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. Rev.5 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 July 2015 and when the application for certification of materials is dated on or after 1 July 2015.

3. 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 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.

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(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

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(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

W31 Application of YP47 Steel Plates

(Jan 2013) (Rev.1 Sept 2015)

1. Application

1.1 General

1.1.1 Steel plates designated as YP47, refer to steel plates with a specified minimum yield point of 460 N/mm^2. The scope of application is defined in 1.1.2 and 1.2.

1.1.2 The YP47 steel can be applied to longitudinal structural members in the upper deck region of container carriers (such as hatch side coaming, hatch coaming top and the attached longitudinals). Special consideration is to be given to the application of YP47 steel plate for other hull structures.

This document defines grade YP47, its approval requirements, its certification requirements, welding consumables requirements and requirements for weld procedure qualification.

1.1.3 In the case where YP47 steel is applied as brittle crack arrest steel required by UR S33, the brittle crack arrest properties shall be in accordance with 2.1.2 of this UR.

1.1.4 Brittle fracture toughness of welded joints is to comply with IACS UR W11, UR W28 and this UR.

1.1.5 Unless otherwise specified in this document, UR W11 is to be followed.

1.2 Thickness

1.2.1 This document gives the requirements for steel plates in thickness greater than 50mm and not greater than 100mm intended for hatch coamings and upper decks of container ships.

1.2.2 For steel plates outside of this thickness range, special consideration is to be given by each Classification Society.

Notes:

1. This UR is to be applied by IACS Societies to ships contracted for construction on or after 1 January 2014.

2. Revision 1 of this UR is to be applied by IACS Societies to ships contracted for construction on or after 1 January 2017.

3. 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.

W31 (cont)

2. General

2.1 Material specifications

2.1.1 Material specifications for YP47 steel plates are defined in Table 1 and Table 2.

Table 1 Conditions of supply, grade and mechanical properties for YP47 steel plates

Supply condition	Grade	Mechanical Properties			Impact test			
		Yield Strength (N/mm^2) min.	Tensile Strength (N/mm^2)	Elongation (%) min	Test Temp. (^oC)	Average Impact Energy (J) min.		
						50 < t ≤ 70	70 < t ≤ 85	85 < t ≤ 100
TMCP*	EH47	460	570/720	17	-40°C	53	64	75

Note

t: thickness (mm)

* Other conditions of supply are to be in accordance with each Classification Society's procedures.

Table 2 Chemical compositions for YP47 steel plates

Chemical composition	C_{eq}*1	P_{cm}*2
As approved by each Classification Society	≤ 0.49%	≤ 0.22%

Note

*1 The carbon equivalent C_{eq} value is to be calculated from the ladle analysis using the following formula.

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

*2 Cold cracking susceptibility is to be calculated using the following formula.

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

The extent of testing is to be one set of three specimens taken from each piece defined in UR W11 11.1.

2.1.2 For the purpose of this UR, brittle crack arrest steel is defined as steel plate with measured crack arrest properties at manufacturing approval stage, K_{ca} at -10 degree C ≥ 6,000 $N/mm^{3/2}$ or other methods based on the determination of Crack Arrest Temperature (CAT).

Note 1: The Crack Arrest Fracture Toughness K_{ca} is to be determined by the ESSO Test shown in this UR or other alternative method. Crack Arrest Temperature (CAT) may also be determined by the Double Tension Wide Plate Test or equivalent. The use of small scale test parameters such as the Nil Ductility Test Temperature (NDTT) may

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(cont)

be considered provided that mathematical relationships of NDTT to K_{ca} or CAT can be shown to be valid.

Note 2: Where the thickness of the steel exceeds 80 mm the required K_{ca} value or alternative crack arrest parameter for the brittle crack arrest steel plate is to be specifically agreed with each Classification Society.

2.2 Manufacturing approval test

2.2.1 General

Approval test items, test methods and acceptance criteria not specified in this document are to be in accordance with each Classification Society's procedures.

2.2.2 Approval range

One test product with the maximum thickness to be approved is to be selected provided the approved target chemical composition range remains unchanged.

2.2.3 Base Metal test

(a) Charpy V-notch Impact Tests

Generally Charpy V-notch impact testing is to be carried out in accordance with IACS UR W11.

Test samples are to be taken from the plate corresponding to the top of the ingot, unless otherwise agreed.

In the case of continuous castings, test samples are to be taken from a randomly selected plate.

The location of the test sample is to be at the square cut end of the plate, approximately one-quarter width from an edge, as shown Fig.1.

Samples are to be taken with respect to the principal rolling direction of the plate at locations representing the top and bottom of the plate as follows:

Longitudinal Charpy V-notch impact tests - Top and bottom,
Transverse Charpy V-notch impact tests - Top only,
Strain aged longitudinal Charpy V-notch impact test - Top only.

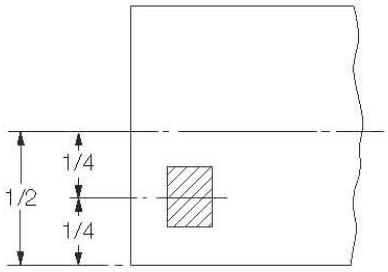

Fig.1 Plates and flats

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(cont)

Charpy V-notch impact tests are required from both the quarter and mid thickness locations of the test samples.

One set of 3 Charpy V-notch impact specimens is required for each impact test.

The Charpy V-notch impact test temperature is to be -40°C.

In addition to the determination of the energy value, the lateral expansion and the percentage crystallinity are also to be reported.

The strain aged samples are to be strained to 5% followed by heating to 250°C for 1 hour prior to testing.

Additionally at each location, Charpy V-notch impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

(b) Brittle fracture initiation test

Deep notch test or Crack Tip Opening Displacement (CTOD) test is to be carried out and the result is to be reported.

Test method is to be in accordance with each Classification Society's practice.

(c) Naval Research Laboratory (NRL) drop weight test

The test method is to comply with ASTM E208 or equivalent method.

Nil Ductility Test Temperature (NDTT) is to be reported for reference and may be used in the qualification of production test methods.

(d) Brittle crack arrest test

ESSO test described in Annex 1 or other alternative test (e.g. double tension test etc.) is to be carried out in order to obtain the brittle crack arrest toughness for reference.

2.2.4 Weldability test

(a) Charpy V-notch Impact Test

Charpy V-notch impact tests are to be taken at a position of 1/4 thickness from the plate surface on the 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.

One additional set of the specimens is to be taken from the root side of the weld with the notch located at the same position and at the same depth as for the face side.

The impact test temperature is -40°C.

Additionally at each location, impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

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(b) Y- shape weld crack test (Hydrogen crack test)

The test method is to be in accordance with recognized national standards such as KS B 0870, JIS Z 3158 or GB 4675.1.

Acceptance criteria are to be in accordance with each society's practice.

(c) Brittle fracture initiation test

Deep notch test or CTOD test is to be carried out.

Test method and results are to be considered appropriate by each Classification Society.

2.3 Welding works

2.3.1 Welder

Welders engaged in YP47 welding work are to possess welder's qualifications specified in each Classification Society's procedures.

2.3.2 Short bead

Short bead length for tack and repairs of welds by welding are not to be less than 50mm.

In the case where P_{cm} is less than or equal to 0.19, 25mm of short bead length may be adopted with approval of each Classification Society.

2.3.3 Preheating

Preheating is to be 50°C or over when air temperature is 5°C or below.

In the case where P_{cm} is less than or equal to 0.19, air temperature of 0°C or below may be adopted with approval of each Classification Society.

2.3.4 Welding consumable

Specifications of welding consumables for YP47 steel plates are to be in accordance with Table 3.

Table 3 Mechanical properties for deposited metal tests for welding consumables

Mechanical Properties			Impact test	
Yield Strength (N/mm^2) min.	Tensile Strength (N/mm^2)	Elongation (%) min	Test Temp. (°C)	Average Impact Energy (J) min.
460	570/720	19	-20	53

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Consumable tests for butt weld assemblies are to be in accordance with Table 4.

Table 4 Mechanical properties for butt weld tests for welding consumables

Tensile strength (N/mm^2)	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests		
		Test temperature (°C)	Average energy (J) min.	
			Downhand, horizontal-vertical, overhead	Vertical (upward and downward)
570 - 720	4	- 20	53	53

2.3.5 Others

Special care is to be paid to the final welding so that harmful defects do not remain.

Jig mountings are to be completely removed with no defects in general, otherwise the treatment of the mounting is to be accepted by each Classification Society.

2.4 Welding Procedure Qualification Test

2.4.1 General

Approval test items, test methods and acceptance criteria not specified in this document are to be in accordance with each Classification Society's procedures.

2.4.2 Approval range

UR W28 is to be followed for approval range.

2.4.3 Impact test

UR W28 is to be followed for impact test. 64J at -20°C is to be satisfied.

2.4.4 Hardness

HV10, as defined in UR W28, is to be not more than 380. Measurement points are to include mid-thickness position in addition to the points required by UR W28.

2.4.5 Tensile test

Tensile strength in transverse tensile test is to be not less than $570N/mm^2$.

2.4.6 Brittle fracture initiation test

Deep notch test or CTOD test may be required.

Test method and acceptance criteria are to be considered appropriate by each Classification Society.

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Annex 1
ESSO Test

1 Scope

1.1 The ESSO test method is used to estimate the brittle crack arrest toughness value K_{ca} of rolled steel plates for hull of thickness 100 mm or less.

2 Symbols

Table 1 Nomenclature

Symbol	Unit	Meaning
t_S	mm	Thickness of test specimen
W_S	mm	Width of test specimen
L_S	mm	Length of test specimen
t_r	mm	Thickness of tab plate
W_r	mm	Width of tab plate
L_r	mm	Length of tab plate
L_P	mm	Distance between pins
a	mm	Length of crack projected on surface normal to the line of load
a_a	mm	Maximum crack length at brittle crack arrest position
T	^oC	Temperature of test specimen
dT/da	^oC/mm	Temperature gradient of test specimen
σ	N/mm^2	Gross stress in tested part ($load / W_S.t_S$)
K_{ca}	N/mm$^{3/2}$	Brittle crack arrest toughness value

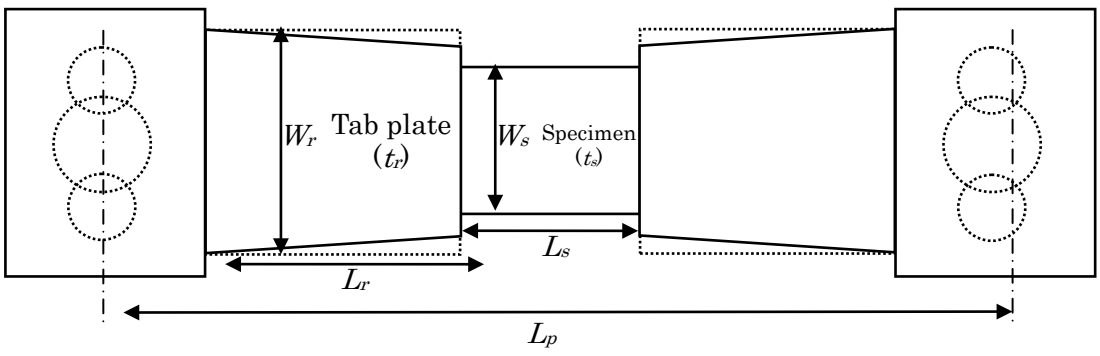

Fig.1 Conceptual view of test specimen, tab and load jig

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3 Purpose

3.1 The purpose of this test is to encourage the performance of a standard test for assessment of brittle crack arrest toughness with temperature gradient and to obtain the corresponding brittle crack arrest toughness value K_{ca}.

4 Standard test specimen

4.1 Fig.2 shows the shape and size of the standard test specimen.

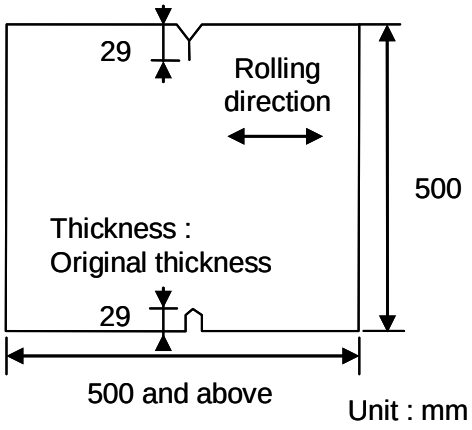

Fig.2 Shape and size of specimen

4.2 The thickness and width of the test specimen are to be in accordance with Table 2.

Table 2 Thickness and width of test specimen

Thickness, t_s	100 mm and below
Width of test specimen, W_s	500 mm

Note: If the width of the test specimen cannot be made at 500 mm, it may be taken as 600 mm.

4.3 The test specimens are to be taken from the same steel plate.

4.4 Test specimens are to be taken in such a way that the axial direction of the load is parallel to the rolling direction of the steel plate.

4.5 The thickness of the test specimen is to be the same as the thickness of the steel plate to be used in the vessel structure.

5 Test equipment

5.1 The test equipment to be used is to consist of pin load type hydraulic test equipment capable of tensile tests.

5.2 The distance between the pins is to be not less than 2,000 mm. The distance between pins refers to the distance between the centres of the pin diameters.

5.3 Drop weight type or air gun type impact equipment may be used for the impact energy required for generating brittle cracks.

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5.4 The wedge is to have an angle greater than the upper notch of the test specimen, and an opening force is to be applied on the notch.

6 Test preparations

6.1 The test piece is to be fixed directly to the pin load jig or by means of weld joint through the tab plate. The overall length of the test specimen and tab plate is to be not less than 3Ws. The thickness and width of the tab plate are to be in accordance with Table 3.

Table 3 Allowable dimensions of tab plate

	Thickness: t_r	Width: W_r
Dimensions of tab plate	0.8ts(Notes 1 and 2) ≤ t_r ≤ 1.5t_s	W_s ≤ W_r ≤ 2W_s

Note 1: t_s: Thickness of test specimen

Note 2: If the tab plate has a thickness smaller than the test specimen, the reflection of stress wave will be on the safer side for the assessment; therefore, considering the actual circumstances for conducting the test, the lower limit of thickness is taken as 0.8t_s.

6.2 Thermocouples are to be fitted at 50 mm pitch on the notch extension line of the test specimen.

6.3 If the brittle crack is estimated to deviate from its presumed course, thermocouples are to be fitted at two points separated by 100 mm on the line of load from the notch extension line at the centre of width of the test specimen.

6.4 If dynamic measurements are necessary, strain gauges and crack gauges are to be fitted at specific locations.

6.5 The test specimen is to be fixed to the testing machine together with the tab plate after welding and the pin load jig.

6.6 The impact equipment is to be mounted. The construction of the impact equipment is to be such that the impact energy is correctly transmitted. An appropriate jig is to be arranged to minimize the effect of bending load due to the impact equipment.

7 Test method

7.1 To eliminate the effect of residual stress or correct the angular deformation of tab welding, a preload less than the test load may be applied before cooling.

7.2 Cooling and heating may be implemented from one side on the side opposite the side on which the thermocouple is fitted, or from both sides.

7.3 The temperature gradient is to be controlled in the range of 0.25°C/mm to 0.35°C/mm in the range of width from 0.3W_s to 0.7W_s at the central part of the test specimen.

7.4 When the specific temperature gradient is reached, the temperature is to be maintained for more than 10 minutes, after which the specified test load may then be applied.

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7.5 After maintaining the test load for at least 30 seconds, a brittle crack is to be generated by impact. The standard impact energy is taken as 20 to 60 J per 1 mm plate thickness. If the brittle crack initiation characteristics of the base metal are high, and it is difficult to generate a brittle crack, the impact energy may be increased to the upper limit of 120 J per 1 mm plate thickness.

7.6 Loading is stopped when the initiation, propagation, and arrest of crack have been confirmed. Normal temperature is restored, and if necessary, the ligament is broken by gas cutting and forcibly the specimen is broken by using the testing machine. Or, after the ductile crack has been propagated to an adequate length with the testing machine, the ligament is broken by gas cutting.

7.7 After forcing the fracture, photos of the fractured surface and the propagation route are to be taken, and the crack length is to be measured.

8 Test results

8.1 The distance from the top of the test specimen including the notch to the maximum length in the plate thickness direction of the arrested crack tip is to be measured. If the crack surface deviates from the surface normal to the line of load of the test specimen, the projected length on the surface normal to the line of load is to be measured. In this case, if the trace of brittle crack arrest is clearly visible on the fractured surface, the first crack arrest position is taken as the arrest crack position.

8.2 From the results of thermocouple measurement, the temperature distribution curve is to be plotted, and the arrest crack temperature is to be measured corresponding to the arrest crack length.

8.3 The brittle crack arrest toughness value (K_{ca} value) of each test is to be determined by using the following formula:

$$K_{ca} = \sigma\sqrt{\pi a}\sqrt{\left(\frac{2W_S}{\pi a}\right)\tan(\pi a / 2W_S)}$$

9 Report

9.1 The following items are to be reported:

(i) Testing machine specifications; testing machine capacity, distance between pins (L_p)

(ii) Load jig dimensions; tab plate thickness (t_r), tab plate width (W_r), test specimen length including tab plate ($L_s + 2L_r$)

(iii) Test specimen dimensions; plate thickness (t_s); test specimen width (W_s) and length (L_s)

(iv) Test conditions; preload stress, test stress, temperature distribution (figure or table) impact energy

(v) Test results; crack arrest length (a_a), temperature gradient at arrest position, brittle crack arrest toughness (K_{ca})

(vi) Dynamic measurement results (if measurement is carried out); crack growth rate, strain change

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(vii) Test specimen photos; fracture route, fractured surface

9.2 If the conditions below are not satisfied, the test results are to be treated as reference values.

(i) The brittle crack arrest position is to be in the range of the hatched part shown in Fig.3. In this case, if the brittle crack arrest position is more than 50 mm away from the centre of the test specimen in the longitudinal direction of the test specimen, the temperature of the thermocouple at the ±100 mm position is to be within ±3°C of the thermocouple at the centre.

(ii) The brittle crack should not have a distinct crack bifurcation while it propagates.

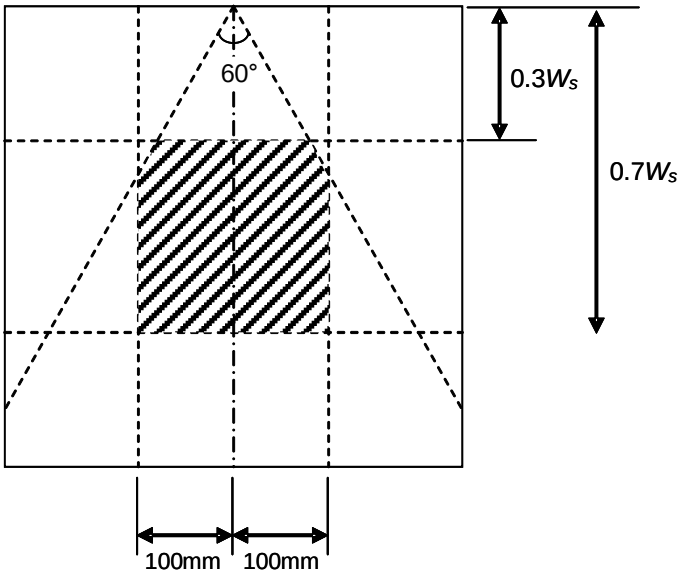

Fig.3 Necessary conditions of arrest crack position

9.3 From effective test results measured at more than 3 points, the linear approximation equation is to be determined on the Arrhenius plot, and K_{ca} at the desired temperature is to be calculated. In this case, data should exist on both sides, that is, the high temperature and low temperature sides around the assessed temperature.

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