TÜRK LOYDU

TL-R W

Requirements Concerning Materials and Welding

January 2021

These requirements are prepared by embedding related IACS Unified Requirements. In order to have consistency, the numbering of the requirements are kept as the same with related IACS Unified Requirements.

Unless otherwise specified, these Rules apply according to the implementation dates as defined in each requirement. See Rule Change Summary on TL website for revision details.

This latest edition incorporates all rule changes.

"General Terms and Conditions" of the respective latest edition will be applicable (see Rules for Classification and Surveys).

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TL- R W1 Material and welding for gas tankers

W1.1 Scope

W1.1.1 This document gives the requirements for plates, sections, pipes, forgings, castings and weldments used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping and secondary barriers. This document also gives the requirement for plates and sections of hull structural steels which are subject to reduced temperature due to the cargo and which are not forming part of secondary barrier. (See G1.9.1 and G1.9.4 of TL- R G1).

The requirements for rolled products, forgings and castings are given in Table 1 through Table 5. The requirements for welding procedure tests are given in W1.4.

W1.1.2 The manufacture, testing, inspection and documentation shall be in accordance with the general practice of TL and the specific requirement given in this document.

W1.2 General

W1.2.1 Tensile test

The test specimens and procedures shall be in accordance with TL- R W2. Tensile strength, yield stress and elongation shall be approved by TL.

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

W1.2.2 Charpy V-notch impact test

Acceptance tests shall include Charpy V-notch impact tests unless otherwise approved. The specified Charpy V-notch impact test requirements are minimum average energy values for three full size (10mm x 10mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch impact test specimens shall be in accordance with the requirements of TL- R W2. The testing of sub-size specimens shall be in accordance with TL- R W2.

For base metal, the largest size Charpy V-notch impact test specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in Figure 1. In the case where the material thickness is 40mm or below, the Charpy V-notch impact test specimens shall be cut with their edge within 2mm from the “as rolled” surface with their longitudinal axes either parallel or transverse to the final direction of rolling of the material.

Note:

1. This requirement is implemented ships contracted for construction on or after 1 January 2017.

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 TL- PR 29.

For a weld specimen, the largest size Charpy V-notch impact test specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to appoint midway between the surface and the centre of the thickness. In all cases, the distance from the surface of material to the edge of the specimen shall be approximately 1mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded side. The specimens shall be taken generally at each of the following locations, as shown in Figure 2, on the centreline of the welds, the fusion line and 1mm, 3mm and 5mm from the fusion line.

The re-testing of Charpy V-notch impact test specimens shall be in accordance with TL- R W2.

If the average value of the three initial Charpy V-notch impact test specimens fails to meet the stated requirements, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results be combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower, than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted.

W1.2.3 Bend test

The bend test may be omitted as a material acceptance test, but is required for weld tests. The test specimens and procedures shall be in accordance with TL- R W2. The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of TL. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

W1.2.4 Section observation and other testing

Macrosection, microsection observations and hardness tests may also be required by TL, and they shall be carried out in accordance with the Rules of TL, where required.

W1.2.5 Definitions

(a) Where reference is made in this R to A, B, D, E, AH, DH, EH and FH hull structural steels, these steel grades are hull structural steels according to TL- R W11. (

b) The definitions of “Piece” and “Batch” are given in 11.1 of TL- R W11.

(c) The definitions of “controlled rolling (CR)”, “Thermo-mechanical controlled processing (TMCP)” and “Accelerated cooling (AcC)” are given in 3.3 of TL- R W11.

W1.3 Material requirements

W1.3.1 The requirements for materials of construction are shown in the tables as follows:

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

Table 2: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to –55°C.

Table 3: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to –165°C.

Table 4: Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to –165°C.

Table 5: Plates and sections for hull structures required by G1.9.1 and G1.9.4 of TL- R G1.

The requirements for castings and forgings intended for cargo and process piping for design temperature above 0°C are at the discretion of TL.

Table 1 Plates, pipes (seamless and welded), [1], [2] sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.

CHEMICAL COMPOSITION AND HEAT TREATMENT		
CARBON-MANGANESE STEEL (Fully killed fine grain steel)		
Small additions of alloying elements by agreement with TL.		
Composition limits to be approved by TL.		
Normalized, or quenched and tempered. [4]		
TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS		
SAMPLING FREQUENCY		
PLATES	Each “piece” to be tested.	
SECTIONS AND FORGINGS	Each “batch” to be tested.	
MECHANICAL PROPERTIES		
TENSILE PROPERTIES	Specified minimum yield stress not to exceed 410 N//mm^2 [5]	
CHARPY V-NOTCH IMPACT TEST		
PLATES	Transverse test pieces. Minimum average energy value (KV) 27J	
SECTIONS AND FORGINGS	Longitudinal test pieces. Minimum average energy value (KV) 41J	
TEST TEMPERATURE	Thickness t (mm)	Test temperature (°C)
	t ≤ 20	0
	20 < t ≤ 40 [3]	–20

NOTES:

(1) For seamless pipes and fittings, normal practice of TL applies. The use of longitudinally or spirally welded pipes shall be specially approved by TL.

(2) Charpy V-notch impact tests are not required for pipes.

(3) This table is generally applicable for material thicknesses up to 40mm. Proposals for greater thicknesses shall be approved by TL.

(4) A controlled rolling procedure or TMCP may be used as an alternative.

(5) Materials with specified minimum yield stress exceeding 410 N/mm^2 may be specially approved by TL. For these materials, particular attention shall be given to the hardness of the weld and heat affected zone.

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

CHEMICAL COMPOSITION AND HEAT TREATMENT					
CARBON-MANGANESE STEEL (Fully killed aluminium treated fine grain steel)					
Chemical composition (ladle analysis)					
C 0.16% max. [(3)]	Mn 0.70-1.60%	Si 0.10-0.50%	S 0.025% max.	P 0.025% max.	
Optional additions:	Alloys and grain refining elements may be generally in accordance with the following:				
Ni 0.80% max.	Cr 0.25% max.	Mo 0.08% max.	Cu 0.35% max.	Nb 0.05% max.	V 0.10% max.
Al content total 0.02% min (Acid soluble 0.015% min)					
Normalized or quenched and tempered [(4)]					
TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS					
SAMPLING FREQUENCY					
PLATES	Each “piece” to be tested.				
SECTIONS AND FORGINGS	Each “batch” to be tested.				
MECHANICAL PROPERTIES					
TENSILE PROPERTIES	Specified minimum yield stress not to exceed 410 N/mm^2 [(5)]				
CHARPY V-NOTCH IMPACT TEST					
PLATES	Transverse test pieces. Minimum average energy value (KV) 27J				
SECTIONS AND FORGINGS [(1)]	Longitudinal test pieces. Minimum average energy value (KV) 41J				
TEST TEMPERATURE	5°C below the design temperature or –20°C, whichever is lower				

NOTES:

(1) The requirements of Charpy V-notch impact test and chemical composition for forgings may be specially considered.

(2) For material thickness more than 25mm, Charpy V-notch impact tests shall be conducted as follows:

Material Thickness	Test Temp.
25 < t ≤ 30 mm	10°C below design temperature or –20 whichever is lower
30 < t ≤ 35 mm	15°C below design temperature or –20 whichever is lower
35 < t ≤ 40 mm	20°C below design temperature
40 mm < t	Temperature approved by TL

The Charpy V-notch impact energy value shall be in accordance with the table for applicable type of test specimen.

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

For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank-shell thickness.

(3) By special agreement with TL the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than –40°C.

(4) A controlled rolling procedure or TMCP may be used as an alternative.

(5) Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by TL. For these materials, particular attention shall be given to the hardness of the weld and heat affected zones.

Guidance:

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

Table 3 Plates, sections and forgings [1] for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to –165°C. [2] Maximum thickness 25mm. [3], [4]

Minimum design temperature (°C)	Chemical composition [5] and heat treatment	Charpy V-notch impact test temperature (°C)
–60	1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6]	–65
–65	2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6], [7]	–70
–90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6], [7]	–95
–105	5% nickel steel – normalized or normalized and tempered or quenched and tempered [6], [7], [8]	–110
–165	9% nickel steel – double normalized and tempered or quenched and tempered [6]	–196
–165	Austenitic steels such as stainless steels (e.g. types 304, 304L, 316, 316L, 321, and 347 Solution treated [9])	–196
–165	Aluminium alloys (e.g. type 5083 Annealed)	Not required
–165	Austenitic Fe-Ni alloy (36% nickel) – Heat treatment as agreed	Not required

TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS	
SAMPLING FREQUENCY	
PLATES	Each “piece” to be tested.
SECTIONS AND FORGINGS	Each “batch” to be tested.
CHARPY V-NOTCH IMPACT TEST	
PLATES	Transverse test pieces. Minimum average energy value (KV) 27J
SECTIONS AND FORGINGS	Longitudinal test pieces. Minimum average energy value (KV) 41J

NOTES:

(1) The Charpy V-notch impact test required for forgings used in critical applications shall be subject to special consideration.

(2) The requirements for design temperatures below –165°C shall be specially agreed.

(3) For materials 1.5% Ni, 2.25% Ni, 3.5% Ni, and 5% Ni, with thickness greater than 25 mm, the Charpy V-notch impact tests shall be conducted as follows:

Material Thickness	Test Temperature
25 < t ≤ 30 mm	10°C below design temperature
30 < t ≤ 35 mm	15°C below design temperature
35 < t ≤ 40 mm	20°C below design temperature

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

(4) For 9% Ni steels, austenitic steels and aluminium alloys, thickness greater than 25 mm may be used.

(5) The chemical composition limits shall be approved by TL.

(6) TMCP nickel steels will be subject to acceptance by TL.

(7) A lower minimum design temperature for quenched and tempered steels may be specially agreed with TL.

(8) A specially heat treated, 5% nickel steel, for example triple heat treated 5% nickel steel may be used down to –165°C upon special agreement with TL, provided that the Charpy V-notch impact tests are carried out at –196°C.

(9) The Charpy V-notch impact test may be omitted subject to agreement with TL.

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

Minimum design temperature (°C)	Chemical composition [5] and heat treatment	Charpy V-notch impact test temperature (°C)	Minimum average energy (KV) (J)
–55	Carbon-manganese steel – Fully killed fine grain. Normalized or as agreed [6]	See Note 4	27
–65	2.25% nickel steel – Normalized or normalized and tempered or quenched and tempered [6]	–70	34
–90	3.5% nickel steel – Normalized or normalized and tempered or quenched and tempered [6]	–95	34
–165	9% nickel steel [7] – Double normalized and tempered or quenched and tempered	–196	41
	Austenitic steels such as stainless steels (e.g. types 304, 304L, 316, 316L, 321, and 347 Solution treated [8])	–196	41
	Aluminium alloys (e.g. type 5083 Annealed)		Not required
TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS			
SAMPLING FREQUENCY			
Each “batch” to be tested			
CHARPY V-NOTCH IMPACT TEST			
CHARPY V-NOTCH IMPACT TEST: Longitudinal test pieces			

NOTES:

(1) The use of longitudinally or spirally welded pipes shall be specially approved by TL. The requirements for forgings and castings may be subject to special consideration.

(2) The requirements for design temperatures below –165°C shall be specially agreed.

(3) The test temperature shall be 5°C below the design temperature or –20°C whichever is lower.

(4) The chemical composition limits shall be approved by TL.

(5) A lower design temperature may be specially agreed for quenched and tempered materials.

(6) The chemical composition is not suitable for castings.

(7) Charpy V-notch impact tests may be omitted subject to agreement with TL.

(8)

Table 5 Plates and sections for hull structures required by G1.9.1 and G1.9.4 of TL- R G1.

Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above (1) –5 and above (2)	Normal practice							
down to –5	15	25	30	50	25	45	50	50
down to –10	x	20	25	50	20	40	50	50
down to –20	x	x	20	50	x	30	50	50
down to –30	x	x	x	40	x	20	40	50
Below –30	In accordance with Table 2 except that the thickness limitation given in Table 2 and in note 2 of Table 2 does not apply.							

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

W1.3.2 Materials with alternative chemical composition or mechanical properties may be accepted by special agreement with TL.

W1.3.3 Where post-weld heat treatment is specified or required, the properties of the base materials shall be determined in the heat treated condition in accordance with the applicable table and the weld properties shall be determined in the heat treated condition in accordance with W1.4. In cases where a post-weld heat treatment is applied, the test requirements may be modified at the discretion of TL.

W1.3.4 Where reference is made to hull structural steels, the requirements of TL- R W11 for appropriate grades apply.

W1.4 Welding and non-destructive testing

W1.4.1 General

The article W1.4 shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. The requirements listed herein are those generally employed for carbon, carbon-manganese, nickel alloy and austenitic steels, aluminium alloy and may form the basis for acceptance testing of other material. At the discretion of TL, Charpy V-notch impact testing of austenitic steels and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

W1.4.2 Welding consumables

Welding consumables intended for welding of cargo tanks shall be approved by TL.

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

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

(a) Number and orientation of test assemblies

Welding procedure tests for cargo tanks and process pressure vessels are required for all butt welds. The test assemblies shall be representative of the following:

(i) Each base material

(ii) Each type of consumable and welding process

(iii) Each welding position

For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be approved by TL. Radiographic or ultrasonic testing may be performed at the option of the fabricator or TL.

(b) Required tests

The following welding procedure tests for cargo tanks and process pressure vessels shall be carried out in accordance with W1.2, with the specimens made from each test assembly:

(i) Cross-weld tensile tests

(ii) Longitudinal all-weld tensile testing, where required by TL.

(iii) Transverse bend tests: which may be face, root or side bends at the discretion of TL. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

(iv) One set of three Charpy V-notch impact test specimens, generally at each of the following indications (see Fig. 2):

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

(v) Macrosection, microsection and hardness survey may also be required at the discretion of TL.

W1.4.4 Test requirements

(a) Tensile tests

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

(b) Bend tests

No fracture is acceptable after 180° bend over a former diameter of 4t where t is the thickness of the test pieces.

(c) Charpy V-notch impact tests

Charpy V-notch impact test shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal Charpy V-notch impact tests, minimum average energy (KV), shall be no less than 27J. The weld metal requirements for subsize specimens and single energy values shall be in accordance with W1.2.2. The results of fusion line and heat affected zone Charpy V-notch impact tests shall show a minimum average energy (KV), are to be generally in accordance with the transverse or longitudinal requirements of the base material whichever is applicable, and for subsize specimens, the minimum average energy (KV), in accordance with W1.2.2. If the material thickness does not permit machining either full size or standard subsize specimens, the testing procedure and acceptance standards shall be approved by TL.

W1.4.5 Fillet welding procedure tests

Fillet welding procedure tests shall be in accordance with the Rules of TL. In such cases, welding consumables shall be selected which exhibit satisfactory Charpy V-notch impact properties.

W1.4.6 Welding procedure tests for secondary barriers

Welding procedure tests for secondary barriers shall be in accordance with the Rules of TL

W1.4.7 Welding procedure tests for piping

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

W1.4.8 Production weld tests

For all cargo tanks and process pressure vessels except for integral and membrane tanks, production tests shall generally be performed for approximately each 50 m of butt weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed except that the number of tests may be reduced subject to the agreement with TL. Tests, other than those specified, may be required for cargo tanks or secondary barriers at the discretion of TL. Test requirements shall be in accordance with W1.4.4.
The quality assurance/quality control programme shall ensure the continued conformity of the production welds as defined in the material manufacturer's quality manual.

(a) Type A and type B independent tanks and semi-membrane tanks

The production tests for type A and type B independent tanks and semi-membrane tanks shall include the following tests:

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

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

(b) Type C independent tanks and process pressure vessels

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

(c) Integral and membrane tanks

The test requirements for integral and membrane tanks are the same as the applicable test requirements listed in W1.4.3.

W1.4.9 Non-destructive testing

All test procedures and acceptance standards shall be in accordance with TL, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used, in principle, to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but, in addition, supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained. The quality assurance/ quality control programme shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual.

(a) Type A and B independent tanks and semi-membrane tanks

(i) For type A independent tanks and semi-membrane tanks where the design temperature is equal to or lower than –20°C, and for type B tanks, regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks shall be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in the first paragraph of W1.4.9.

(ii) For type A independent tanks and semi-membrane tanks, where the design temperature is higher than –20°C, all full penetration butt welds in way of intersections and at least 10% of the remaining full penetration butt welds of tank structures shall be subjected to radiographic testing or ultrasonic testing under the same conditions as described in the first paragraph of W1.4.9.

(iii) In each case, the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be tested by magnetic particle or dye penetrant methods, as considered necessary by TL.

(b) Type C independent tanks and process pressure vessels

Inspection of type C independent tanks and process pressure vessels shall be carried out in accordance with G 2.8.2(i) or (ii) of TL- R G2.

(c) Integral and membrane tanks

Special weld inspection procedures and acceptable standards shall be submitted by the designers of integral and membrane tanks for approval by TL.

(d) Piping

Inspection of piping shall be carried out in accordance with TL- R G3.

(e) Secondary barriers

The secondary barrier shall be non-destructive tested for internal defects as considered necessary. When the outer shell of the hull is part of the secondary barrier, all sheerstrake butts and the intersections of all butts and seams in the side shell shall be tested by radiographic testing.

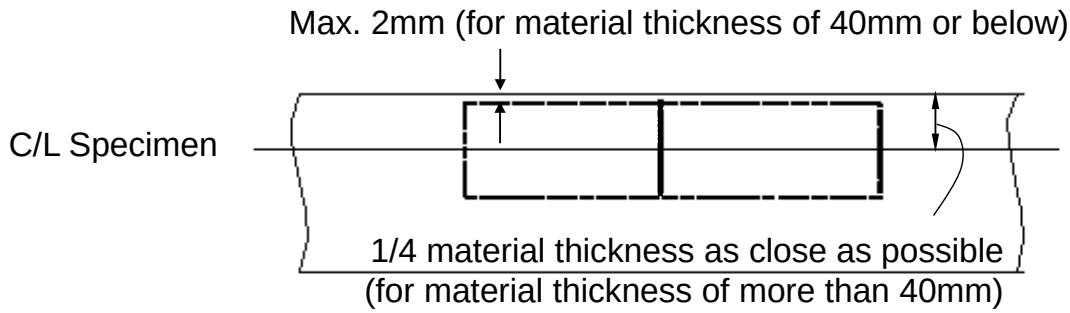


Figure 1 Sampling position of Charpy V-notch impact test specimens (Base metal)

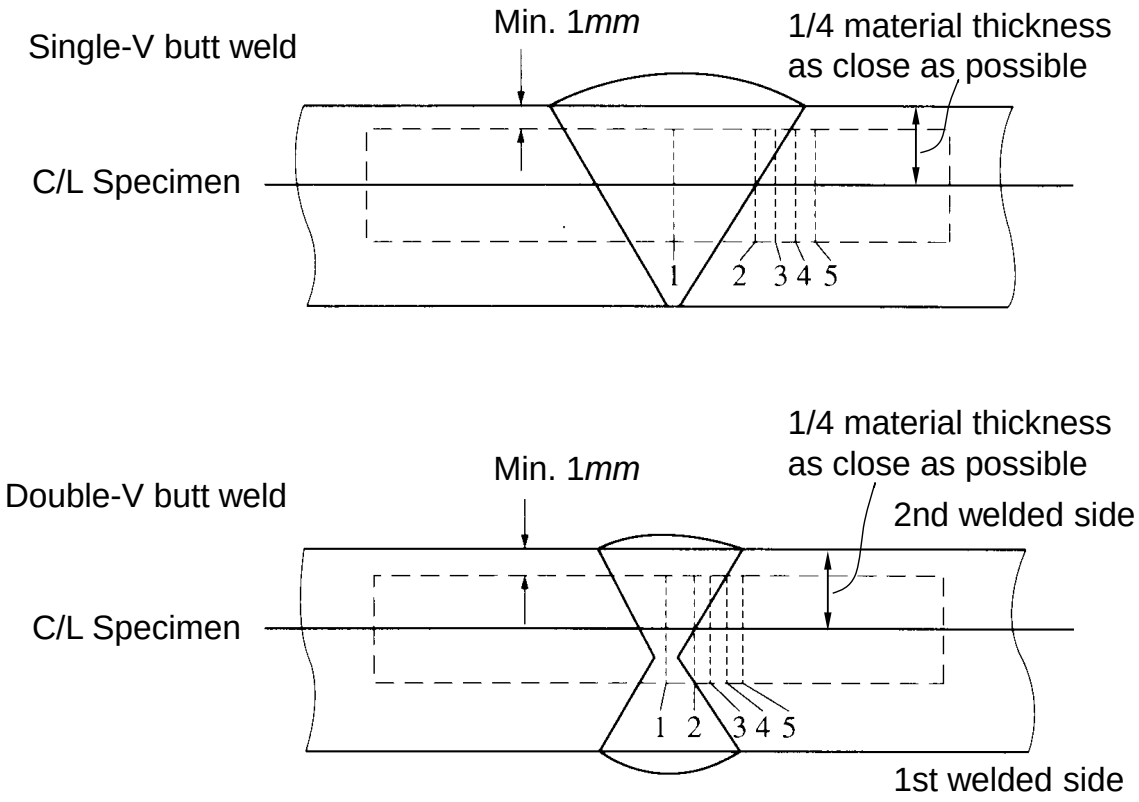


Figure 2 Sampling position of Charpy V-notch impact test specimens (Weld)

Notch location

1 Centreline of the weld
2 Fusion line
3 In HAZ, 1mm from fusion line
4 In HAZ, 3mm from fusion line
5 In HAZ, 5mm from fusion line

TL- R W2 Test specimens and mechanical testing procedures for materials

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 TL. 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 TL.

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.

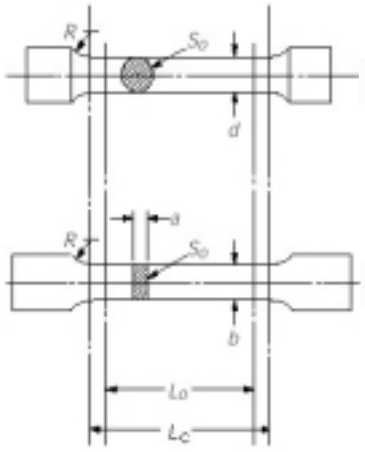
Tension/compression testing machines are to be calibrated in accordance with ISO 7500-1 or other recognised standard.

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



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 requirements refer to this gauge length, L_0 should preferably be greater than 20mm. The gauge length may be rounded off to the nearest 5 mm provided that the difference between this length and Lo is less than 10% of Lo.

W 2.4.2.2 Plates, strips and sections

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

a) **Proportional flat specimen**

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

b) **Non-proportional flat specimen**

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

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

c) **Round specimen**

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

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

W2.4.2.3 Aluminium Alloys

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

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

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

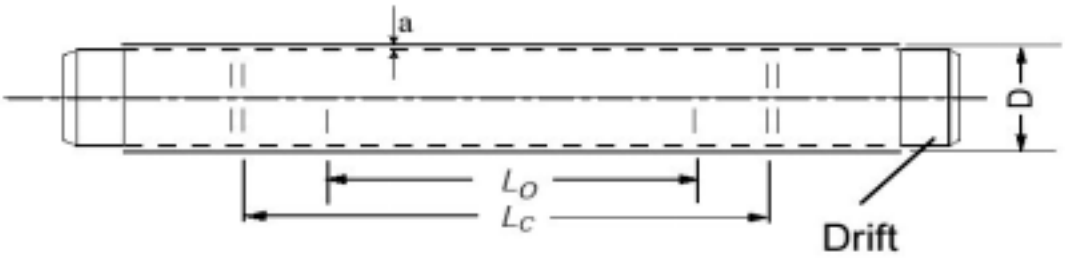
W2.4.2.5 Tubes

The test specimen shall conform with the following :

a) full cross-section specimen with plugged ends :

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

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

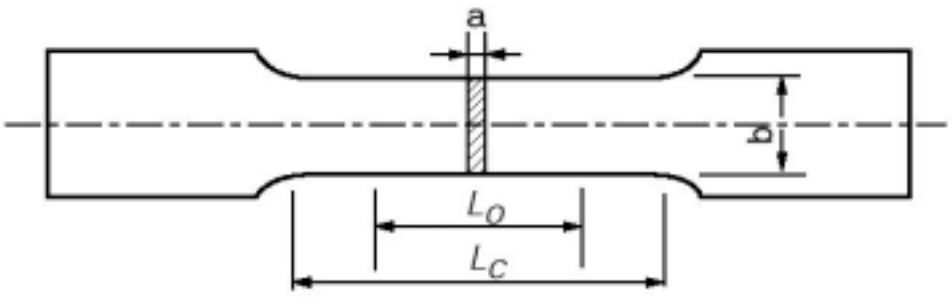


b) Strips cut longitudinally
a = t
b ≥ 12 mm

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

Lc = Lo + 2b

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



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

W2.4.2.6 Wires

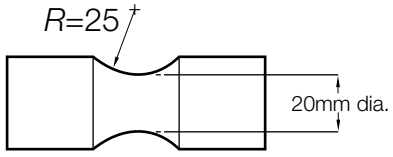
Full cross-section test specimen with the following dimension is to be used:

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 :

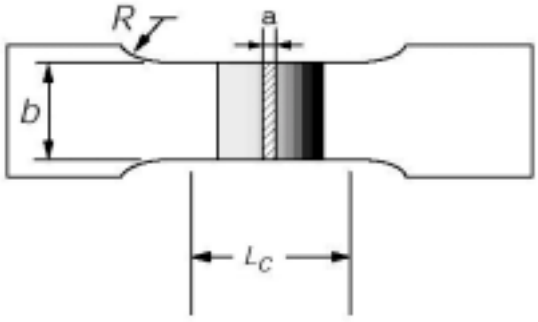
d = 10 mm
Lo = 50 mm
Lc ≥ 55 mm
R ≥ 10 mm

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

b) Butt weld tensile test

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

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



W2.4.2.9 Through thickness tensile test specimen

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

W2.4.2.10 Tolerances

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

W 2.4.3 Retest Procedure

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

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

W2.5 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^2s^{-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.

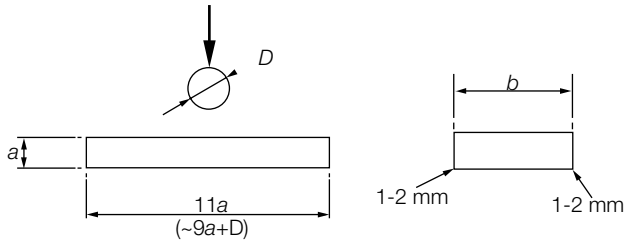
If the material is a ferritic steel of low or medium strength and not cold worked and the elongation as measured on a non-proportional gauge length, the required elongation A_0 on that gauge length L_0 may after agreement be calculated from the following formula:

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

For tables and graphs see ISO/DIS 2566.

W2.6 Bend test specimen

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



W2.6.2 Forgings, castings and semi-finished products

a = 20 mm
b = 25 mm

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

W2.6.4 Butt welds, transverse specimen

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

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

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

b) side bend

a = 10 mm
b = *t*

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

W2.6.5 Butt weld, longitudinal specimens

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

W2.7 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 TL. 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.

▶

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

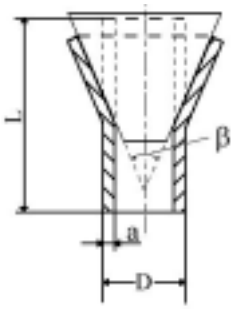
Length is to be from 10mm to 100mm. Plain and smoothed ends cut perpendicular to the tube axis. Reference is made to ISO 8492.

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.

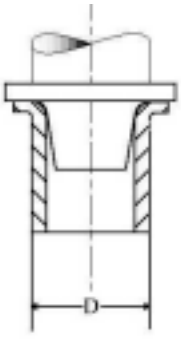
Metallic tubes: *L* equal to twice the external diameter *D* of the tube if the angle of the drift β is 30°, and *L* equal to 1.5*D* if the angle of the drift is 45° or 60°. The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5D.

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



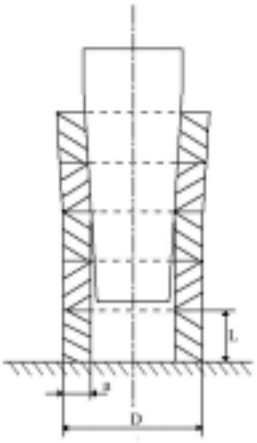
W2.8.3 Flanging test

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.



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.

TL- R W7 Hull and machinery steel forgings

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 TL.

W7.1.4 (void)

W7.2 Manufacture

W7.2.1 Forgings are to be made at a manufacturer approved by TL.

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

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 TL. 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 ▶

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 TL.

[5] One or more of the elements is to comply with the minimum content.

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 TL.

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 TL.

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 TL. For the purposes of this approval, the manufacture may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

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

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

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

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

W7.6 Mechanical tests

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

W7.6.2 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).

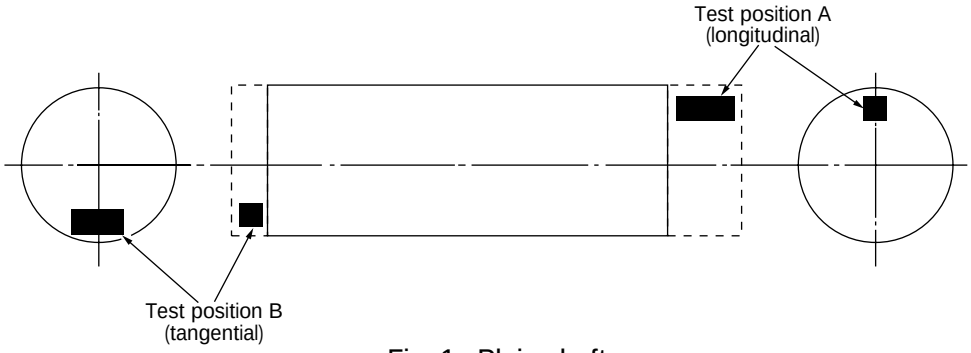


Fig. 1 Plain shaft

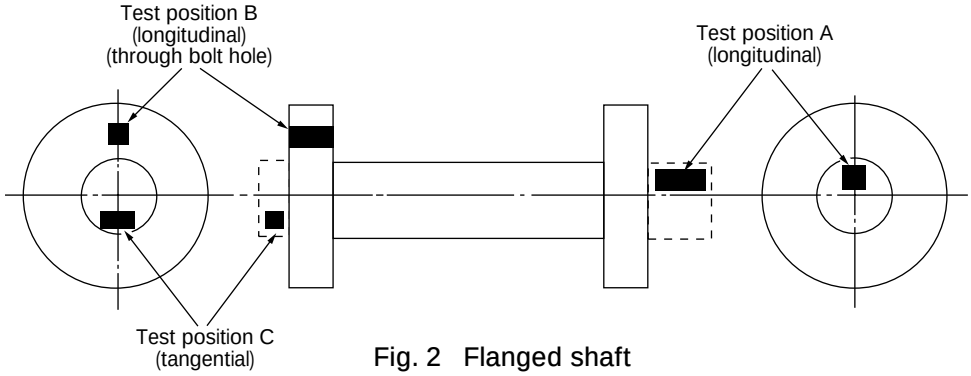


Fig. 2 Flanged shaft

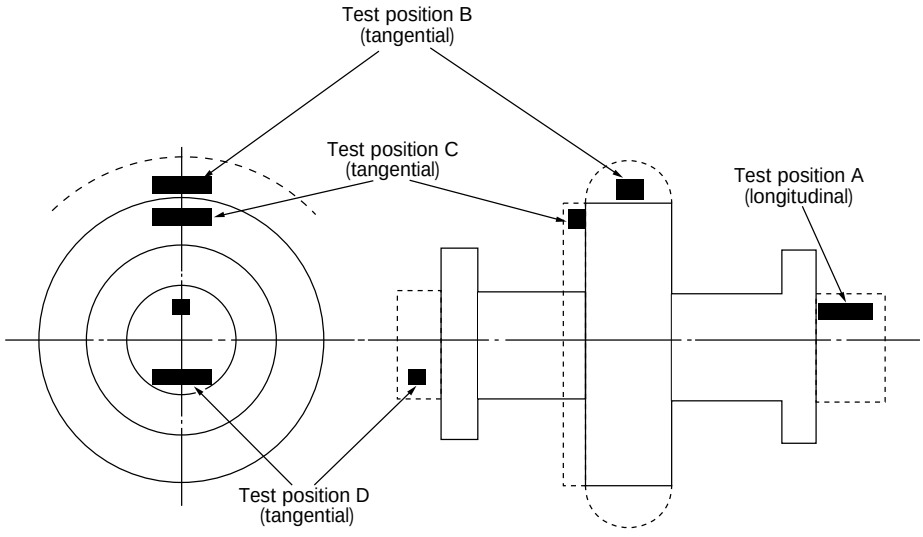


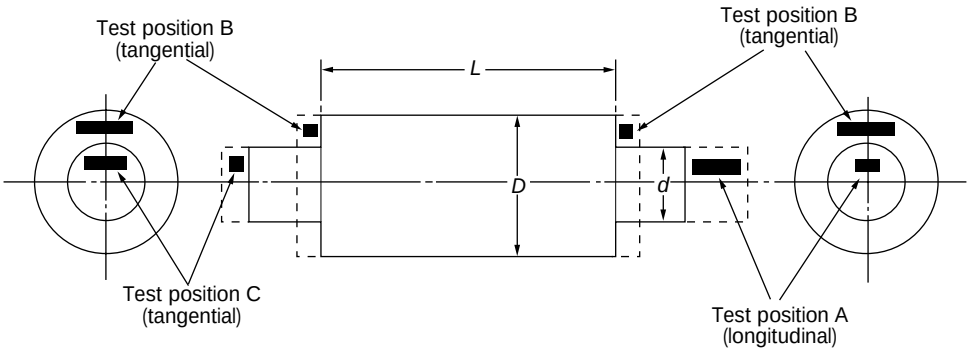
Fig. 3 Flanged shaft with collar

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 TL 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.

▶



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

Fig. 4 Pinion

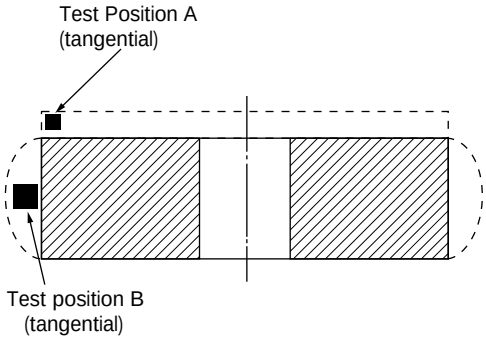


Fig. 5 Gear wheel

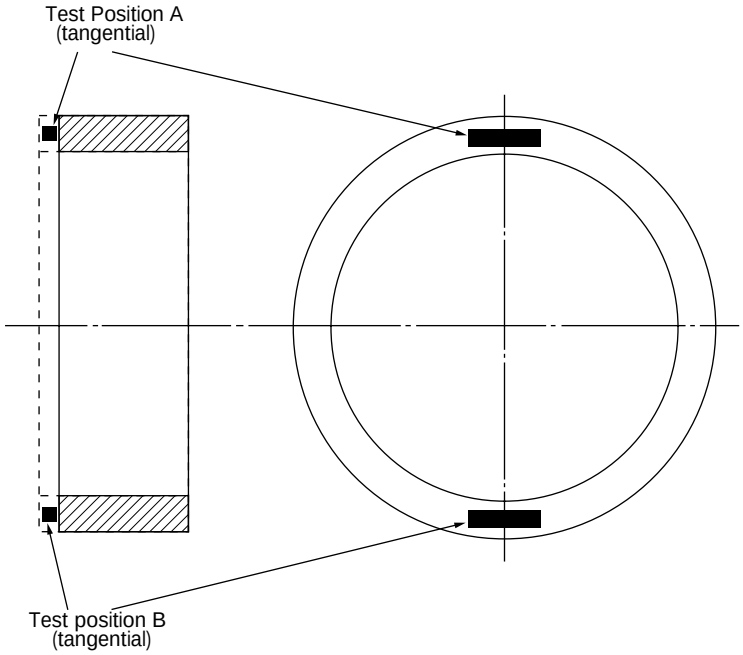


Fig. 6 Gear rim (made by expanding)

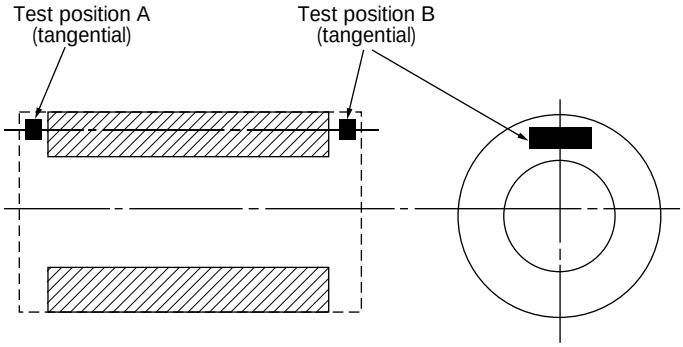


Fig. 7 Pinion sleeve

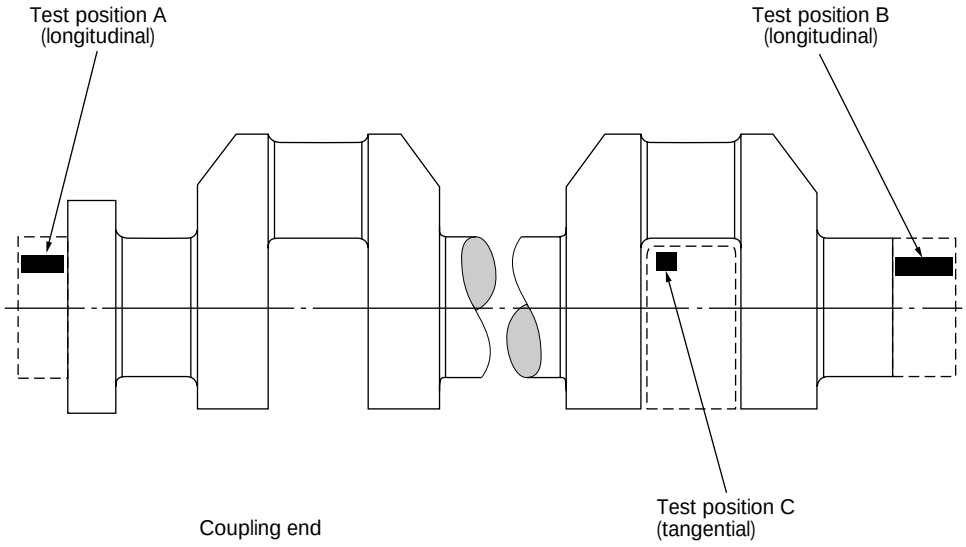


Fig. 8 Solid forged crankshaft

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 TL.

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 TL 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 TL- R W2.

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

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.

W7.8 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 TL. TL- G 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 TL. 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 TL 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) TL's name, initials or symbol.
(v) Abbreviated name of TL'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 TL.

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.

TL- R W8 Hull and machinery steel castings

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 TL.

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 TL.

W8.1.5 (void)

W8.2 Manufacture

W8.2.1 Castings are to be made at a manufacturer approved by TL.

W8.2.2 The steel is to be manufactured by a process approved by TL.

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 TL.

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 ▶

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 TL. 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.

W8.6 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 TL in accordance with W8.2.4, the number and position of test samples is to be agreed with TL 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 TL- R 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 TL- R 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.

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 TL. TL- G 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

W8.9.1 General

(i) The approval of TL 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 TL- G 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 TL, 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.

W8.10.2 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 TL 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) TL's name, initials or symbol.
(v) Abbreviated name of TL'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 TL.

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.

TL- R W11 Normal and higher strength hull structural steels

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 TL. Such steels are to be given a special designation.

Note:

1. This requirement is implemented 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.

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 TL- PR 29.

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 requirement, 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 TL 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 TL.

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 TL.

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 TL. The same applies for the use of tempering after completion of the TM-rolling.

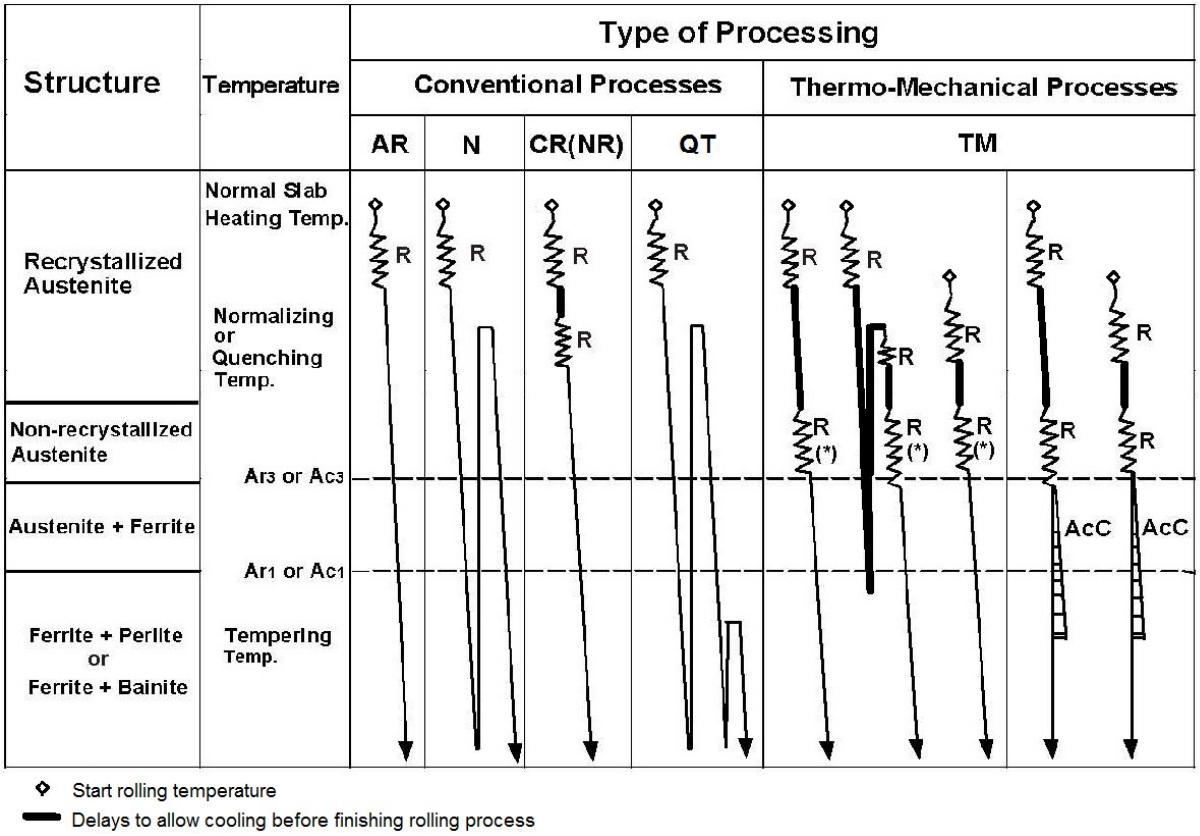
(vi) Accelerated Cooling, AcC
Accelerated cooling is a process, which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM-rolling operation. Direct quenching is excluded from accelerated cooling.

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

Where NR (CR) and TM with/without AcC are applied, the programmed rolling schedules are to be verified by TL 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.

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 TL.

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

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 TL.
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 TL.
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 TL. Other suitable grain refining elements may be used subject to the special approval of TL.

7. TL 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.

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 TL.

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 TL;

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

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

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 TL, 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 TL, 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.

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 TL [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 TL [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 TL, 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 TL, 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).

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 TL.

(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 TL.

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 TL 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 TL. 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 TL or sub-size specimens, as specified in TL- R 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.

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 TL, 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, TL 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 TL.

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 TL, are not exceeded and the remaining plate or wide flat thickness remains within the average allowable minus thickness tolerance specified in TL- R 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 TL, 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:

(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 TL- R 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 TL. 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 TL 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 TL.
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 TL.

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

9. Tolerances

9.1 Unless otherwise agreed or specially required the thickness tolerances in TL- R 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 TL- R 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 TL- R 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 TL'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.

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).

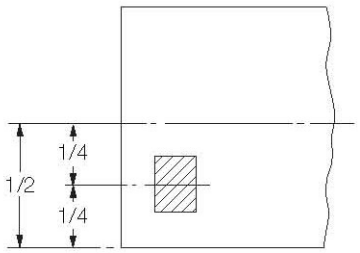


Fig. 1 Plates and flats

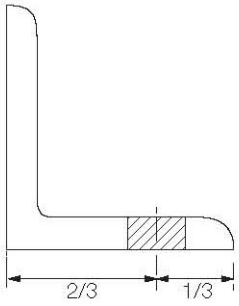


Fig. 2 Angles

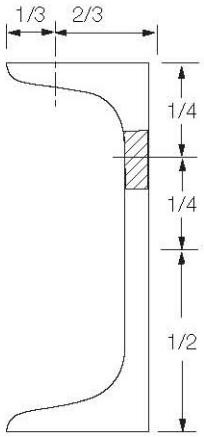


Fig. 3 Channel

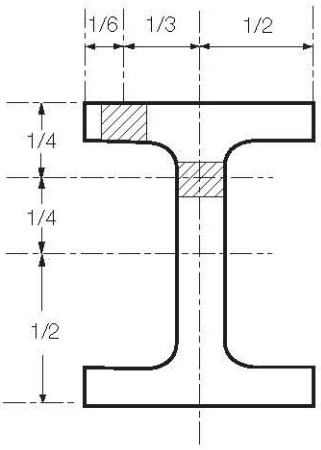


Fig. 4 H-sections

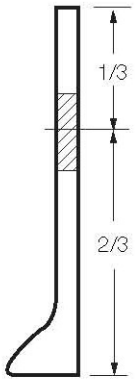


Fig. 5 Bulb flats

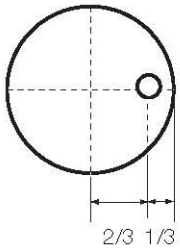


Fig. 6 Bars;

13. Mechanical Test specimens

13.1 Tensile Test Specimens. The dimensions of the tensil test specimens are to be in accordance with TL- R 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 TL, 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 TL, for each batch presented, at least one set of three Charpy V-notch test specimens is to be made from one piece unless the weight of finished material is greater than 50 tonnes, in which case one extra set of three test specimens is to be made from a different piece from each 50 tonnes or fraction thereof. When steel plates except for Grade A steel over 50 mm in thickness is supplied in the controlled rolled condition, the frequency of impact test is to be made from a different piece from each 25 tonnes or fraction thereof.

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

(iii) When, subject to the special approval of TL, 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 TL, 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 TL- R 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 TL- R 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

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 TL'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 TL 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 TL, 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 TL, brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

16.5 In the event of any material bearing TL'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 TL, of the test certificates or shipping statements for all accepted materials. TL 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 TL 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 TL."

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

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

Remarks:

1. Condition of Supply
   A – Any
   N – Normalised Condition
   CR – Controlled Rolled Condition
   TM – Thermo-Mechanical rolling
   AR* – As Rolled Condition subject to special approval of TL
   CR* – Controlled Rolled Condition subject to special approval of TL
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.

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)	Not applicable
					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
A40	Killed and fine grain treated	Any	Plates	A(50)	N(50) CR(50) TM(50)	N(50) TM(50) QT(Each length as heat treated)
			Sections	A(50)	N(50) CR(50) TM(50)	Not applicable
D32 D36	Killed and fine grain treated	Nb and/or V	Plates	A(50)	N(50) CR(50), TM(50)	N(50), CR(25), TM(50)
			Sections	A(50)	N(50) CR(50), TM(50) AR* (25)	Not applicable
		Al alone or with Ti	Plates	A(50)	AR*(25)	Not applicable
					N(50), CR(50), TM (50)	N(50), CR25, TM(50)
			Sections	A(50)	N(50) CR(50), TM(50) AR* (25)	Not applicable
D40	Killed and fine grain treated	Any	Plates	N(50) CR(50) TM(50)		N(50) TM(50) QT(Each length as heat treated)
			Sections	N(50) CR(50) TM(50)		Not applicable
E32 E36	Killed and fine grain treated	Any	Plates	N(Each piece) TM(Each piece)		
			Sections	N(25) TM(25) AR* (15), CR* (15)		Not applicable
E40	Killed and fine grain treated	Any	Plates	N(Each piece) TM(Each piece) QT(Each length as heat treated)		N (Each piece) TM(Each piece) QT(Each length as heat treated)
			Sections	N(25) TM(25) QT(25)		Not applicable

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 TL
- CR* - Controlled Rolled Condition subject to the special approval of TL

(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.)

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 TL, 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

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 TL 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 TL taking into account:

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

b) Types of steel to be approved and availability of long term statistic results of chemical properties and of mechanical tests performed on rolled products.
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 TL 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, TL will require full tests indicated in Appendix A2.3 to be performed at rolling mill on the minimum thickness semi finished product.

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

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

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 TL, 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 TL, 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 TL prior to an implementation of revision 4 of this requirement regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 4 becomes effective.

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 TL, 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

- 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 TL is to be included.

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 TL 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 TL 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 TL taking into account previous approval as follows:

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

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 TL-

R W2. In particular the following applies:

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

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

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 TL.

3.7 Weldability tests

3.7.1 General

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

3.7.2 Preparation and welding of the test assemblies

The following tests are in general required:

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

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.

5. Certification

5.1 Approval

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

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 TL, 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 TL, 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 TL prior to an implementation of revision 4 of this requirement regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 4 becomes effective.

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 TL- R 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 TL, 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 TL:

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.

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 TL.

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 TL.

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

3.3 Test plate

Test plate is to be manufactured by a process approved by TL in accordance with the requirements of TL- R 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 TL.

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 TL.

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

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 TL- R 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 TL- R 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 TL- R 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.

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 TL.

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 TL (see section 3.2).

4. Results

The manufacturer is to submit to TL 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 TL in accordance with this weldability confirmation scheme.

5. Certification

TL 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.

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 TL 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

3. Approval of test plan

3.1 The test program submitted by the manufacturer is to be reviewed by TL, 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 TL 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 TL 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 TL 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 TL determines that the data of the corrosion resistance test result obtained for setting the control range of chemical composition varies too widely;

(c) When TL 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 TL's surveyor has not attended the corrosion resistance tests for setting the control range of chemical composition, and TL 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 TL'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.

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 TL.

6.2 TL will give approval for corrosion resistant steel where approval tests are considered by TL 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 TL 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)).

TL- R W13 Thickness tolerances of steel plates and wide flats

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 TL- R W11

(ii) High strength steels for welded structures according to TL- R W16

(iii) Steels for machinery structures in accordance with the individual Rules of TL.

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 TL.

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. This requirement is implemented on ships contracted for construction on or after 1 July 2019

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 TL- PR 29.

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 TL 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 TL- R W11 and TL- R 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)
$3 \leq t < 5$	-0.3
$5 \leq t < 8$	-0.4
$8 \leq t < 15$	-0.5
$15 \leq t < 25$	-0.6
$25 \leq t < 40$	-0.7
$40 \leq t < 80$	-0.9
$80 \leq t < 150$	-1.1
$150 \leq t < 250$	-1.2
$t \geq 250$	-1.3

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

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

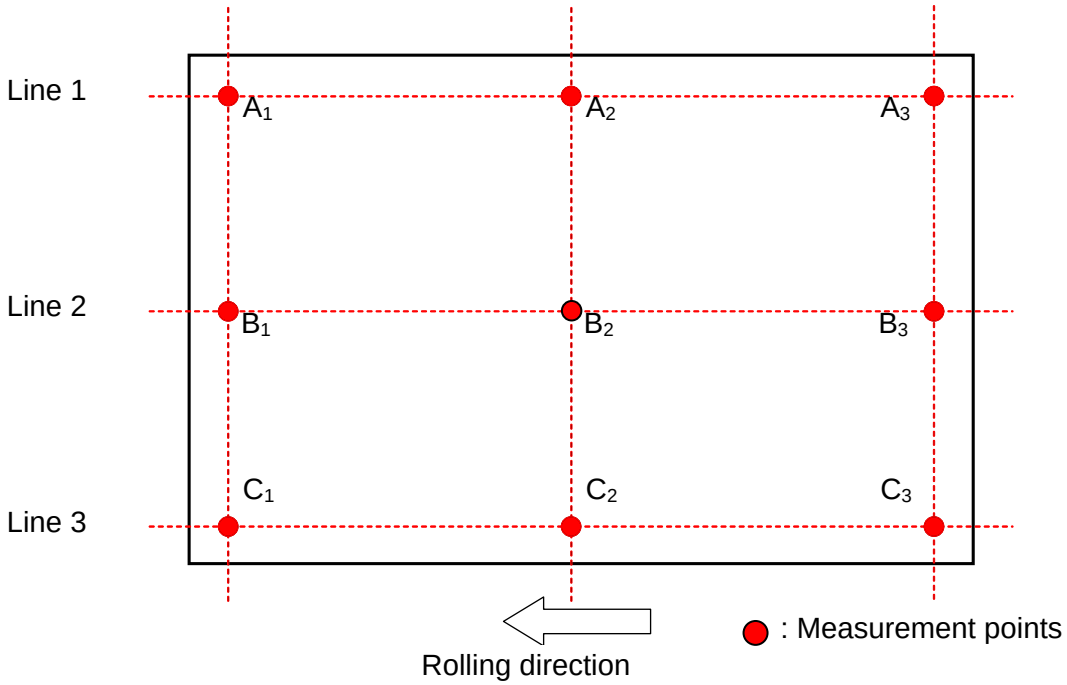
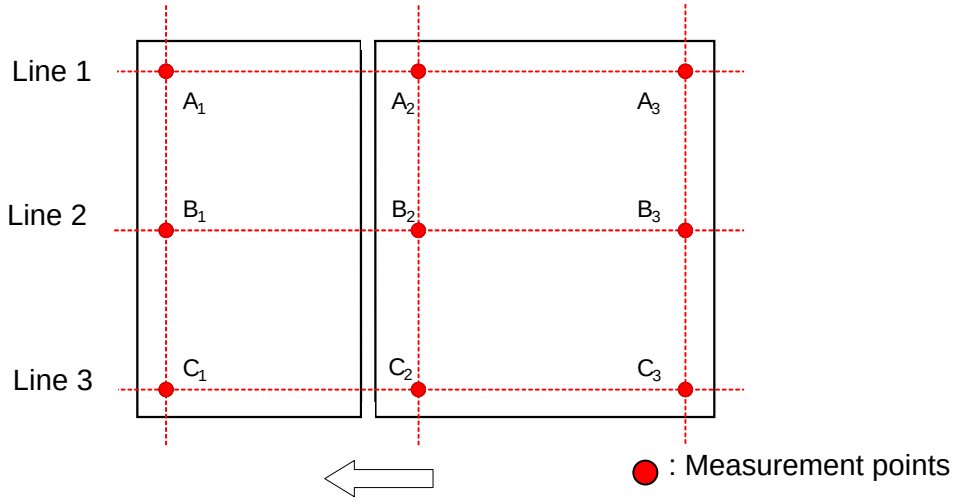
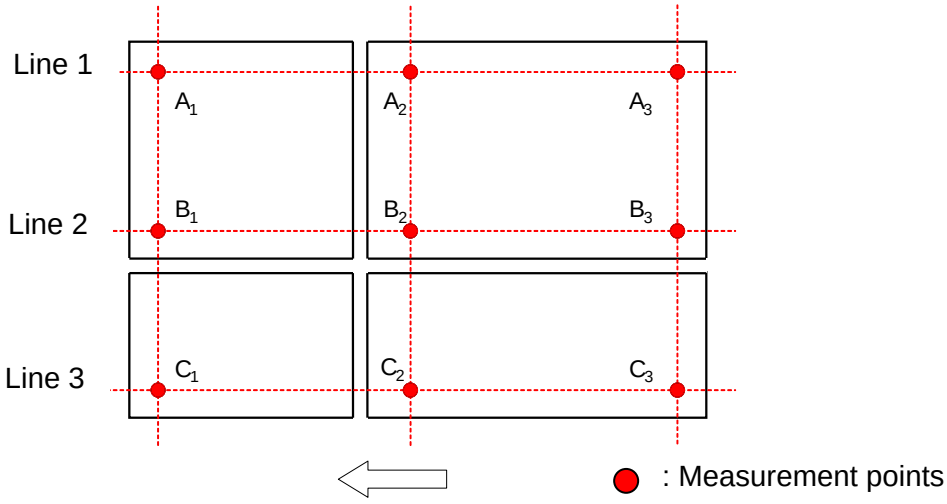
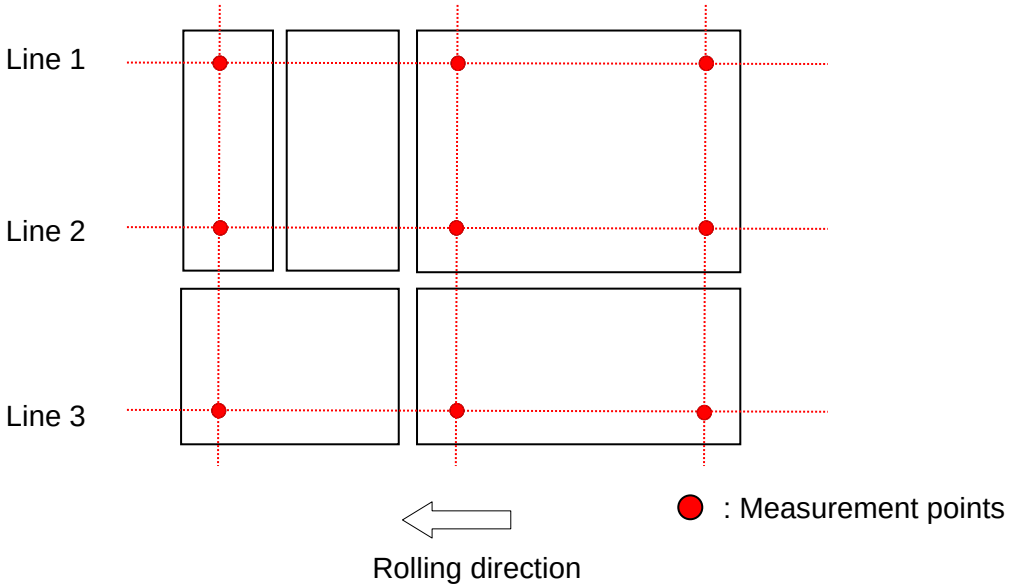


Figure A.2 - Locations of Thickness Measuring Points for the Cut Steel Products







TL- R W14 Steel plates and wide flats with specified minimum through thickness properties (“Z” quality)

W14.1 Scope

These requirements supplement those given in TL- R W11 and TL- R 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.

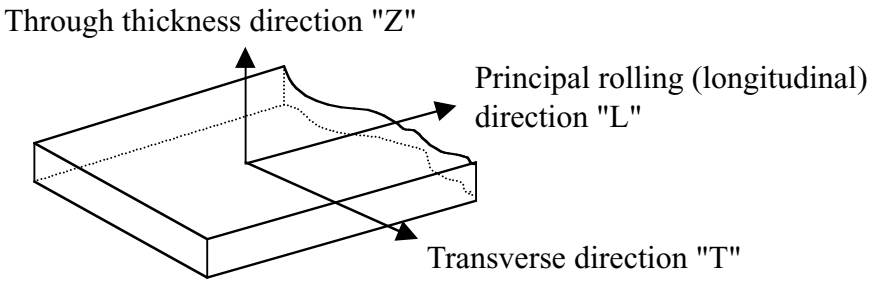


Figure 1 Schematic of testing directions

W14.2 Manufacture

All the materials are to be manufactured at works approved by TL for "Z" quality steels.

The approval should follow the procedure given in TL- R 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 TL- R W11 or TL- R 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 TL- R W11 or TL- R 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.

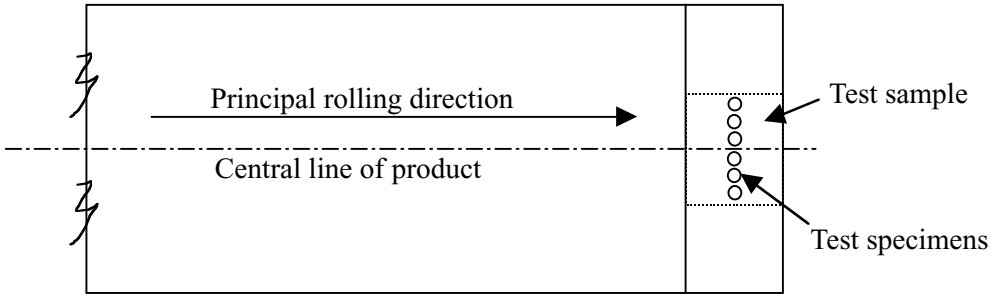


Figure 2 Plate and wide flat sampling position

W14.3.3 Tensile test specimen dimensions

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

W14.3.4 Tensile test results

The test is considered invalid and further replacement test is required if the fracture occurs in the weld or heat affected zone.

The minimum average value for the reduction of area of at least 3 tensile test specimens taken in the through thickness direction must be that shown for the appropriate grade given in Table 2. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade. See Figure 3.

A value less than the minimum individual value is a cause for rejection.

Table 2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

W14.4 Retest procedure

Figure 3 shows the three cases where a retest situation is permitted. In these instances three more tensile tests are to be taken from the remaining test sample. The average of all 6 tensile tests is to be greater than the required minimum average with no greater than two results below the minimum average.

In the case of failure after retest, either the batch represented by the piece is rejected or each piece within the batch is required to be tested.

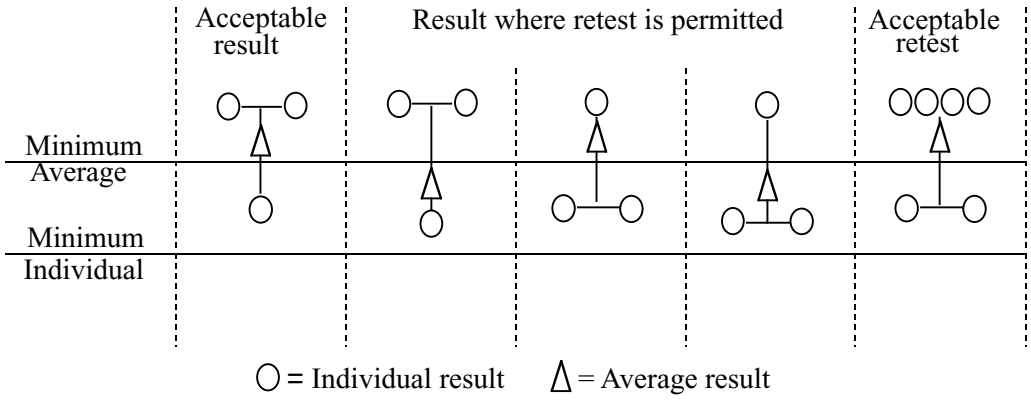


Figure 3 Diagram showing acceptance / rejection and retest criteria

W14.5 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 TL- R W11 or TL- R 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 TL- R W11 or TL- R W16:

(a) Through thickness reduction in area (%)
(b) Steel grade with Z25 or Z35 notation.

TL- R W16 High Strength Steels for Welded Structures

1. Scope

1.1 These requirements apply to hot-rolled, fine-grain, weldable high strength structural steels, intended for use in marine and offshore structural applications. These requirements do not apply to steels intended for hull structure of commercial ships whose requirements are specified in TL- R W11.

1.2 Steels covered by the scope of these requirements are specified in yield strength levels of 420, 460, 500, 550, 620, 690, 890 and 960 N/mm^2. For each yield strength level grades A, D, E and F are specified, based on the impact test temperature, except for yield strength level of 890 and 960 N/mm^2 for which grade F is not applicable.

The full list of grades are:

AH420	DH420	EH420	FH420
AH460	DH460	EH460	FH460
AH500	DH500	EH500	FH500
AH550	DH550	EH550	FH550
AH620	DH620	EH620	FH620
AH690	DH690	EH690	FH690
AH890	DH890	EH890	
AH960	DH960	EH960	

1.3 Steels covered by the scope may be delivered in Normalized (N)/Normalised rolled (NR); Thermo-mechanical controlled rolled (TM) or Quenched and Tempered (QT) condition.

Note:
TM is a generic delivery condition that may or may not include accelerated cooling, and may or may not include direct quenching followed by tempering after TM-rolling.

1.4 Product forms include plates, wide flats, sections, bars and seamless tubulars.

Note:

1. This requirement is implemented in marine and offshore structures contracted for construction on or after 1 July 2017, or when the application for certification of steel products submitted by an approved manufacturer is dated on or after 1 July 2017, or the application for certification of manufacturer approval is dated on or after 1 July 2017.

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 TL-PR 29.

1.5 Steels with a thickness beyond the maximum thicknesses as given in Table 3 of section 5.3 may be approved at the discretion of TL.

1.6 Steels differing in chemical composition, deoxidation practice, delivery condition and mechanical properties may be accepted, subject to the special approval of TL. Such steels are to be given a special designation.

2. Approval

2.1 For applications subjected to Classification, all steels are to be manufactured at steel works which have been approved by TL for the type and grade of steel which is being supplied. The procedure for approval is shown in Appendix A.

2.2 It is the steelmaker's responsibility to assure that effective quality, process and production controls during manufacturing are adhered to within the manufacturing specification. The manufacturing specification shall be submitted to TL at the time of initial approval.

2.3 Where non-conformities arise, the manufacturer is to identify the root cause and establish countermeasures to prevent its recurrence. The non-conformities and the countermeasures are to be documented and reported to TL.

2.4 When the semi-finished products were not manufactured by the approved manufacturer of the finish rolled and heat treated products, the manufacturer of the semi-finished product shall also be subject to approval by TL.

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 high strength steel may not be greater than that of a welded joint in normal strength steels.

Note 2:
Before subjecting steels produced by both thermo-mechanical rolling or quenched and tempered after 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 making process

3.1.1 The steel is to be manufactured, by the basic oxygen, basic electric arc furnace or by processes specially approved by TL.

3.1.2 Vacuum degassing shall be used for any of the following:

a) All steels with enhanced through-thickness properties, and

b) All steels of grade H690, H890 and H960.

3.2 Deoxidation

3.2.1 The steel is to be fully killed.

3.3 Grain size

3.3.1 The steel is to be fine grain treated, and is to have a fine grain structure. The fine grain practice is to be as detailed in the manufacturing specification.

Note:
A fine grain structure has an equivalent index ≥ 6 determined by micrographic examination in accordance with ISO 643 or alternative test method.

3.4 Nitrogen control

3.4.1 The steels shall contain nitrogen binding elements as detailed in the manufacturing specification. Also see note 4 in Table 1.

4. Chemical Composition

4.1 The chemical composition is to be determined by the steelmaker in an adequately equipped and competently staffed laboratory. The method of sampling is to follow that carried out for the initial approval tests, either from the ladle, the tundish or the mould in the case of continuous casting. The aim analysis is to be in accordance with the manufacturing specification. All the elements listed in Table 1 are to be reported.

4.2 Elements used for alloying, nitrogen binding, and fine grain treatment, and as well as the residual elements are to be as detailed in the manufacturing specification, e.g. when boron is deliberately added for enhancement of hardenability of the steels, the maximum content of the boron content shall not be higher than 0.005%; and the analysis result shall be reported.

4.3 The carbon equivalent value is to be calculated from the ladle analysis. Maximum values are specified in Table 2.

a) For all steel grades the following formula of IIW may be used:

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

b) For steel grades H460 and higher, *CET* may be used instead of *Ceq* at the discretion of the manufacturer, and is to be calculated according to the following formula:

$$CET = C + \frac{(Mn + Mo)}{10} + \frac{(Cr + Cu)}{20} + \frac{Ni}{40}\ (\%)$$

Note:
The *CET* is included in the standard EN 1011-2:2001 used as one of the parameters for pre-heating temperature determination which is necessary for avoiding cold cracking.

c) For TM and QT steels with carbon content not more than 0.12%, the cold cracking susceptibility *P*cm for evaluating weldability may be used instead of carbon equivalent of *Ceq* or *CET* at manufacturer's discretion and is to be calculated using the following formula:

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

Table 1 Chemical Composition

Delivery condition[1)]	**N/NR**		**TM**		**QT**	
Steel grade / **Chemical Composition[2)]**	**AH420 DH420 AH460 DH460**	**EH420 EH460**	**AH420 DH420 AH460 DH460 AH500 DH500 AH550 DH550 AH620 DH620 AH690 DH690 AH890**	**EH420 FH420 EH460 FH460 EH500 FH500 EH550 FH550 EH620 FH620 EH690 FH690 DH890 EH890**	**AH420 DH420 AH460 DH460 AH500 DH500 AH550 DH550 AH620 DH620 AH690 DH690 AH890 AH960**	**EH420 FH420 EH460 FH460 EH500 FH500 EH550 FH550 EH620 FH620 EH690 FH690 DH890 EH890 DH960 EH960**
Carbon % max	0.20	0.18	0.16	0.14	0.18	
Manganese %	1.0~1.70		1.0~1.70		1.70	
Silicon % max	0.60		0.60		0.80	
Phosphorus % max[3)]	0.030	0.025	0.025	0.020	0.025	0.020
Sulphur % max[3)]	0.025	0.020	0.015	0.010	0.015	0.010
$Aluminium_{total}$ % min[4)]	0.02		0.02		0.018	
Niobium % max[5)]	0.05		0.05		0.06	
Vanadium % max[5)]	0.20		0.12		0.12	
Titanium % max[5)]	0.05		0.05		0.05	
Nickel % max[6)]	0.80		2.00[6)]		2.00[6)]	
Copper % max	0.55		0.55		0.50	
Chromium % max[5)]	0.30		0.50		1.50	
Molybdenum % max[5)]	0.10		0.50		0.70	
Nitrogen % max	0.025		0.025		0.015	
Oxygen ppm max[7)]	Not applicable		Not applicable	50	Not applicable	30

Note 1 See section 5.1 for definition of delivery conditions.

Note 2 The chemical composition is to be determined by ladle analysis and shall meet the approved manufacturing specification at the time of approval.

Note 3 For sections the P and S content can be 0.005% higher than the value specified in the table.

Note 4 The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N ratio do not apply.

Note 5 Total Nb+V+Ti ≤ 0.26% and Mo+Cr ≤ 0.65%, not applicable for QT steels.

Note 6 Higher Ni content may be approved at the discretion of TL.

Note 7 The requirement on maximum Oxygen content is only applicable to DH890; EH890; DH960 and EH960.

Table 2 Maximum *Ceq*, *CET* and *P*cm values

Steel grade and delivery condition	Carbon Equivalent (%)							
	Ceq						*CET*	*P*cm
	Plates			Sections	Bars	Tubulars	all	all
	t ≤ 50 (mm)	50 < t ≤ 100 (mm)	100 < t ≤ 250 (mm)	t ≤ 50 (mm)	t ≤ 250 or d ≤ 250 (mm)	t ≤ 65 (mm)	all	all
H420N/NR	0.46	0.48	0.52	0.47	0.53	0.47	N.A	N.A
H420TM	0.43	0.45	0.47	0.44	N.A	N.A	N.A	N.A
H420QT	0.45	0.47	0.49	N.A	N.A	0.46	N.A	N.A
H460N/NR	0.50	0.52	0.54	0.51	0.55	0.51	0.25	N.A
H460TM	0.45	0.47	0.48	0.46	N.A	N.A	0.30	0.23
H460QT	0.47	0.48	0.50	N.A	N.A	0.48	0.32	0.24
H500TM	0.46	0.48	0.50	N.A	N.A	N.A	0.32	0.24
H500QT	0.48	0.50	0.54	N.A	N.A	0.50	0.34	0.25
H550TM	0.48	0.50	0.54	N.A	N.A	N.A	0.34	0.25
H550QT	0.56	0.60	0.64	N.A	N.A	0.56	0.36	0.28
H620TM	0.50	0.52	N.A	N.A	N.A	N.A	0.34	0.26
H620QT	0.56	0.60	0.64	N.A	N.A	0.58	0.38	0.30
H690TM	0.56	N.A	N.A	N.A	N.A	N.A	0.36	0.30
H690QT	0.64	0.66	0.70	N.A	N.A	0.68	0.40	0.33
H890TM	0.60	N.A	N.A	N.A	N.A	N.A	0.38	0.28
H890QT	0.68	0.75	N.A	N.A	N.A	N.A	0.40	N.A
H960QT	0.75	N.A	N.A	N.A	N.A	N.A	0.40	N.A

Note N.A = Not applicable

5. Delivery Condition - Rolling Process and Heat Treatment

5.1 Steel is to be delivered in accordance with the processes approved by TL. These processes include:

- Normalized (N)/Normalized rolled (NR)
- Thermo-mechanical controlled rolled (TM)/with Accelerated cooling (TM+AcC)/with direct quenching followed by tempering (TM+DQ), or

- Quenched and Tempered condition (QT)

The definition of these delivery conditions are defined in TL- R W11.

Note:
Direct quenching after hot-rolling followed by tempering is considered equivalent to conventional quenching and tempering.

5.2 Rolling reduction ratio

5.2.1 The rolling reduction ratio of slab, billet, bloom or ingot should not be less than 3:1 unless agreed at the time of approval.

5.3 Thickness limits for approval

5.3.1 The maximum thickness of slab, billet or bloom from the continuous casting process shall be at the manufacturer's discretion.

5.3.2 Maximum thickness of plates, sections, bars and tubulars over which a specific delivery condition is applicable are shown in Table 3.

Table 3 Maximum thickness limits

Delivery condition	Maximum thickness (mm)			
	Plates	Sections	Bars	Tubulars
N	250[2)]	50	250	65
NR	150	[1)]		
TM	150	50	Not applicable	Not applicable
QT	150[2)]	50	Not applicable	50

Note 1 The maximum thickness limits of sections, bars and tubulars produced by NR process route are less than those manufactured by N route, and shall be at the discretion of TL.

Note 2 Approval for N steels with thickness larger than 250 mm and QT steels with thickness larger than 150 mm is subject to the special consideration of TL.

6. Mechanical Properties

Test specimens and test procedures for mechanical properties are in accordance with TL- R W2 and TL- R W11.

6.1 Tensile test

6.1.1 Test specimens are to be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of sections, bars, tubulars and rolled flats with a finished width of 600 mm or less, where the tensile specimens may be taken in the longitudinal direction.

6.1.2 Full thickness flat tensile specimens are to be prepared. The specimens are to be prepared in such a manner as to maintain the rolling scale at least at one side. When the capacity of the test machine is exceeded by the use of a full thickness specimen, sub-sized flat tensile specimens representing either the full thickness or half of the product thickness retaining one rolled surface are to be used. Alternatively, machined round test specimens

may be used. The specimens are to be located at a position lying at a distance of t/4 from the surface and additionally at t/2 for thickness above 100 mm or as near as possible to these positions.

6.1.3 The results of the tests are to comply with the appropriate requirements of Table 4. In the case of product forms other than plates and wide flats where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those transverse requirements as listed in Table 4.

Table 4 Tensile properties at ambient temperature for all steel grades

Mechanical properties / Steel grade and delivery condition		Minimum yield strength R_{eH}[1] (N/mm²)			Ultimate tensile strength R_m (N/mm²)		Minimum percentage elongation after fracture (%) $L_0=5.65\sqrt{S_0}$ [2]		Charpy V-notch impact test		
		Nominal thickness (mm)[4]			Nominal thickness (mm)[4]				Test temp (°C)	Minimum (Joules)	
		≥ 3 ≤ 50	> 50 ≤ 100	> 100 ≤ 250	≥ 3 ≤ 100	> 100 ≤ 250	T	L[3]		T	L
H420N/NR H420TM H420QT	A D E F	420	390	365	520~680	470~650	19	21	0 -20 -40 -60	28	42
H460N/NR H460TM H460QT	A D E F	460	430	390	540~720	500~710	17	19	0 -20 -40 -60	31	46
H500TM H500QT	A D E F	500	480	440	590~770	540~720	17	19	0 -20 -40 -60	33	50
H550TM H550QT	A D E F	550	530	490	640~820	590~770	16	18	0 -20 -40 -60	37	55
H620TM H620QT	A D E F	620	580	560	700~890	650~830	15	17	0 -20 -40 -60	41	62
H690TM H690QT	A D E F	690	650	630	770~940	710~900	14	16	0 -20 -40 -60	46	69
H890TM H890QT	A D E	890	830	Not applicable	940~1100	Not applicable	11	13	0 -20 -40	46	69
H960QT	A D E	960	Not applicable	Not applicable	980~1150	Not applicable	10	12	0 -20 -40	46	69

Note 1 For tensile test either the upper yield stress (R_{eH}) or where R_{eH} cannot be determined, the 0,2 percent proof st*r*ess (*R*p0.2) is to be determined and the material is considered to comply with the requirement if either value meets or exceeds the specified minimum value of yield strength.

Note 2 For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the minimum values shown in Table 5.

Note 3 In the case that the tensile specimen is parallel to the final rolling direction, the test result shall comply with the requirement of elongation for longitudinal (L) direction.

Note 4 For plates and sections for applications, such as racks in offshore platforms etc, where the design requires that tensile properties are maintained through the thickness, a decrease in the minimum specified tensile properties is not permitted with an increase in the thickness.

Table 5 Elongation Minimum Values for a Width of 25 mm and a 200 mm Gauge Length[1)]

Strength level	Thickness (mm)						
	≤ 10	> 10 ≤ 15	> 15 ≤ 20	> 20 ≤ 25	> 25 ≤ 40	> 40 ≤ 50	> 50 ≤ 70
H420	11	13	14	15	16	17	18
H460	11	12	13	14	15	16	17
H500	10	11	12	13	14	15	16
H550	10	11	12	13	14	15	16
H620	9	11	12	12	13	14	15
H690	9[2)]	10[2)]	11[2)]	11	12	13	14

Note 1 The tabulated elongation minimum values are the requirements for testing specimen in transverse direction. H890 and 960 specimens and specimens which are not included in this table shall be proportional specimens with a gauge length of $L_0=5.65\sqrt{S_0}$.

Note 2 For H690 plates with thickness ≤ 20 mm, round specimen in accordance with TL- R W2 may be used instead of the flat tensile specimen. The minimum elongation for testing specimen in transverse direction is 14%.

6.2 Impact test

6.2.1 The Charpy V-notch impact test specimens for plates and wide flats over 600 mm in width are to be taken with their axes transverse to the final rolling direction and the results should comply with the appropriate requirements for transverse direction of Table 4. For other product forms, the impact tests are to be in the longitudinal direction, the results of the tests are to comply with the appropriate requirements for longitudinal direction of Table 4.

6.2.2 Sub-surface test specimens will be taken in such a way that one side is not further away than 2 mm from a rolled surface, however, for material with a thickness in excess of 50 mm, impact tests shall be taken at the quarter thickness (t/4) location and mid-thickness (t/2).

6.2.3 Impact test for a nominal thickness less than 6 mm are normally not required.

6.3 Test frequency

6.3.1 Tensile test sample is to be randomly selected from each batch, as defined in TL- R W11, that is to be less than or equal to 25 tonnes, and to be from the same cast, in the same delivery condition and of the same thickness.

6.3.2 Impact test

a) For steels plates in N/NR or TM condition test sample is to be taken from each piece.

b) For steels in QT condition test sample is to be taken from each individually heat treated part thereof.

c) For sections, bars and tubulars, test sample is to be taken from each batch of 25 tonnes or fraction thereof.

Note 1:
If the mass of the finished material is greater than 25 tonnes, one set of tests from each 25 tonnes and/or fraction thereof is required. (e.g. for consignment of 60 tonnes would require 3 plates to be tested).

Note 2:
For continuous heat treated product special consideration may be given to the number and location of test specimens required by the manufacturer to be agreed by TL.

6.4 Traceability

Traceability of test material, specimen sampling and test procedures including test equipment with respect to mechanical properties testing, is to be in accordance with TL- R W11.

6.5 Re-test procedures

Re-test procedures for tensile tests and Charpy impact tests are to be in accordance with TL- R W2.

6.6 Through thickness tensile test

6.6.1 For steels designated with improved through thickness properties, through thickness tensile tests are to be performed in accordance with TL- R W14, “Steel plates and wide flats with specified minimum through thickness properties (“Z” quality)”.

6.6.2 Subject to the discretion of TL, through thickness tensile strength may be required to be not less than 80% of the specified minimum tensile strength.

7. Tolerances

Unless otherwise agreed or specially required, the thickness tolerances in TL- R W13, “Allowable under thickness tolerances of steel plates and wide flats” are applicable.

8. Surface Quality

8.1 All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects.

8.2 The surface quality inspection method shall be in accordance with recognised national or international standards agreed between purchaser and manufacturer.

a) Welding repair procedures and the method for reporting repairs are to be approved by TL.

b) Where repair by grinding is carried out then the remaining plate thickness below the ground area must be within the allowable under thickness tolerance.

8.3 Surface finish requirement shall be in accordance with the relevant requirements in TL- R W11.

8.4 Surface inspection is the responsibility of the manufacturer. The acceptance by TL's Surveyor of material later found to be defective shall not absolve the manufacturer of this responsibility.

9. Internal Soundness

9.1 Verification of internal soundness is the responsibility of the manufacturer. The acceptance by TL's Surveyor shall not absolve the manufacturer of this responsibility.

9.2 Ultrasonic examination

9.2.1 If required by TL, ultrasonic examination should be carried out in accordance with TL- R W11 for the requirement of internal soundness, and is to be performed in accordance with an approved standard.

10. Stress relieving heat treatment and other heat treatments

10.1 Steels approved by the procedures given in Appendix A with respect to Heat Treatment are suitable for stress relieving heat treatment such as post-weld heat treatment and stress relieving heat treatment after cold forming for the purpose of reducing the risk of brittle fracture, increasing the fatigue lifetime and dimensional stability for machining.

Note:
Products can be susceptible to deterioration in mechanical strength and toughness if they are subjected to incorrect post-weld heat treatment procedures or other processes involving heating such as flame straightening, rerolling, etc. where the heating temperature and the holding time exceed the limits given by the manufacturer.

11. Facilities for Inspection

11.1 Testing is to be carried out under the witness of the Surveyor, or an authorised deputy, in order to verify whether the test results meet the specified requirements.

11.2 The manufacturer is to afford the Surveyor all necessary facilities and access to all relevant parts of the steel works to enable him to verify the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by this requirement. Also for verifying the accuracy of the testing, calibration of inspection equipment and traceability of materials.

12. Identification of Materials

12.1 The manufacturer is to adopt a system for the identification of ingots, slabs, billet or bloom and finished products, which will enable the material to be traced to its original cast. The Surveyor is to be given full facilities for so tracing the material when required.

13. Branding

13.1 Each finished piece is to be clearly marked by the manufacturer with the following particulars:

a) TL's brand mark

b) Unified identification mark for the grade of steel (e.g. EH620)

c) Name or initials to identify the steelworks

d) Cast number/Heat number, plate number or equivalent identification mark

e) Delivery condition (N/NR, TM/TM+AcC/TM+DQ or Q&T)

The entire markings are to be encircled with paint or otherwise marked so as to be easily recognised. Steels which have been specially approved by TL and which differ from these requirements (see W16.1.6) are to have the letter “S” after the identification mark (e.g. EH620S)

14. Documentation of Inspection Tests

14.1 The Surveyor is to be supplied with two copies, of the test certificates or shipping statements for all accepted materials. In addition to the description, dimensions, etc., of the material, the following particulars are to be included:

a) Purchaser's order number

b) Identification of the cast and piece

c) Manufacturer’s identification

d) Identification of the grade of steel

e) Chemical analysis, *Ceq*, *CET* or *P*cm value

f) Delivery condition with heat treatment temperatures

g) Mechanical properties test results, including traceable test identification

h) Surface quality and inspection results

i) UT result, where applicable

14.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

“We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of TL”.

Appendix A. Manufacturing Approval Scheme of High Strength Steels for Welded Structures

1. Scope of application

This appendix specifies the procedure for the approval of the manufacturing process of high strength steels for welded structures.

All materials are to be manufactured at works which have been approved by TL for the type, delivery condition, grade and thickness 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.

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 W16.2.2.

2. Approval application

2.1 Documents to be submitted

The manufacturer is to submit to TL, a request for approval, a proposed approval test program (see A3.1) 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, as deemed useful.

b) Organisation and quality

- organisational chart
- number of staff employed
- staff employed and organisation 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 manufacturing

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 (NDE)
- list of quality control procedures

2.2 Manufacturing specification

a) Material to be approved, including type of products (plates, sections, bars and tubular), delivery condition, grades of steel, range of thickness and aim material properties as follows:

- range of chemical composition, aim analyses and associated control limits, including grain refining, nitrogen binding, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and delivery condition, the different ranges are to be specified, as appropriate.
- in addition, where zirconium, calcium and rare earth metals have been used during steelmaking for grain refinement and, or inclusion modification, the contents of these elements shall be specified in the manufacturing specification.
- aim carbon equivalent *Ceq* according to IIW formula or *CET* formula and/or aim *P*cm content and associated control limits.
- production statistics of the chemical composition and mechanical properties (R_{eH}, R_m, A% and CVN). The statistics are intended to demonstrate the capability to manufacture the steel products.

b) Steelmaking (if applicable)

- steel making process and capacity of furnace/s or converter/s
- raw material used
- deoxidation, grain refining, nitrogen binding and alloying practice
- desulphurisation, dehydrogenation, sulphide treatment, ladle refining 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
- casting/solidification cooling rate control
- ingot or slab size and weight
- ingot or slab treatment: scarfing and discarding procedures

c) Reheating and rolling

- type of furnace and treatment parameters
- rolling: reduction ratio of ingot/slab/bloom/billet to finished product, rolling and finishing temperatures for each grade/thickness combination
- descaling treatment during rolling
- capacity of the rolling stands

d) Heat treatment

- type of furnaces, heat treatment parameters for products to be approved
- accuracy and calibration of temperature control devices
- the methods used to determine austenitizing temperature, re-crystallization temperature and Ar3 temperature
- description of quenching and tempering process, if applicable

e) Programmed rolling

For products delivered in the Normalised rolling (NR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:

- description of the rolling process
- the methods used to determine austenitizing temperature, re-crystallization temperature and Ar3 temperature
- 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

f) Recommendations for fabrication and welding in particular for products delivered in the NR 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 and recommended pre-heat/interpass temperature

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

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

2.3 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to TL 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 ingots, 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 TL 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 where available the long term statistical results of chemical and mechanical properties.

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 be considered by TL taking into account previous approval as follows:

- the rolled steel manufacturer has already been approved for the rolling process and heat treatment using approved other semi finished products characterized by the same thickness range, steel grade, grain refining and micro-alloying elements, steel making(deoxidation) and casting process.

- the semi finished products have 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 TL 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 accredited 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, TL will require selection of one test product of representative thickness.

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

3.5 Position of the test samples and specimens

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar and tubular) corresponding to the top and bottom of the ingot as indicated in Table A1, 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, (top and bottom of the piece) and the direction of the test specimens with respect to the final rolling direction of the material are indicated in Table A1.

The position of the samples in the width of the product is to be in accordance with TL- R W11.

The position of the tensile and Charpy impact test samples with respect to the plate thickness is to be in accordance with Appendix 2 section 3.6.2 of TL- R W11.

3.6 Tests on base material

3.6.1 Type of tests

The tests to be carried out are indicated in the following Table A1.

Table A1 Tests on base material

Type of Test		Position and direction of test specimens	Remarks			
1	Chemical analysis (ladle and product[1)])	Top	a) Contents of C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Ti, B, Zr, Cu, As, Sn, Bi, Pb, Ca, Sb, O, H are to be reported. b) Carbon equivalent calculation, and/or c) *P*cm calculation, as applicable.			
2	Segregation examination	Top	Sulphur prints[2)] 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.			
3	Micrographic examination[3)]	Top	a) Grain size determination. Ferrite and/or prior austenite grain size should be determined. b) All photomicrographs are to be taken at x 100 and 500 magnification. c) Non-metallic inclusion contents/Cleanliness The level of non-metallic inclusions and impurities in term of amount, size, shape and distribution shall be controlled by the manufacturer. The standards of the micrographic examination methods ISO 4967 or equivalent standards are applicable. Alternative methods for demonstrating the non-metallic inclusions and impurities may be used by the manufacturer.			
4	Tensile test	Top and bottom - longitudinal and transverse direction	Yield strength (R_{eH}), Tensile strength (R_m), Elongation (A5), Reduction in Area (RA) and Y/T ratio are to be reported.			
5a	Charpy Impact tests on unstrained specimens for grades[4)]	Top and bottom	Testing temperature (°C)			
	AH	Longitudinal and transverse direction	+20	0	-20	
	DH		0	-20	-40	
	EH		0	-20	-40	-60
	FH		-20	-40	-60	-80

Type of Test		Position and direction of test specimens	Remarks			
5b	Charpy Impact tests on strain aged specimens for grades[4)5)]	Top	Deformation of 5% + 1 hour at 250°C			
	AH	Either longitudinal or transverse	+20	0	-20	
	DH		0	-20	-40	
	EH		0	-20	-40	-60
	FH		-20	-40	-60	-80
6	Drop weight test	Top	The test is to be performed only on plates 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.			
7	Through thickness tensile tests	Top and bottom	Optional for grades with improved through thickness properties, testing in accordance with UR W14.			
8	Weldability test[6)]					
a)	Butt Weld Assembly as-welded	Top	Cross weld tensile, Charpy impact test on WM, FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.			
b)	Butt Weld Assembly (PWHT), if applicable	Top	Cross weld tensile, Charpy impact test on WM, FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.			
c)	Y-shape weld crack test (Hydrogen crack test)	Top				

Note 1 The product analyses should be taken from the tensile specimen. The deviation of the product analysis from the ladle analysis shall be permissible in accordance with the limits given in the manufacturing specification.

Note 2 Other tests than Sulphur prints for segregation examination may be applied and subject to acceptance by TL.

Note 3 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, 1/4t and 1/2t of the product.

Note 4 In addition to the determination of the absorbed energy value, also the lateral expansion and the percentage crystallinity are to be reported.

Note 5 Strain ageing test is to be carried out on the thickest plate.

Note 6 Weldability test is to be carried out on the thickest plate.

3.6.2 Test specimens and testing procedure

The test specimens and testing procedures are to be in accordance with TL- R W2, where applicable.

3.6.3 Other tests

Additional tests such as CTOD test on parent plate, 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 W16, or when deemed necessary by TL.

3.7 Weldability tests - Butt weld test

3.7.1 For H420 to H500 grade steels: Weldability tests are to be carried out on samples of the thickest plate. Testing on higher grades can cover the lower strength and toughness grades.

a) 1x butt weld test assembly welded with a heat input 15±2 kJ/cm is to be tested as-welded.

b) 1x butt weld test assembly welded with a heat input 50±5 kJ/cm for N/NR and TM and 35±3.5 kJ/cm for QT steels is to be tested as-welded.

c) 1x butt weld test assembly welded with the same heat input as given in b) is to be post-weld heat treated (PWHT) prior to testing.

Option: Steels intended to be designated as steels for high heat input welding are to be tested with 1x butt weld test assembly in the as-welded condition and 1x test assembly in the PWHT condition, both welded with the maximum heat input being approved.

3.7.2 For H550 to H960 grade steels:

In general, the thickest plate with the highest toughness grade for each strength grade is to be tested. Provided the chemical composition of the higher grade is representative to the lower grade, testing requirements on the lower grades may be reduced at the discretion of TL.

a) 1x butt weld test assembly welded with a heat input 10±2 kJ/cm is to be tested as-welded.

b) 1x butt weld test assembly welded with a maximum heat input as proposed by the manufacturer is to be tested as-welded. The approved maximum heat input shall be stated on the manufacturer approval certificate.

Option: If the manufacturer requests to include the approval for Post Weld Heat Treated (PWHT) condition, 1x additional butt weld test assembly welded with a maximum heat input proposed by the manufacturer for the approval same as test assembly b) is to be post-weld heat treated (PWHT) prior to testing.

3.7.3 Butt weld test assembly

The butt weld test assemblies of N/NR plates are to be prepared with the weld seam transverse to the final plate rolling direction.

The butt weld test assemblies of TM/TM+AcC/TM+DQ and QT plates are to be prepared with the weld seam parallel to the final plate rolling direction. The butt weld test assemblies of long

products, sections and seamless tubular in any delivery condition are to be prepared with the weld seam transverse to the rolling direction.

3.7.4 Bevel preparation

The bevel preparation should be preferably 1/2V or K related to thickness.

The welding procedure should be as far as possible in accordance with the normal welding practice used for the type of steel in question.

The welding procedure and welding record are to be submitted to TL for review.

3.7.5 Post-weld heat treatment procedure

a) Steels delivered in N/NR or TM/TM+AcC/TM+DQ condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes and needs not be more than 150 minutes) at a maximum holding temperature of 580°C, unless otherwise approved at the time of approval.

b) Steels delivered in QT condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes and needs not be more than 150 minutes) at a maximum holding temperature of 550°C with the maximum holding temperature of at least 30°C below the previous tempering temperature, unless otherwise approved at the time of approval.

c) Heating and cooling above 300°C shall be carried out in a controlled manner in order to heat/cool the material uniformly. The cooling rate from the max. holding temperature to 300°C shall not be slower than 55°C/hr.

3.7.6 Type of tests

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

a) 1 cross weld tensile test - 1 full thickness test sample or sub-sized samples cover the full thickness cross section.

b) 1 set of 3 Charpy V-notch impact specimens transverse to the weld seam and 1-2 mm below the surface with the notch located at the fusion line and at a distance 2, 5 and 20 mm from the straight fusion line. An additional set of 3 Charpy test specimens at root is required for each aforementioned position for plate thickness $t \geq 50$ mm. 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.

c) Hardness tests HV10 across the weldment. The indentations are to be made along a 1-2 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 350HV for grade steels H420 to H460; not be higher than 420HV for H500 to H690; and not be higher than 450HV for H890 and H960.

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.

d) CTOD test

CTOD test specimens are to be taken from butt weld test assembly specified in 3.7.1 b) or 3.7.2 b) in Appendix A of this requirement. CTOD test is to be carried out in accordance with EN ISO 15653 or equivalent.

- the specimen geometry (B = W) is permitted for plate thickness up to 50 mm. For plate thicker than 50 mm, subsidiary specimen geometry (50x50 mm) is permitted, which is to be taken 50 mm in depth through thickness from the subsurface and 50 mm in width. See Figure A1 a) and b) for more details

- the specimens shall be notched in through thickness direction

- grain-coarsened HAZ (GCHAZ) shall be targeted for the sampling position of the crack tip

- the test specimens shall be in as-welded and post-weld heat treated, if applicable

- three tests shall be performed at -10°C on each butt weld test assembly

For grades H690 and above, dehydrogenation of as-welded test pieces may be carried out by a low temperature heat treatment, prior to CTOD testing. Heat treatment conditions of 200°C for 4 h are recommended, and the exact parameters shall be notified with the CTOD test results.

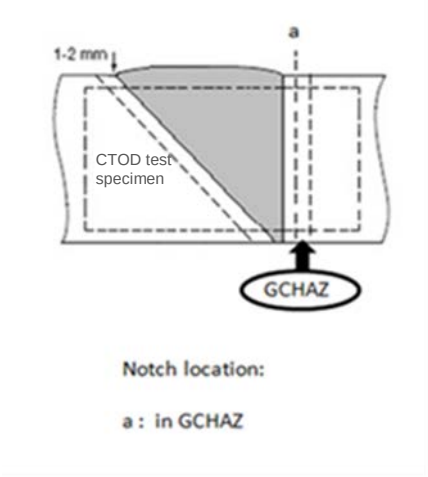
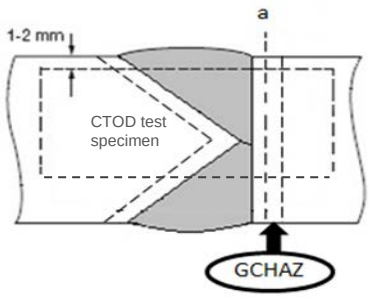


Figure A1 a) - For plate thickness t ≤ 50 mm, CTOD test specimen is to be sampled in full thickness



Notch location:

a : in GCHAZ

Figure A1 b) - For plate thickness t > 50 mm, subsidiary test specimen with a thickness of maximum 50 mm in subsurface area is to be sampled

3.7.7 Crack susceptibility weld test (Hydrogen crack test)

Testing in accordance with national and international recognised standards such as GB/T4675.1 and JIS Z 3158 for Y-groove weld crack test. Minimum preheat temperature is to be determined and the relationship of minimum preheat temperature with thickness is to be derived.

3.7.8 Other tests

Additional tests may be required in the case of newly developed types of steel, outside the scope of W16, or when deemed necessary by TL.

4. Results

All the results are to comply with the requirements of the scheme of initial approval.

The subject manufacturer shall submit all the test results together with the manufacturing specification containing all the information required under Appendix A, Section 2, and manufacturing records relevant to steel making, casting, rolling and heat treatment, applicable to the product submitted to the tests.

5. Certification

5.1 Approval

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

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 granted by a periodic inspection and evaluation of the result of the inspection to the surveyor's satisfaction 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 the statistical data of results of production of similar grades of products, at the discretion of TL, be reapproved.

7. Removal 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 TL, to the extent of invalidating 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 TL prior to an implementation of revision 3 of this TL- R W16 regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 3 becomes effective.

End of Document

TL- R W17 Approval of consumables for welding normal and higher strength hull structural steels

1. General

1.1 Scope

1.1.1 These requirements give the conditions of approval and inspection of welding consumables used for hull structural steel according to TL- R W11as follows:

- normal strength steels Grades A, B, D and E,
- higher strength steels Grades A32, D32, E32, A36, D36 and E36,
- higher strength steels with minimum yield strength 390 N/mm^2: Grades A40, D40 and E40,
- higher strength steels for low temperature application: Grades F32, F36 and F40.

Welding consumables for high strength steels for welded structures are to comply with the requirements of TL- R W23.

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

1.1.2 Categories of products

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

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

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Note:

1. This requirement is implemented from when an application for approval is dated on after 1 July 2019.

1.2 Grading

1.2.1 Basic groups and grades

Filler metals are divided into three groups:

- normal strength filler metals for welding normal strength hull structural steels,
- higher strength filler metals for welding normal and higher strength hull structural steels with minimum yield strength up to 355 N/mm^2,
- higher strength filler metals for welding normal and higher strength hull structural steels with minimum yield strength up to 390 N/mm^2.

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

Each filler metal group is further divided into several grades:

- Grades 1, 2 and 3 for ordinary-strength filler metals,
- Grades 1Y, 2Y, 3Y and 4Y for higher strength filler metals for steels up to 355 N/mm^2 yield strength,
- Grades 2Y40, 3Y40, 4Y40 and 5Y40 for higher strength filler metals for steels up to 390 N/mm^2 yield strength.

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

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

1.2.2 Correlation of welding consumables to hull structural steel grades.

The correlation between the hull steel grades and the welding consumables grades that must be used for the hull steel welding, is stated in the following Table 1:

Table 1 Correlation of welding consumables to hull structural steels

Grades of welding	Hull structural steel grades											
consumables (see notes)	A	B	D	E	A32/36	D32/36	E32/36	F32/36	A40	D40	E40	F40
1, 1S, 1T, 1M, 1TM, IV	X											
1YS, 1YT, 1YM, 1YTM, 1YV	X				2)							
2, 2S, 2T, 2M, 2TM, 2V	X	X	X									
2Y, 2YS, 2YT, 2YM, 2YTM, 2YV	X	X	X		X	X						
2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V	1)	1)	1)		X	X			X	X		
3, 3S, 3T, 3M, 3TM, 3V	X	X	X	X								
3Y, 3YS, 3YT, 3YM, 3YTM, 3YV	X	X	X	X	X	X	X					
3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V	1)	1)	1)	1)	X	X	X		X	X	X	
4Y, 4YS, 4YT, 4YM, 4YTM, 4YV	X	X	X	X	X	X	X	X				
4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V	1)	1)	1)	1)	X	X	X	X	X	X	X	X
5Y40, 5Y40S, 5Y40T, 5Y40M, 5Y40TM, 5Y40V	1)	1)	1)	1)	X	X	X	X	X	X	X	X
1) see note d) 2) see note e)												

NOTES:

(a) When joining normal to higher strength structural steel, consumables of the lowest acceptable grade for either material being joined may be used.

(b) When joining steels of the same strength level but of different toughness grade, consumables of the lowest acceptable grade for either material being joined may be used.

(c) It is recommended that controlled low hydrogen type consumables are to be used when joining higher strength structural steel to the same or lower strength level, except that other consumables may be used at the discretion of TL when the carbon equivalent is below or equal to 0.41%.When other than controlled low hydrogen type electrodes are used appropriate procedure tests for hydrogen cracking may be conducted at the discretion of TL.

(d) The welding consumables approved for steel Grades A40, D40, E40 and/or F40 may also be used for welding of the corresponding grades of normal strength steels subject to the special agreement with TL.

(e) When joining higher strength steels using Grade 1Y welding consumables, the material thicknesses should not exceed 25 mm.

1.2.3 Hydrogen marks

Welding consumables of Grades 2 and 3 and Grades 2Y, 3Y and 4Y and of Grades 2Y40, 3Y40, 4Y40 and 5Y40, for which the hydrogen content has been controlled in accordance with paragraph 4.5.3 are identified by the mark H15, H10 or H5.

1.3 Manufacture

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

2. Approval procedure

2.1 Plant inspection

2.1.1 The Surveyor is to be satisfied that the manufacturer's plant, methods of production and quality control of welding consumables are to be such as to ensure a reasonable uniformity in manufacture, as mentioned in 1.3.1 above.

2.2 Test assemblies

2.2.1 Preparation

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

When a welded joint is performed, the edges of the plates are to be bevelled either by mechanical machining or by oxygen cutting; in the later case, a de-scaling of the bevelled edges is necessary.

2.2.2 Welding conditions

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

2.3 Firms with several factories - sister firms

When a filler product is manufactured in several factories of the same company, the complete series of approval tests should be carried out in one of the works only. In the other factories, a reduced test programme at least equivalent to annual tests is permitted if the manufacturer can certify that the materials used and the fabrication process are identical with those used in the main works.
This requirement is applicable to all manufacturers of filler products under license (sister firms). However, should there be any doubt, complete test-series may be required.

NOTE:

Wire flux combination for submerged arc welding. If a unique powder flux is combined with different wires coming from several factories belonging to the same firm, it may be admitted to perform only one test-series if the different wires are conformable to the same technical specification, after approval of TL.

2.4 Annual inspection and tests

The production techniques and associated quality control procedures at all establishments approved for the manufacture of welding consumables are to be subjected to an annual re-appraisal. On these occasions, samples of the approved consumable are to be selected by the Surveyor and subjected to the tests detailed in subsequent sections of these Requirements. These are to be completed and reported within the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year. Equivalent alternative arrangements may be accepted subject to special agreement with TL.

2.5 Alterations to approved consumables

Any alteration proposed by the manufacturer to the approved consumable which may result in a change in the chemical composition and the mechanical properties of the deposited metal, must be immediately notified to TL. Additional tests may be necessary.

2.6 Upgrading and uprating

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

2.7 Additional tests

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

3. Mechanical testing procedure

3.1 Test specimens

3.1.1 Specimens dimensions

Deposited metal and butt weld tensile, butt weld bend and Charpy V-notch impact test specimens are to be machined to the dimensions given in TL- R W2.

3.1.2 Specimens location and preparation

.1 Deposited metal tensile
The longitudinal axis must coincide with the centre of the weld and:

(i) the mid thickness of the weld in the deposited metal test assemblies;
(ii) the mid thickness of the 2nd run in the two-run welded test assemblies.

The specimens may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal prior to testing.

.2. Butt weld tensile
The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

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

.4 Charpy V-notch impact
The test specimens shall be cut with their longitudinal axes transverse to the weld length and:

(i) at mid thickness of the weld in the deposit metal and butt weld test assemblies with multi-run technique;
(ii) on the 2nd run side, 2 mm maximum below the surface in the two-run welded test assemblies;
(iii) 2 mm maximum below one surface in the electroslag or electrogas welded test assemblies.

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

3.2 Testing procedures

3.2.1 Tensile

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

3.2.2 Bend

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

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

3.2.3 Charpy V-notch impact

Impact tests are to be carried out on a Charpy impact machine of an approved type.

A set of three test specimens is to be prepared and tested. The average absorbed energy value is to comply with the requirements of subsequent sections. One individual value may be less than the required average value provided that it is not less than 70% of this value.

The test temperature for Grades 2, 2Y, 2Y40, 3, 3Y, 3Y40, 4Y, 4Y40 and 5Y40 test pieces is to be controlled to within ±2°C of the prescribed temperature.

3.3 Re-test procedures

3.3.1 Tensile and bend

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

3.3.2 Charpy V-notch impact

Re-test requirements for Charpy impact tests are to be in accordance with TL- R W2. Further re-tests may be made at the Surveyor's discretion, but these must be made on a new welded assembly and must include all tests required for the original assembly, even those which were previously satisfactory.

4. Covered electrodes for manual arc welding

4.1 General

4.1.1 Grades

Depending on the results of the Charpy V-notch impact tests, electrodes are divided into the following grades

- for normal strength steel: Grades 1, 2 and 3
- for higher strength steel with minimum yield strength up to 355 N/mm^2: Grades 2Y and 3Y and 4Y (Grade 1Y not applicable for manual welding).

- for higher strength steels with minimum yield strength up to 390 N/mm^2: Grades 2Y40, 3Y40, 4Y40 and 5Y40.

4.1.2 Hydrogen marks

If the electrodes are in compliance with the requirements of the hydrogen test given in 4.5 hereafter, a suffix H15, H10 or H5 will be added to the Grade mark.

4.2 Deposited metal tests

4.2.1 Preparation of deposited metal test assemblies

Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig 4.1, one with 4 mm diameter electrodes and the other with the largest size manufactured. If an electrode is available in one diameter only, one test assembly is sufficient. Any grade of ship structural steel may be used for the preparation of these test assemblies.

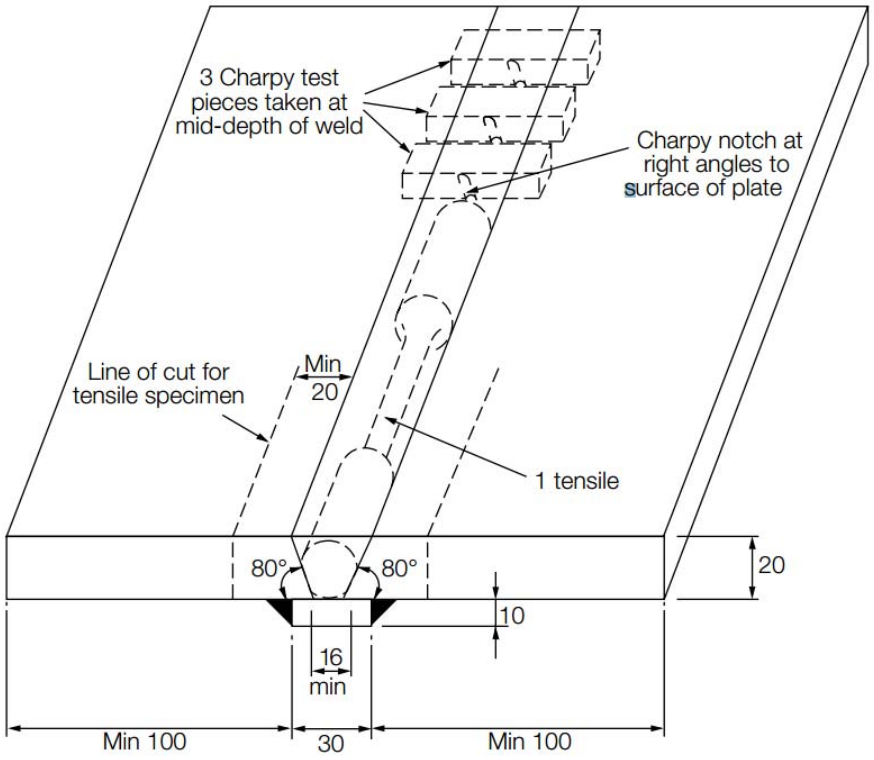


Figure 4.1 Deposited metal test assembly

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

4.2.2 Chemical analysis

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

4.2.3 Execution of tests

One tensile and three impact test specimens are to be taken from each test assembly as shown in Figure 4.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. Tests are to be performed according to Section 3 of these requirements.

4.2.4 Results of tests and requirements

The results of all tests are to comply with the requirements of Table 4a as appropriate.

Table 4a Requirements for deposited metal tests (covered manual electrodes)

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm gauge length (L_0=5 d) % minimum	Charpy V-notch impact tests	
				Test Temperature °C	Average Energy J minimum
1 2 3	305	400-560	22	20 0 -20	47 47 47
2Y 3Y 4Y	375	490-660	22	0 -20 -40	47 47 47
2Y40 3Y40 4Y40 5Y40	400	510-690	22	0 -20 -40 -60	47 47 47 47

4.3 Butt weld tests

4.3.1 Preparation of butt weld test assemblies

Butt weld assemblies as shown in Fig 4.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward and overhead) for which the electrode is recommended by the manufacturer, except that electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position subject to the agreement of TL.

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

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

- Grade 1 electrodes : A
- Grade 2 electrodes : A, B, D

-	Grade 3 electrodes	:	A, B, D, E
-	Grade 2Y electrodes	:	A32, A36, D32, D36
-	Grade 3Y electrodes	:	A32, A36, D32, D36, E32, E36
-	Grade 4Y electrodes	:	A32, A36, D32, D36, E32, E36, F32, F36
-	Grade 2Y40 electrodes	:	A40, D40
-	Grade 3Y40 electrodes	:	A40, D40, E40
-	Grade 4Y40 electrodes	:	A40, D40, E40, F40
-	Grade 5Y40 electrodes	:	A40, D40, E40, F40

Where higher strength steel with minimum yield strength 315 N/mm^2 is used for grade 2Y, 3Y and 4Y electrodes, the actual tensile strength of the steel is to be not less than 490 N/mm^2. The chemical composition including the content of grain refining elements is to be reported.

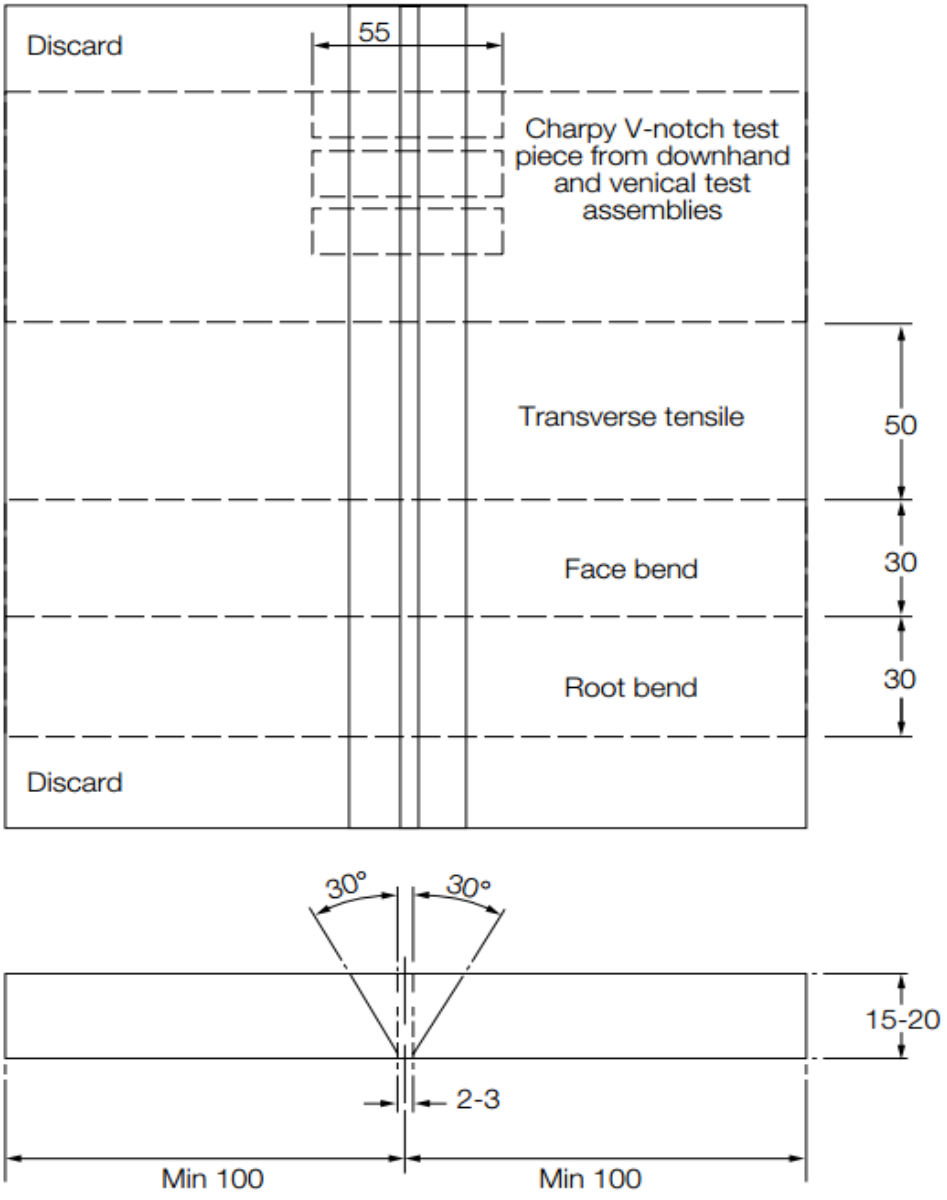


Figure 4.2 Butt weld test assembly

4.3.2 Sequence of welding

The following welding procedure is to be adopted in making test assemblies:

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

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

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

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

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

For all assemblies the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

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

4.3.3 Radiographic examination

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

4.3.4 Execution of tests

The test specimens as shown in Figure 4.2 are to be prepared from each test assembly. Tests are to be performed according to Section 3 requirements.

4.3.5 Result of tests and requirements

The results of all tensile and impact tests are to comply with the requirements of table 4b as appropriate. The position of fracture in the transverse tensile test is to be reported. The bend test specimens can be considered as complying with the requirements if, after bending, no crack or defect having any dimensions exceeding 3 mm can be seen on the outer surface of the test specimen.

Table 4b Requirements for butt weld test (covered manual electrodes)

Grade	Tensile strength (transverse test) N/mm^2	Charpy V-notch impact tests		
		Test Temperature °C	Average energy - J minimum	
			Downhand, horizontal-vertical, overhead	Vertical (upward and downward)
1	400	20	47	34
2		0	47	34
3		-20	47	34
2Y	490	0	47	34
3Y		-20	47	34
4Y		-40	47	34
2Y40	510	0	47	39
3Y40		-20	47	39
4Y40		-40	47	39
5Y40		-60	47	39

4.4 Hot cracking test

4.4.1 Hot cracking test may be required at the discretion of TL.

4.5 Hydrogen test

4.5.1 Hydrogen marks

At the request of the manufacturer, electrodes may be submitted to a hydrogen test. A suffix H15, H10 or H 5 will be added to the grade number to indicate compliance with the requirements of this test.

4.5.2 Execution of hydrogen test

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

Measuring Method		Test Temperature (°C)	Minimum Holding Time (h)
Thermal Conductivity Detector Method (1)	Gas Chromatography	45	72
		150	6

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

The use of the glycerine method may be admitted at TL discretion. This method is described hereafter.

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

The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer. Within 30 seconds of the completion of the welding of each specimen the slag is to be removed and the specimen quenched in water at approximately 20°C.

After 30 seconds in the water, the specimen is to be cleaned and dried, and then placed in an apparatus suitable for the collection of hydrogen by displacement of glycerine. The glycerine is to be kept at a temperature of 45°C during the test. All four specimens are to be welded and placed in individual hydrogen collecting apparatus within a period of time which will limit any variation in hydrogen content due to variation in exposure to moisture absorption following any drying treatment. This should not exceed 30 minutes.

The specimens are to be kept immersed in the glycerine for a period of 48 hours and, after removal, are to be cleaned in water and spirit dried and weighed to the nearest 0.1 gram to determine the amount of weld deposit. The amount of gas involved is to be measured to the nearest 0.05 cm^3 and corrected for temperature and pressure to 0°C and 760 mm Hg.

4.5.3 Results to be obtained

The individual and average diffusible hydrogen contents of the four specimens are to be reported, and the average value in cm^3 per 100 grams is not to exceed the following:

Mark	Diffusible Hydrogen Contents	Measuring Method
H 15	15[1]	Mercury Method Thermal Conductivity Detector Method Glycerine Method
H 10	10[2]	
H 5	5	Mercury Method Thermal Conductivity Detector Method
[1] 10 cm^3 per 100 grams where the glycerine method is used. [2] 5 cm^3 per 100 grams where the glycerine method is used.		

Note: The glycerine method is not to be used for the welding consumables with H 5 mark.

4.6 Covered electrodes for manual fillet welding

4.6.1 General

Where an electrode is submitted only to approval for fillet welding and to which the butt weld test provided in 4.3 is not considered applicable, the first approval tests are to consist of the fillet weld tests given in 4.6.2, and deposited metal tests similar to those indicated in 4.2. Where an electrode is submitted to approval for both butt and fillet welding, the first approval tests may, at the discretion of TL, include one fillet weld test as detailed hereunder and welded in the horizontal-vertical position.

4.6.2 Fillet weld test assemblies

When the electrode is proposed only for fillet welding, fillet weld assemblies as shown in figure 4.3, are to be prepared for each welding position (horizontal-vertical, vertical upwards, vertical downwards or overhead) for which the electrode is recommended by the manufacturer. The length of the test assemblies L is to be sufficient to allow at least the deposition of the entire length of the electrode being tested.

The grade of steel used for the test assemblies is to be as detailed in 4.3.1.

The first side is to be welded using the maximum size of electrode manufactured and the second side is to be welded using the minimum size of electrode manufactured and recommended for fillet welding.

The fillet size will in general be determined by the electrode size and the welding current employed during testing.

4.6.3 Tests on fillet weld assemblies

.1 Macrographs

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

.2 Hardness

At the discretion of TL, the hardness of the weld, of the heat affected zone (HAZ) and of parent metal may be determined, and reported for information (see figure 4.4).

.3 Fracture

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

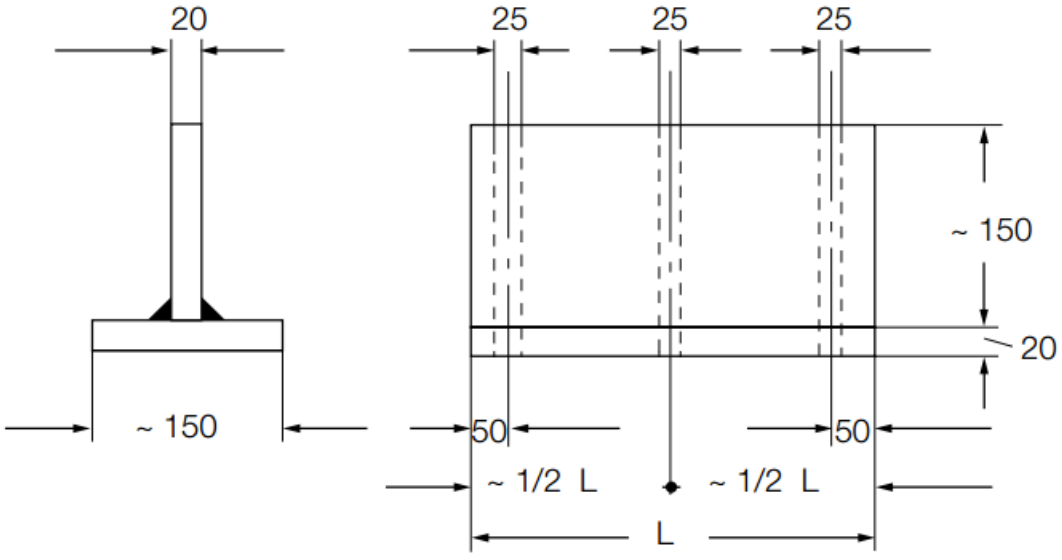


Figure 4.3 Fillet weld test assembly

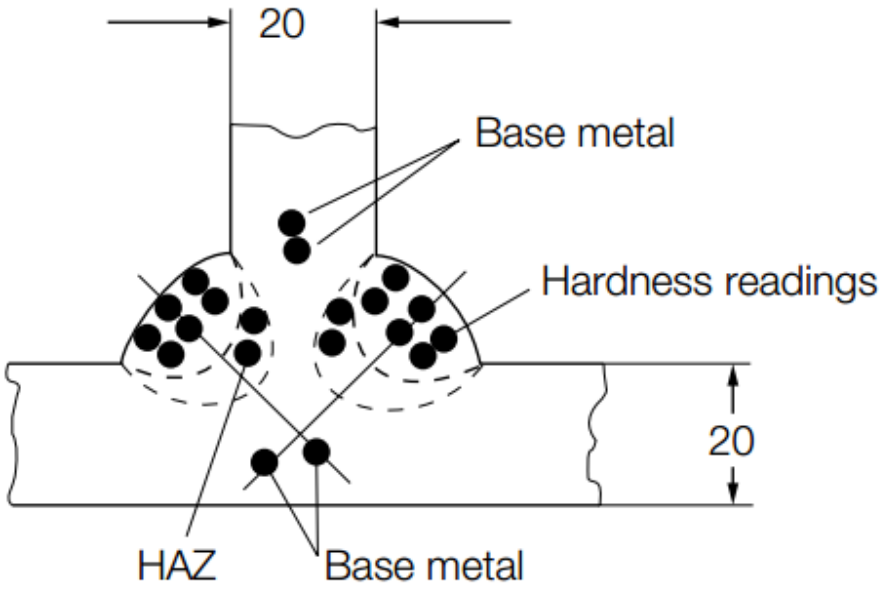


Figure 4.4 Hardness readings

4.7 Covered electrodes for gravity or contact welding

Where an electrode is submitted solely to approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, fillet weld tests (see 4-6) and, where appropriate, but weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

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

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

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

4.8 Annual tests and upgrading

4.8.1 Annual tests and periodical inspection of manufacturer's plant
All establishments where approved electrodes are manufactured shall be subject to annual inspection.

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

.1 Covered electrode for normal manual arc welding

Two deposited metal test assemblies are to be prepared in accordance with 4.2. The mechanical properties (one tensile test, 3 Charpy-V impact tests on each assembly) are to be

in accordance with Table 4.a. This also applies to electrodes which are approved only for fillet welding.

At the discretion of TL a butt weld test to be welded in down-hand or in vertical position, can be required in lieu of the deposited metal test 4 mm electrodes. Three Charpy V-notch impact test specimens are to be taken from the butt weld assembly.
For Mark H 10 and Mark H 5 covered electrodes, a hydrogen test following 4.5 can also be required for each annual test at the discretion of TL.

.2 Covered electrodes for gravity or contact welding

Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer. If this electrode is approved also for normal manual arc welding the annual test is to be performed according to 4.8.1.1.

4.8.2 Upgrading and uprating of electrodes

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

.2 Upgrading refers to notch toughness and consequently, only Charpy V impact tests are required from the respective butt-weld assemblies as required by 4-3 (downhand, horizontal vertical, vertical up or/and down, overhead, as applicable), and have to be performed at the upgraded temperature.

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

.3 Uprating refers to the extension of approval in order to cover the welding of higher strength steels; of course, welding of normal strength steels continue to be covered by the extended approval, as stated in 1.2.1.

For this purpose all butt-weld tests are to be made again, as required in 4.3 and using higher strength steel, as parent metal.

5. Wire flux combinations for submerged arc welding

5.1 General

5.1.1 Categories

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

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

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

5.1.2 Grades

Depending on the results of impact tests, wire-flux combinations are divided into the following grades:

- For normal strength steel: Grades 1, 2 or 3
- For higher strength steels with minimum yield strength up to 355 N/mm^2: Grades 1Y, 2Y, 3Y or 4Y.
- For higher strength steels with minimum yield strength up to 390 N/mm^2: Grades 2Y40, 3Y40, 4Y40 or 5Y40.

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

5.1.3 Multiple electrode submerged arc welding

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

5.1.4 Mechanical tests on assemblies

Mechanical tests on assemblies with submerged arc welding for wire/flux approval are given in Table 5a.

5.2 Approval tests for multi-run technique

5.2.1 Grades of steel

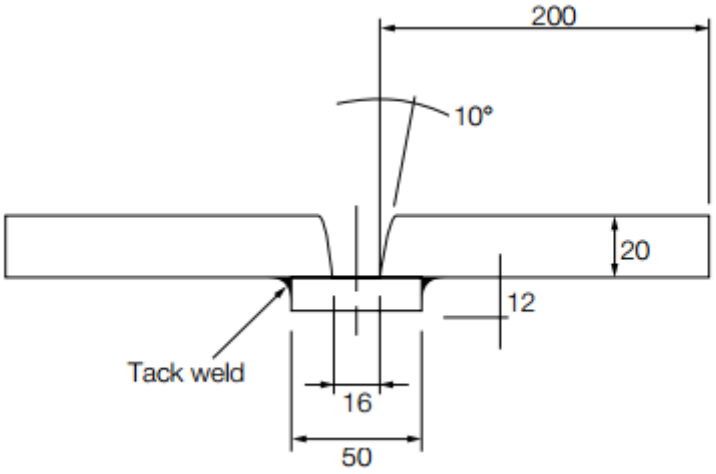
Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.
For deposited metal test assembly any grade of ship structural steel may be used.
For butt weld test assembly one of the grades of steel as listed below for the individual grades of wire-flux combinations shall be used:

- Grade 1 wire-flux combinations: A
- Grade 2 wire-flux combinations: A, B, D
- Grade 3 wire-flux combinations: A, B, D, E
- Grade 1Y wire-flux combinations: A32, A36
- Grade 2Y wire-flux combinations: A32, A36, D32, D36
- Grade 3Y wire-flux combinations: A32, A36, D32, D36, E32, E36
- Grade 4Y wire-flux combinations: A32, A36, D32, D36, E32, E36, F32, F36
- Grade 2Y40 wire-flux combinations: A40, D40
- Grade 3Y40 wire-flux combinations: A40, D40, E40
- Grade 4Y40 wire-flux combinations: A40, D40, E40, F40
- Grade 5Y40 wire-flux combinations: A40, D40, E40, F40

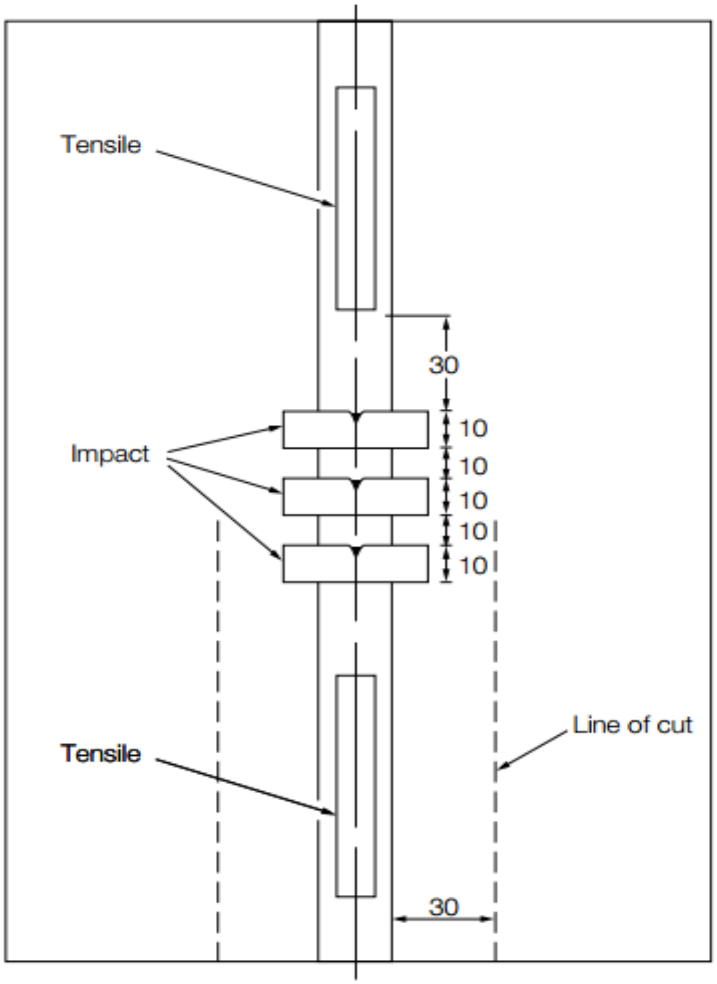
5.2.2 Deposited metal test assembly

.1 Preparation

One deposited metal test assembly is to be prepared as shown in Figure 5.1



All dimensions in mm unless otherwise indicated



All dimensions in mm unless otherwise indicated

Figure 5.1

Table 5a General table giving the mechanical tests on assemblies with submerged arc welding for wire/flux approval

M (multi-run technique)		T (two-run technique)		TM (two-run and multi-run technique)			
Deposited metal assembly	Butt weld assembly	Butt weld assembly (minimum thickness)	Butt weld assembly (maximum thickness)	Deposited metal assembly	Butt Weld Assembly		
					Multi-run technique	Two-run technique	
						(Minimum thickness)	(Maximum thickness)
3 CV 2 LT	2 TT 4 TB 3 CV	2 TT 2 TB 3 CV	2 TT 2 TB 3 CV 1LT	3 CV 1 LT	2 TT 4 TB 3 CV	2 TT 2 TB 3 CV	2 TT 2 TB 3 CV 1 LT

Symbol Definition: TT: Transverse Tensile Test on the butt weld assembly
TB: Transverse Bend Test on the butt weld assembly
CV: Charpy-V Impact Test in the axis of the weld
LT: Longitudinal Tensile Test in the weld

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

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

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

.3 Execution of tests
In accordance with Table 5a, the test specimens as shown in Figure 5.1 are to be prepared from each test assembly. Tests are to be performed according to Section 3 requirements.

.4 Results and requirements
The results of all tests are to comply with the requirements of Table 5b, as appropriate.

Table 5b Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm^2 minimum	Tensile Strength N/mm^2	Elongation on 50 mm gauge length ($L_o = 5$ d) % minimum	Charpy V-notch impact tests	
				Test Temperature °C	Average Energy J minimum
1	305	400-560	22	20	34
2				0	34
3				-20	34
1Y	375	490-660	22	20	34
2Y				0	34
3Y				-20	34
4Y				-40	34
2Y40	400	510-690	22	0	39
3Y40				-20	39
4Y40				-40	39
5Y40				-60	39

5.2.3 Butt Weld Test Assembly

.1 Preparation

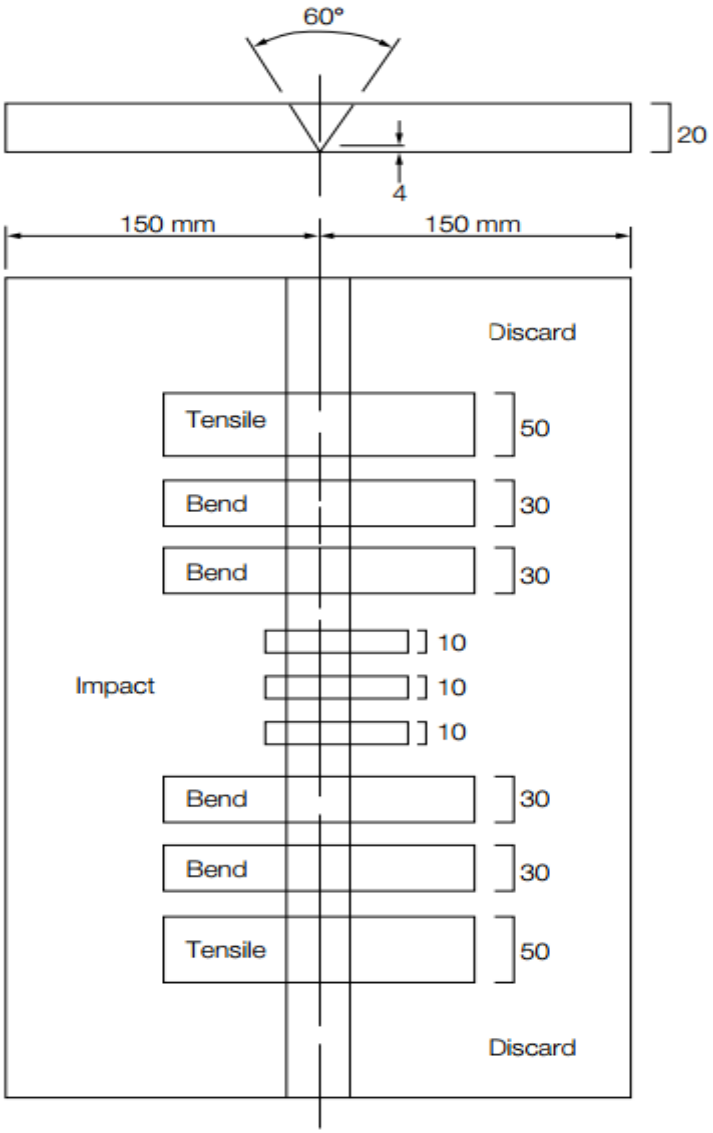
One butt weld test assembly is to be prepared as shown in Figure 5.2 in the downhand position by welding together two plates (20 to 25 mm thick), each not less than 150 mm in width and sufficient length to allow the cutting out of test specimens of the prescribed number and size.

The plate edges are to be prepared to form a single vee joint, the included angle between the fusion faces being 60° and the root face being 4 mm.

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

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

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



All dimensions in mm unless otherwise indicated

Figure 5.2 Multi-run butt weld test assembly (submerged arc welding)

.2 Radiographic examination

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

.3 Execution of tests

The test specimen to be prepared from the welded assembly are given in Table 5a and shown in Fig. 5.2. The tests are to be performed according to the requirements of Section 3.

.4 Results of tests and requirements

The results of all tensile and impact tests are to comply with the requirements of Table 5c as appropriate. The position of the fracture in the transverse tensile test is to be reported.

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

Table 5c Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength (transverse test) N/mm^2	Charpy V-notch impact tests	
		Test temperature ^oC	Average energy J minimum
1	400	20	34
2		0	34
3		-20	34
1Y	490	20	34
2Y		0	34
3Y		-20	34
4Y		-40	34
2Y40	510	0	39
3Y40		-20	39
4Y40		-40	39
5Y40		-60	39

5.3 Approval tests for two run techniques

5.3.1 Number of test assemblies

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

- For grades 1 and 1Y: 12 to 15 mm and 20 to 25 mm
- For Grades 2, 2Y, 3, 3Y and 4Y: 20 to 25 mm and 30 to 35 mm
- For Grades 2Y40, 3Y40, 4Y40 and 5Y40: 20 to 25 mm and 30 to 35 mm

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

When a wire-flux combination is offered to approval for use with the two-run technique only, it is reminded that no deposited metal test assemblies have to be done. In this case approval tests are limited to the butt welds on two-run assemblies described in 5.3.2 hereafter.

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

5.3.2 Butt weld test assemblies

.1 Preparation of assemblies

The maximum diameter of wire, grades of steel plate and edge preparation to be used are to be in accordance with Fig. 5.3. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The root gap should not exceed 1 mm.

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

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

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

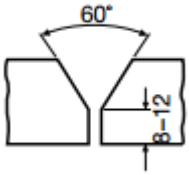
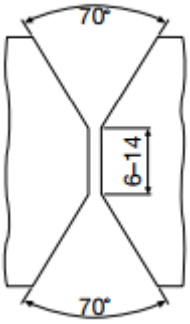
Plate thickness [mm]	Recommended preparation [mm]	Maximum diameter of wire [mm]	Grade wire-flux combination	Grade of normal strength steel	Grade of higher strength steel
about 12-15		5	1 1Y	A -	 A32, A36
about 20-25		6	1 1Y 2 2Y 2Y40 3 3Y 3Y40 4Y 4Y40 5Y40	A - A, B or D - - A, B, D or E - - - - -	- A32, A36 - A32, A36, D32, D36 A40, D40 - A32, A36, D32 D36, E32, E36 A40, D40, E40 A32, A36, D32, D36, E32, E36, F32, F36 A40, D40, E40, F40 A40, D40, E40, F40
about 30-35		7	2 2Y 2Y40 3 3Y 3Y40 4Y 4Y40 5Y40	A, B or D - - A, B, D or E - - - - -	- A32, A36, D32, D36 A40, D40 - A32, A36, D32, D36, E32, E36 A40, D40, E40 A32, A36, D32, D36 E32, E36, F32, F36 A40, D40, E40, F40 A40, D40, E40, F40

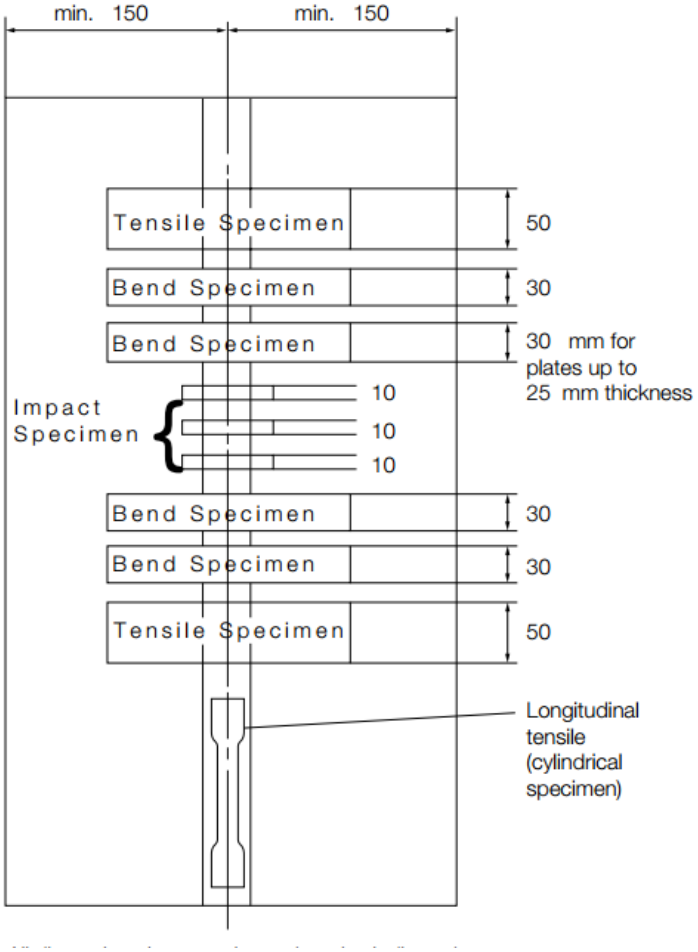
Figure 5.3 Butt weld test assemblies (two-run technique)

.2 Radiographic examination

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

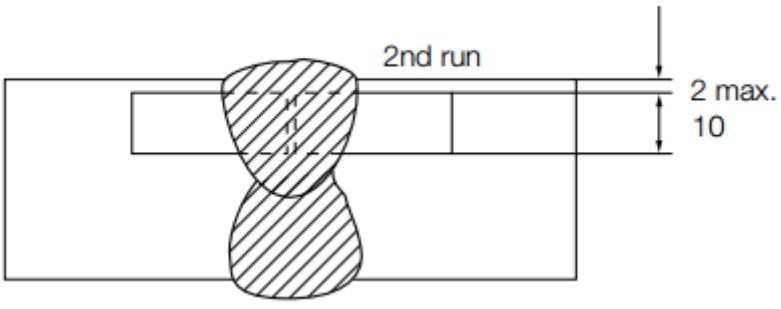
.3 Execution of tests

The test specimens indicated in Table 5a and shown in Figure 5.4 are to be prepared from each test assembly. Tests are to be performed according to Section 3 requirements. The Charpy V-notch impact test specimens are to be machined from each welded assembly from the positions and with the orientations shown in Fig. 5.5.



All dimensions in mm otherwise indicated

Figure 5.4



All dimensions in mm otherwise indicated

Figure 5.5

.4 Results of tests and requirements

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

.5 Chemical analysis

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

5.4 Annual tests – upgrading

5.4.1 Annual tests

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

Annual tests are to consist of at least the following:

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

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

Where a wire-flux combination is approved for welding both normal strength and higher strength steel, the latter steel is to be used for the preparation of the butt weld assembly required by 5.4.1 b).

5.4.2 Upgrading and rating

5.4.2.1 Upgrading of wire-flux combinations in connection with the impact properties will be considered as detailed in 4.8.2.2, and for wire-flux combinations approved for two runs welding, a butt-weld in the maximum thickness approved is to be made and sampled for Charpy-V testing in accordance with 5.3.2.3.

5.4.2.2 Uprating of wire-flux combinations in connection with the tensile properties will be considered as detailed in 4.6.2.3.

6. Wires and wire-gas combinations for metal arc welding

6.1 General

6.1.1 Categories

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

a) For use in semi-automatic multi-run welding.
b) For use in single electrode automatic multi-run welding.
c) For use in single electrode automatic two-run welding.

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

6.1.2 Grades and suffixes

.1 Depending on the results of impact tests, wires and wire-gas combinations are divided into the following grades:

- For normal strength steel Grades 1, 2 and 3;
- For higher strength steels with minimum yield strength up to 355 N/mm^2: Grades 1Y, 2Y, 3Y and 4Y.
- For higher strength steels with minimum yield strength up to 390 N/mm^2: Grades 2Y40, 3Y40, 4Y40 and 5Y40.

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

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

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

6.1.3 Composition of shielding gas

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

.2 The approval of a wire in combination with any particular gas can be applied or transferred to any combination of the same wire and any gas in the same numbered group as defined in Table 6a, subject to the agreement of TL.

Table 6a Compositional limits of designated groups of gas types and mixtures.

Group		Gas composition (Vol. %)			
		Co_2	O_2	H_2	A_r
M1	1	> 0 to 5	-	> 0 to 5	Rest 1) 2)
	2	> 0 to 5	-	-	Rest 1) 2)
	3	-	> 0 to 3	-	Rest 1) 2)
	4	> 0 to 5	> 0 to 3	-	Rest 1) 2)
M2	1	> 5 to 25	-	-	Rest 1) 2)
	2	-	> 3 to 10	-	Rest 1) 2)
	3	> 5 to 25	> 0 to 8	-	Rest 1) 2)
M3	1	> 25 to 50	-	-	Rest 1) 2)
	2	-	> 10 to 15	-	Rest 1) 2)
	3	> 5 to 50	> 8 to 15	-	Rest 1) 2)
C	1	100	-	-	-
	2	Rest	> 0 to 30	-	-

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

6.1.4 Low hydrogen approval

.1 Flux-cored or flux-coated wires which have satisfied the requirements for Grades 2, 2Y, 2Y40, 3, 3Y, 3Y40, 4Y, 4Y40 and 5Y40 may, at manufacturer's option, be submitted to the hydrogen test as detailed in 4.5, using the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weight of weld deposit per sample similar to that deposited when using manual electrodes.

.2 A suffix H15, H10 or H5 will be added to the grade mark, in the same conditions as for manual arc welding electrodes (see 4.5.3 above) to indicate compliance with the requirements of the test.

6.2 Approval for semi-automatic multi-run welding

6.2.1 General

Approval tests for semi-automatic multi-run welding are to be carried out generally in accordance with Section 4, except as required by 6.2, using the semi-automatic multi-run technique for the preparation of all test assemblies.

6.2.2 Preparation of deposited metal assemblies

.1 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 4.1, one using the smallest diameter, and the other using the largest diameter of wire intended for the welding of ship structures. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

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

6.2.3 Chemical analysis

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

6.2.4 Mechanical tests

On each assembly, tests are to be made in accordance with 4.2.3, and the results are to comply with the requirements of 4.2.4, appropriate to the required grade.

6.2.5 Preparation of butt weld assemblies

.1 Butt weld assemblies as shown in Fig. 4.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical upwards, vertical downwards and overhead) for which the wire or wire-gas combination is recommended by the manufacturer.

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

.3 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using wires of different diameter from those required by 6.2.5.2. Where only one diameter is manufactured, only one downhand butt weld assembly is to be prepared.

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

6.2.6 Radiographic examination

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

6.2.7 On each assembly, tests are to be made in accordance with 4.3.4, and the results are to comply with the requirements of 4.3.5.

6.2.8 Fillet weld tests

Fillet weld test assemblies are required to be made in accordance with 4.6.1 and 4.6.2, and tested in accordance with 4.6.3.

6.3 Approval for automatic multi-run welding

6.3.1 General

Approval tests for automatic multi-run welding are to be carried out generally in accordance with section 5 multi-run approval, except as required by 5.2, using the automatic multi-run technique for the preparation of all test assemblies.

6.3.2 Preparation of deposited metal assembly

One deposited metal assembly is to be prepared as shown in Fig. 5.1. Welding is to be as detailed in 5.2.2.1, except that the thickness of each layer is to be not less than 3 mm.

6.3.3 Chemical analysis

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

6.3.4 Mechanical tests

Tests on this assembly are to be made in accordance with 5.2.2.3, and the results are to comply with the requirements of 5.2.2.4.

6.3.5 Preparation of butt weld assemblies

One butt weld assembly is to be prepared in each welding position which is to be approved. Generally, this will be the downhand position only, in which case only one assembly is required. Preparation of the assembly is to be in accordance with 5.2.3.1.

6.3.6 Radiographic examination

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

6.3.7 Mechanical tests

Tests are to be made on each assembly in accordance with 5.2.3.3 and the results are to comply with the requirements of Table 5c. Where more than one assembly is prepared and tested, the number of transverse tensile and bend test specimens from each assembly may be halved.

6.3.8 Discretionary approval

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

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

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

6.4 Approval for automatic two-run welding

6.4.1 General

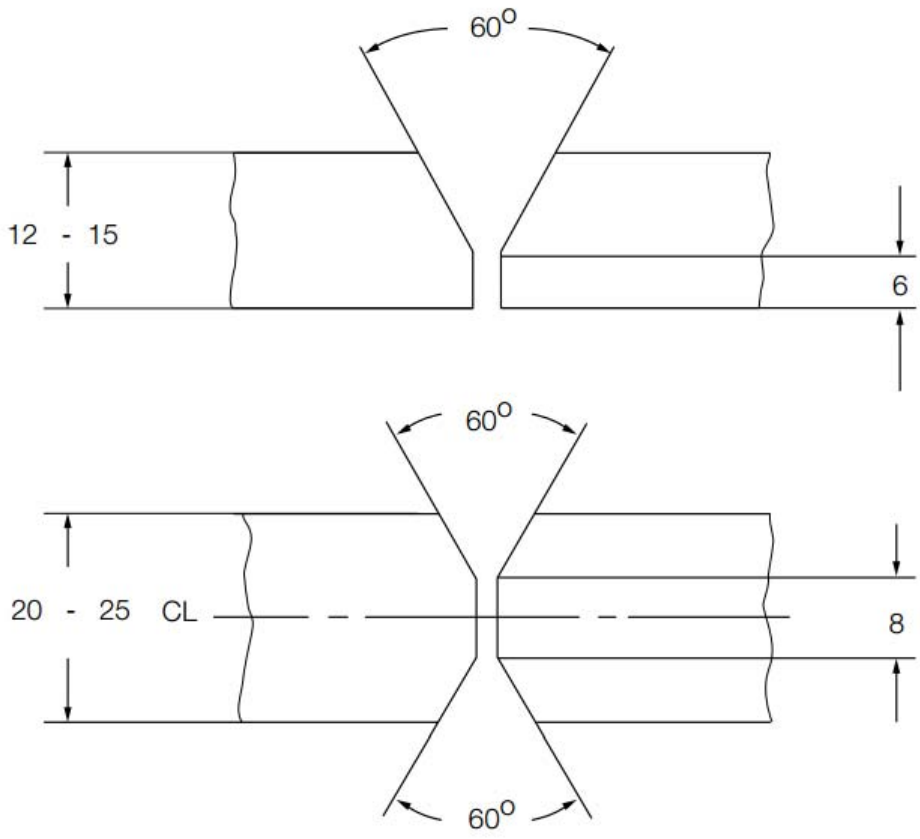
Approval tests for automatic two-run welding are to be carried out generally in accordance with the requirements of Section 5.3, except as required by 6.4, using the automatic two-run welding technique for the preparation of all test assemblies.

6.4.2 Preparation of butt weld assemblies

.1 Two butt weld test assemblies are to be prepared, generally as detailed in 5.3.1 and 5.3.2, using plates 12-15 mm and 20-25 mm in thickness. If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

.2 The plate preparation of the test assemblies is to be as shown in Fig. 6.1. Small deviations in the edge preparation may be allowed, if requested by the manufacturer. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for

information. Deviations or variations will be expected to form part of the manufacturer's standard recommended procedure for this technique and thickness range.



All dimensions in mm unless otherwise indicated

Figure 6.1 Recommended edge preparation for two-run butt weld test assemblies

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

6.4.3 Radiographic examination

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

6.4.4 Mechanical tests

Tests are to be made on each assembly in accordance with 5.3.2.3 to 5.3.2.6 and the results are to comply with the requirements of 5.2.2.4 and Table 5c.

6.4.5 Chemical analysis

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

6.5 Annual tests and up-grading

6.5.1 Annual tests

.1 Annual tests are to consist of at least:

a) Wires approved for semi-automatic or both semi-automatic and automatic multi-run welding : one deposited metal test assembly prepared in accordance with 6.2.2 using a wire of diameter within the range approved for the semi-automatic multi-run welding of ship structures.

b) Wires approved for automatic multi-run welding: one deposited metal test assembly prepared in accordance with 6.3.2 using a wire of diameter within the range approved for automatic multi-run welding of ship structures.

c) Wires approved for automatic two-run welding: one butt weld test assembly prepared in accordance with 6.4.2 using plates of 20-25 mm in thickness. The wire diameter used is to be reported.

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

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

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

Note:
At the discretion of TL, hydrogen test can be carried out following 4.5.

6.5.2 Up-grading and up-rating

.1 Up-grading of flux cored wires and wire-gas combinations in connection with the impact properties will be considered as detailed in 4.8.2.2.

.2 Up-rating of flux cored wires and wire-gas combinations with the tensile properties will be considered as detailed in 4.8.2.3.

7. Consumables for use in eletroslag and electrogas vertical welding

7.1 General

7.1.1 The requirements for the two-run technique as detailed in Section 5 are applicable for the approval of special consumables used in electro-slag and electro-gas vertical welding with or without consumable nozzles except as otherwise required by the following requirements especially as regards the number and kind of the test-pieces used for the mechanical tests and taken from the butt welded assemblies.

7.1.2 For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40, 4Y40 and 5Y40 approval of the consumables may be restricted for use only with specific types of higher strength steel. This is in respect of the content of grain refining elements, and if general approval is required, a niobium treated steel is to be used for the approval tests.
7.1.3 For these special welding consumables, the prescription 1.2.1 may not be entirely applicable for technical reasons.

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

7.2 Butt weld tests

7.2.1 Preparation of test assemblies

Two butt weld test assemblies are to be prepared, one of them with plates 20/25 mm thick, the other with plates 35/40 mm thick or more. The grade of the steel to be used for each one of these assemblies must be selected according to the requirements given in the figure 5.3 for two-run submerged arc welding.

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

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

7.2.2 Radiographic examination

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

7.2.3 Test series

Each assembly shall be cut to give test specimens according to Figure 7.1.

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

- 2 longitudinal tensile test specimens with their axis at the centre of the weld.
- 2 transverse tensile test specimens.
- 2 side bend test specimens.
- 2 sets of 3 Charpy-V notch impact test specimens in accordance with Figure 7.1:

  .1 set with the notch in the axes of the weld,

.1 set with the notch at 2 mm from the fusion line in the deposited metal.

- 2 macro-sections to the weld (towards the middle of the weld and towards one end).

7.2.4 Results to be obtained

The results of the tensile, bend and impact tests are to comply with the requirements of paragraph 5.3 (two-run welding) for the class of filler product in question.

7.3 Annual tests and up-grading

7.3.1 All factories which manufacture approved consumables for use in electroslag and electrogas welding must be subject to an annual inspection and tests in accordance with 2.4.

7.3.2 One test assembly must be prepared from plates 20/25 mm thick, and tested as indicated in 7.2.
The following specimens are to be selected:

- 1 longitudinal tensile specimen from the axis of the weld,
- 1 transverse tensile specimen,
- 2 side bend specimens,
- 3 Charpy-V specimens notched at the centre of the weld (position 1 Fig. 7.1),
- 3 Charpy-V specimens cut out transverse to the weld with their notches at 2 mm from the fusion line, in the weld,
- macro section.

7.3.3 The results to be obtained should meet the requirements given in 5.3 (two-run welding) for the class of the consumables in question.

7.3.4 Upgrading and uprating

Upgrading and uprating will be considered only at the manufacturers' request, at the time of annual testing. Generally, for this purpose, full tests from butt weld assemblies as indicated in 7.2 will be required, irrespective of the other tests requested if the concerned consumable is also approved (and possibly upgraded or uprated) according to Section 5 or Section 6.

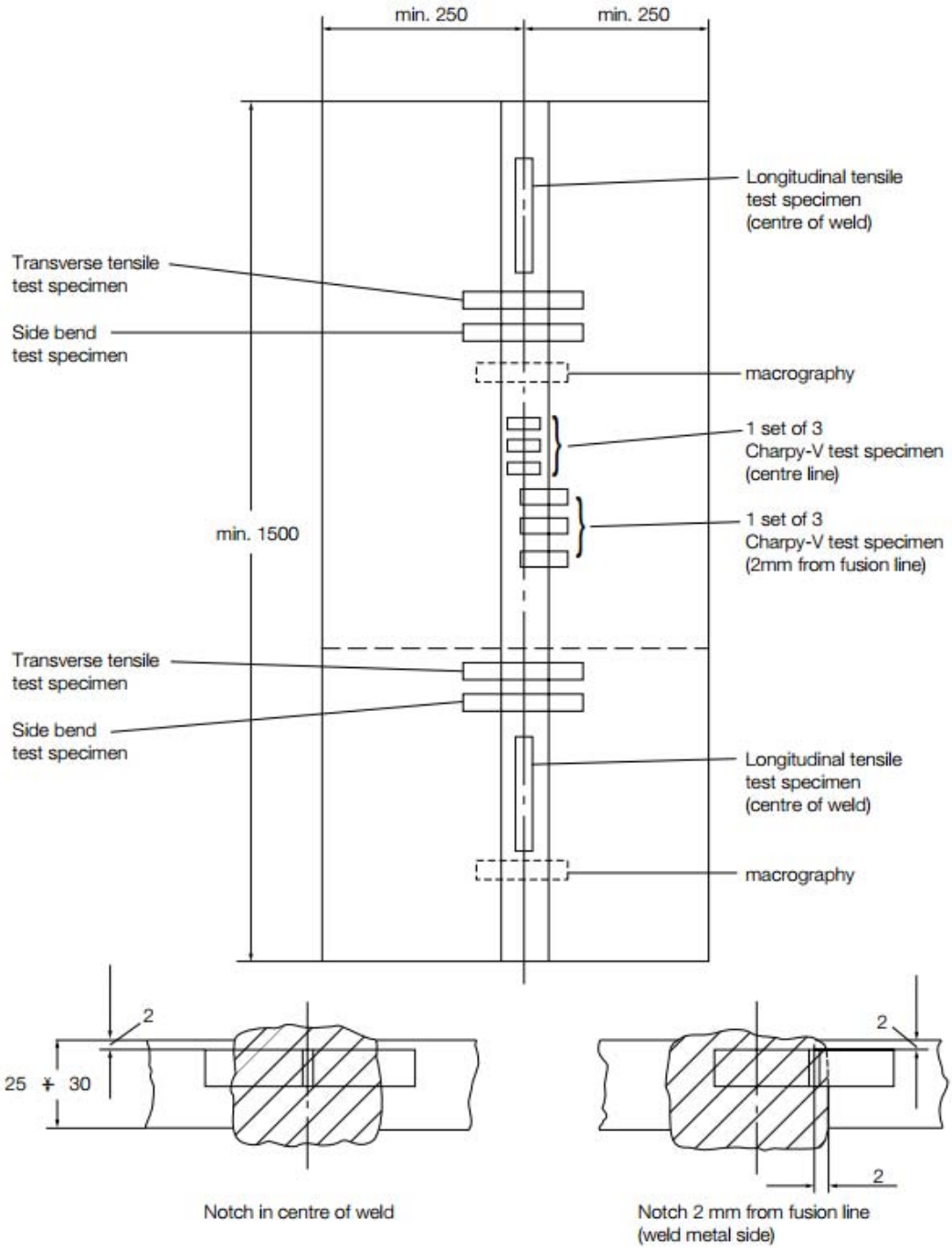


Figure 7.1 Electroslag and electrogas butt weld test assembly

TL- R W18 Anchor chain cables and accessories including chafing chain for emergency towing arrangements

W18.1 General requirements

1.1 Scope

These rules apply to the materials, design, manufacture and testing of stud link anchor chain cables and accessories used for ships. Where, in exceptional cases, studless short link chain cables are used with the consent of TL, they must comply with recognized national or international standards. The requirements for chafing chain for Emergency Towing Arrangements (ETA) are given in the Appendix A.

1.2 Chain cable grades

Depending on the nominal tensile strength of the chain cable steel used for manufacture, stud link chain cables are to be subdivided into Grades 1, 2 and 3.

1.3 Approval of chain manufacturers

1.3.1 Anchor chain cables and accessories are to be manufactured only by works approved by TL. For this purpose approval tests are to be carried out, the scope of which is to be agreed with the TL.

1.3.2 Applications for approval are to be made to TL, stating the method of manufacture used, the grades of materials, the nominal dimensions and - where applicable - the material specification. A procedure test carried out on a high-strength chain cable may cover approval of lesser grades, provided that the material type, method of manufacture and the nature of the heat treatment are the same.

W18.2 Materials

2.1 Scope

These rules apply to rolled steels, forgings and castings used for the manufacture of anchor chain cables and accessories.

2.2 Requirements for material manufacturers

2.2.1 All materials used for the manufacture of anchor chain cables and accessories are to be supplied by manufacturers approved by TL. TL approval is not required for Grade 1 steel bars.

2.2.2 Materials suppliers or chain cable manufacturers are to submit specifications for Grade 3 steel bars. These specifications should contain all necessary details, such as manufacturing procedure, deoxydation practice, specified chemical composition, heat treatment, and mechanical properties.

2.2.3 (void)

▶

2.3 Rolled steel bars

2.3.1 Supply condition
Unless otherwise stipulated, the steel bars will be supplied in as rolled condition.

2.3.2 Chemical composition
The chemical composition of the steel bars is to be generally within the limits given in Table 1.

Table 1 Chemical composition of rolled steel bars

Grade	Chemical composition in maximum percent, unless specified.					
	C	Si	Mn	P	S	Al tot [1] min.
1	0.20	0.15-0.35	min. 0.40	0.040	0.040	NR
2[2]	0.24	0.15-0.55	1.60	0.035	0.035	0.020
3[3]	In accordance with an approved specification					

[1] Aluminum may be replaced partly by other grain refining elements.
[2] If TL agrees, additional alloying elements may be added.
[3] To be killed and fine grain.
NR = Not required.

2.3.3 Mechanical tests

2.3.3.1 Mechanical tests representing the steel bars are normally to be carried out by the steel mill, and the results are to meet the requirements in Table 2. The test coupons are to be in a heat treatment condition equivalent to that of the finished chain cable and accessories.

Table 2 Mechnical properties of rolled steel bars

Grade	R_{eH} N/mm² min.	R_m N/mm²	A_5 % min.	Z % min.	Charpy V-notch impact test	
					Test temp. in °C	Absorbed energy in Joules, min.
1	NR	370-490	25	NR	NR	NR
2	295	490-690	22	NR	0	27[1]
3	410	min. 690	17	40	0[2]	60
					-20	35

[1] The impact test of Grade 2 materials may be waived, if the chain cable is to be supplied in a heat treated condition as per Table 6.
[2] Testing is normally to be carried out at 0°C.

NR = Not required.

▶

2.3.3.2 For performance of the mechanical tests the steel bars shall be sorted according to heats and diameters into test units not exceeding 50 tons each. From each test unit a test sample shall be taken for the tests mentioned in 2.3.3.4 and 2.3.3.5. Prior to sampling, the test samples must be subjected to the heat treatment provided for the finished chain cable; see Section 3.3. Details of the heat treatment must be indicated by the chain cable manufacturer.

2.3.3.3 Tensile and Charpy V-notch impact test specimens shall be taken from the test sample in the longitudinal direction at a distance of 1/6 diameter from the surface or as close as possible to this position, as shown in Figure 1.

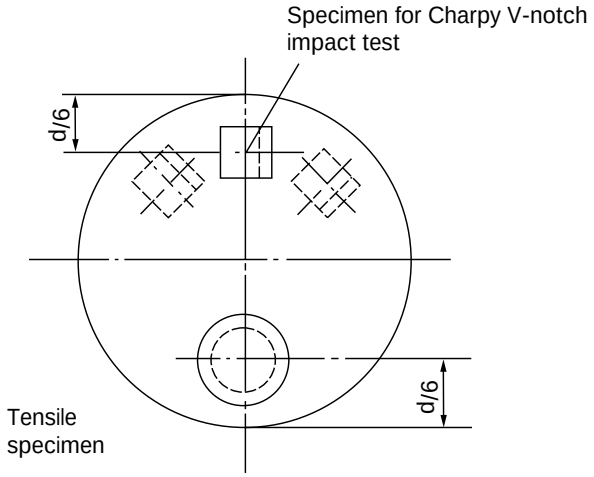


Figure 1 Sampling Locations

2.3.3.4 For the tensile test, one specimen shall be taken from each test unit and tested, all in accordance with TL- R W2.

2.3.3.5 One set of longitudinal Charpy V-notch test specimens shall be taken from each test unit and tested at the temperature prescribed in Table 2, all in accordance with TL-R W2. The specimen transverse axis is to be radial to the steel bar. The average value obtained from one set of three impacts specimens is to comply with the requirements given in Table 2. One individual value only may be below the specified average value provided it is not less than 70% of that value.

2.3.3.6 Re-test requirements for tensile tests are to be in accordance with TL- R W2 with specimens taken from the same sample. Failure to meet the specified requirements of either of both additional tests will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment; see 2.3.3.8.

2.3.3.7 Re-test requirements for Charpy impact tests are to be in accordance with TL- R W2. Specimens are to be selected from the same sample. Failure to meet the requirements will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment; see 2.3.3.8.

2.3.3.8 If failure to pass the tensile test or the Charpy V-notch impact test is definitely attributable to improper heat treatment of the test sample, a new test sample may be taken from the same piece and reheat treated. The complete test (both tensile and impact test) is to be repeated; and the original results obtained may be disregarded.

2.3.4 Dimensional tolerances
The diameter and roundness shall be within the tolerances specified in Table 3 unless otherwise agreed.

Table 3 Dimensional tolerance of rolled steel bars

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness (d_{max} - d_{min}) mm
less than 25	-0 + 1.0	0.6
25 - 35	-0 + 1.2	0.8
36 - 50	-0 + 1.6	1.1
51 - 80	-0 + 2.0	1.5
81 - 100	-0 + 2.6	1.95
101 - 120	-0 + 3.0	2.25
121 - 160	-0 + 4.0	3.00

2.3.5 Freedom from defects
The materials have to be free from internal and surface defects that might impair proper workability and use. Surface defects may be repaired by grinding, provided the admissible tolerance is not exceeded.

2.3.6 Identification of material
Manufacturers are to effectively operate an identification system ensuring traceability of the material to the original cast.

2.3.7 Marking
The minimum markings required for the steel bars are the manufacturers' brandmark, the steel grade and an abbreviated symbol of the heat. Steel bars having diameters of up to and including 40 mm and combined into bundles, may be marked on permanently affixed labels.

2.3.8 Material certification
Bar material for Grade 2 or Grade 3 is to be certified by TL. For each consignment manufacturers shall forward to the Surveyor a certificate containing at least the following data:
– manufacturer's name and/or purchaser's order No.
– number and dimensions of bars and weight of consignment
– steel specification and chain grade
– heat number
– manufacturing procedure
– chemical composition
– details of heat treatment of the test sample (where applicable)
– results of mechanical tests (where applicable)
– number of test specimens (where applicable)

2.4 Forged steels for chain cables and accessories

2.4.1 General requirements
Forged steels used for the manufacture of chain cables and accessories are to be in compliance with TL-R W7, Hull and machinery steel forgings, unless otherwise specified in the following paragraphs.

2.4.2 Chemical composition
The chemical composition is to comply with the specification approved by TL. The steel manufacturer must determine and certify the chemical composition of every heat of material.

2.4.3 Heat treatment
The stock material may be supplied in the as rolled condition. Finished forgings are to be properly heat treated, i.e. normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant steel grade in Table 4.

2.4.4 (void)

2.4.5 (void)

2.5 Cast steels for chain cables and accessories

2.5.1 General requirements

Cast steels used for the manufacture of chain cables and accessories are to be in compliance with TL-R W8, Hull and machinery steel castings, unless otherwise specified in the following paragraphs.

2.5.2 Chemical composition
The chemical composition is to comply with the specification approved by TL. The foundry is to determine and certify the chemical composition of every heat.

2.5.3 Heat treatment
All castings must be properly heat treated, i.e., normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant cast steel grade in Table 4.

2.5.4 (void)

2.5.5 (void)

2.6 Materials for studs

The studs are to be made of steel corresponding to that of the chain cable or from rolled, cast or forged mild steels. The use of other materials, e.g. grey or nodular cast iron is not permitted.

W18.3 Design and manufacture of chain cables and accessories

3.1 Design

Chain cables must be designed according to a standard recognized by TL, such as ISO 1704. A length of chain cable must comprise an odd number of links. Where designs do not comply with this and where accessories are of welded construction, drawings giving full details of the design, the manufacturing process and the heat treatment are to be submitted to TL for approval.

3.2 Dimensions and dimensional tolerances

3.2.1 The shape and proportions of links and accessories must conform to a recognized standard, such as ISO 1704 or the designs specially approved.

3.2.2. The following tolerances are applicable to links:

a) Diameter measured at the crown (Two measurements are to be taken at the same location: one in the plane of the link{see dp in Figure 2}, and one perpendicular to the plane of the link):
up to 40mm nominal diameter : –1mm
over 40 up to 84mm nominal diameter : – 2mm
over 84 up to 122mm nominal diameter : – 3mm
over 122mm nominal diameter : – 4mm
The plus tolerance may be up to 5% of the nominal diameter. The cross sectional area of the crown must have no negative tolerance.

b) Diameter measured at locations other than the crown:
The diameter is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter. The approved manufacturer's specification is applicable to the plus tolerance of the diamter at the flush-butt weld.

c) The maximum allowable tolerance on assembly measured over a length of 5 links may equal +2.5%, but may not be negative (measured with the chain under tension after proof load test).

d) All other dimensions are subject to a manufacturing tolerance of ±2.5%, provided always that all of the final link parts of the chain cable fit together properly.

e) Studs must be located in the links centrally and at right angles to the sides of the link, although the studs at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances are regarded as being inherent in the method of manufacture and will not be objected to provided that the stud fits snugly and its ends lie practically flush against the inside of the link.
Maximum off-centre distance "X" : 10% of the nominal diameter d
Maximum deviation "α" from the 90° - position : 4°
The tolerances are to be measured in accordance with Figure 2.

3.2.3 The following tolerances are applicable to accessories:
nominal diameter : + 5%, -0%
other dimentions : ± 2.5%

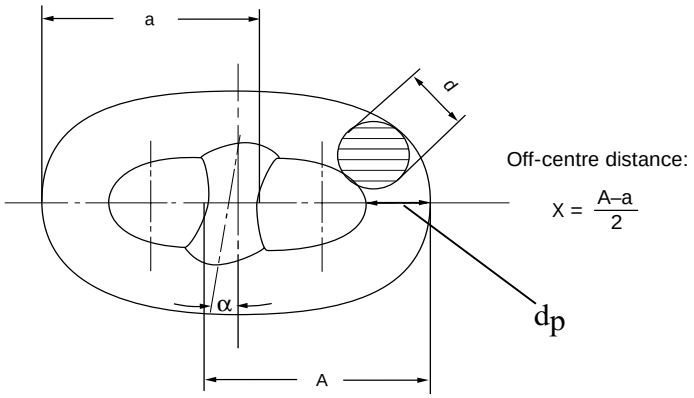


Figure 2 Manufacturing tolerances

3.3 Manufacturing process

3.3.1 Stud link chain cables should preferably be manufactured by flash butt welding using Grade 1, 2 or 3 bar material. Manufacture of the links by drop forging or castings is permitted. On request, pressure butt welding may also be approved for studless, Grade 1 and 2 chain cables, provided that the nominal diameter of the chain cable does not exceed 26mm.

3.3.2 Accessories such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade 2. The welded construction of these parts may also be approved.

3.4 Welding of studs

The welding of studs is to be in accordance with an approved procedure subject to the following conditions:

a) The studs must be of weldable steel; cf. 2.6.
b) The studs are to be welded at one end only, i.e., opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.
c) The welds, preferably in the horizontal position, shall be executed by qualified welders using suitable welding consumables.
d) All welds must be carried out before the final heat treatment of the chain cable.
e) The welds must be free from defects liable to impair the proper use of the chain. Under-cuts, end craters and similar defects shall, where necessary, be ground off.

TL reserves the right to call for a procedure test for the welding of chain studs.

3.5 Heat treatment

According to the grade of steel, chain cables and accessories are to be supplied in one of the conditions specified in Table 4. The heat treatment shall in every case be performed before the proof load test, the breaking load test, and all mechanical testing.

The mechanical properties of finished chain cables and accessories are to be in accordance with Table 7.

Table 4 Condition of supply of chain cables and accessories

Grade	Chain cables	Accessories
1	As welded or Normalized	NA
2	As welded or Normalized [1)]	Normalized
3	Normalized, Normalized and tempered or Quenched and tempered	Normalized, Normalized and tempered or Quench and tempered

1) Grade 2 chain cables made by forging or casting are to be supplied in the normalized condition.

NA = Not Applicable.

3.6 Freedom from defects

3.6.1 All individual parts must have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects imparing the performance of the product. The flashes produced by upsetting or drop forging must be properly removed.

3.6.2 Minor surface defects may be ground off so as to leave a gentle transition to the surrounding surface. Remote from the crown local grinding up to 5% of the nominal link diameter may be permitted.

W18.4 Testing and certification of finished chain cables

4.1 Proof and breaking load tests

4.1.1 Finished chain cables are to be subjected to the proof load test and the breaking load test in the presence of the Surveyor, and shall not fracture or exhibit cracking. Special attention is to be given to the visual inspection of the flash-butt weld, if present. For this purpose, the chain cables must be free from paint and anti-corrosion media.

4.1.2 Each chain cable length (27.5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as given by Table 5 and using an approved testing machine.

Table 5 Formulas for proof load and breaking load tests

Test	Grade 1	Grade 2	Grade 3
Proof load (kN)	$0.00686d^2(44-0.08d)$	$0.00981d^2(44-0.08d)$	$0.01373d^2(44-0.08d)$
Breaking load (kN)	$0.00981d^2(44-0.08d)$	$0.01373d^2(44-0.08d)$	$0.01961d^2(44-0.08d)$

***Note*: d = nominal diameter, in mm.**

4.1.3 For the breaking load test, one sample comprising at least of three links is to be taken from every four lengths or fraction of chain cables and tested at the breaking loads given by Table 5. The breaking load is to be maintained for a minimum of 30 seconds. The links concerned shall be made in a single manufacturing cycle together with the chain cable and must be welded and heat treated together with it. Only after this may they be separated from the chain cable in the presence of the Surveyor.

4.1.4 If the tensile loading capacity of the testing machine is insufficient to apply the breaking load for chain cables of large diameter, another equivalent testing method shall be agreed with TL.

4.2 Retests

4.2.1 Should a breaking load test fail, a further test specimen may be taken from the same length of chain cable and tested. The test shall be considered successful if the requirements are then satisfied.
If the retest fails, the length of chain cable concerned shall be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the unit test quality may then be individually subjected to test at the breaking load. If one such test fails to meet the requirements, the entire unit test quantity is rejected.

4.2.2 Should a proof load test fail, the defective link(s) is (are) to be replaced, a local heat treatment to be carried out on the new link(s) and the proof load test is to be repeated. In addition, an investigation is to be made to identify the cause of the failure.

4.3 Mechanical tests on grade 2 and 3 chain cable

4.3.1 For Grade 2 and 3 chain cables, mechanical test specimens required in Table 6 are to be taken from every four lengths in accordance with 4.3.2. For forged or cast chain cables where the batch size is less than four lengths, the sampling frequency will be by heat and heat treatment charge. Mechanical tests are to be carried out in the presence of the Surveyor. For the location of the test specimens see 2.3.3.3 and Figure 1. Testing is to follow 2.3.3.4 and 2.3.3.5. Retesting is to follow 2.3.3.6 and 2.3.3.7.

4.3.2 An additional link (or where the links are small, several links) for mechanical test specimen removal is (are) to be provided in a length of chain cable not containing the specimen for the breaking test. The specimen link must be manufactured and heat treated together with the length of chain cable.

Table 6 Number of mechanical test specimens for finished chain cables and accessories

Grade	Manufacturing method	Condition of supply[1)]	Number of test specimens		
			Tensile test for base metal	Charpy V-notch impact test	
				Base metal	Weldment
1	Flush-butt welded	AW N	NR	NR	NR
2	Flush-butt welded	AW	1	3	3
		N	NR	NR	NR
	Forged or Cast	N	1	3[2)]	NA
3	Flush-butt welded	N NT QT	1	3	3
	Forged or Cast	N NT QT	1	3	NA

1) AW = As welded, N = Normalized, NT = Normalized and tempered, QT = Quenched and tempered
2) For chain cables, Charpy V-notch impact test is not required.
NR = Not required
NA = Not applicable

4.3.3 The mechanical properties must be in accordance with the values indicated in Table 7.

Table 7 Mechanical properties of finished chain cables and accessories

Grade	R_{eH} N/mm² min.	R_m N/mm²	A_5 % min.	Z % min.	Charpy V-notch impact test		
					Test temperature, in °C	Absorbed energy, in Joules min.	
						Base metal	Weldment
1	NR	NR	NR	NR	NR	NR	NR
2	295	490-690	22	NR	0	27	27
3	410	690 min.	17	40	0[1)]	60	50
					-20	35	27

[1)] Testing is normally to be carried out at 0°C.

NR = Not required.

4.4 Marking

Chain cables which meet the requirements are to be stamped at both ends of each length at least with the following marks; cf. Figure 3.

- Chain cable grade
- Certificate number
- Society's stamp

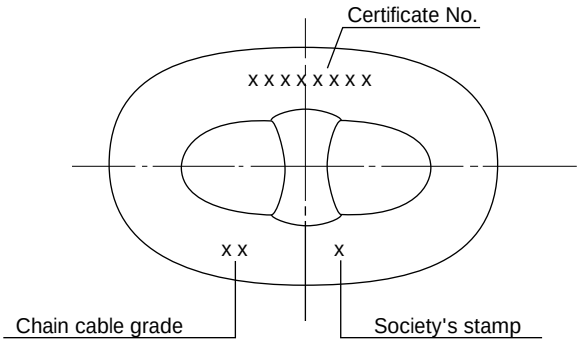


Figure 3 Marking of chain cables

4.5 Certification

Chain cables which meet the requirements are to be certified by TL at least with the following items:

- Manufacturer's name
- Grade
- Chemical composition (including total aluminum content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to chain
- Length
- Mechanical properties, where applicable

W18.5 Testing and certification of accessories

5.1 Proof load test

All accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain given by Table 5, and in accordance with the provisions of 4.1, as appropriate.

5.2 Breaking load test

5.2.1 From each manufacturing batch (same accessory type, grade, size and heat treatment charge, but not necessarily representative of each heat of steel or individual purchase order) of 25 units or less of detachable links, shackles, swivels, swivel shackles, enlarged links, and end links, and from each manufacturing batch of 50 units or less of kenter shackles, one unit is to be subjected to the breaking load test at the break load specified for the corresponding chain given by Table 5 and in accordance with the provisions of 4.1, as appropriate. Parts tested in this way may not be put to further use. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

5.2.2 TL may waive the breaking load test if:

a) the breaking load has been demonstrated on the occasion of the approval testing of parts of the same design, and
b) the mechanical properties of each manufacturing batch are proved, and
c) the parts are subjected to suitable non-destructive testing.

5.2.3 Notwithstanding the above, the accessories, which have been successfully tested at the prescribed breaking load appropriate to the chain, may be used in service at the discretion of TL where the accessories are manufactured with the following:

a) the material having higher strength characteristics than those specified for the part in question (e.g. Grade 3 material for accessories for Grade 2 chain),
b) or alternatively, the same grade material as the chain but with increased dimensions subject to the successful procedure tests that such accessories are so designed that the breaking strength is not less than 1.4 times the prescribed breaking load of the chain for which they are intended.

5.3 Mechanical properties and tests

Unless otherwise specified, the forging or casting must at least comply with the mechanical properties given in Table 7, when properly heat treated. For test sampling, forgings or castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. Mechanical tests are to be carried out in the presence of the Surveyor depending on the type and grade of material used. From each test unit, one tensile test specimen and three Charpy V-notch impact test specimens are to be taken in accordance with Table 6 and tested in accordance with YL- R W2. For the location of the test specimens see 2.3.3.3 and Figure 1. Testing is to follow 2.3.3.4 and 2.3.3.5. Retesting is to follow 2.3.3.6 and 2.3.3.7. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

5.4 Marking

Accessories which meet the requirements are to be stamped as follows:

- Chain cable grade
- Certificate number
- Society's stamp

5.5 Certification

Chain accessories which meet the requirements are to be certified by TL at least with the following items:

- Manufacturer’s name
- Grade
- Heat Number
- Chemical composition (including total aluminum content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to accessory
- Mechanical properties, where applicable

Appendix A

Chafing Chain for Emergency Towing Arrangements

1. Scope

These requirements apply to the chafing chain for chafing gear of two types of Emergency Towing Arrangement (ETA) with specified safe working load (SWL) of 1000kN (ETA1000) and 2000kN (ETA2000). Chafing chains other than those specified can be used subject to special agreement with TL.

2. Approval of manufacturing

The chafing chain is to be manufactured by works approved by TL according to W18.1.3.

3. Materials

The materials used for the manufacture of the chafing chain are to satisfy the requirements of W 18.2.

4. Design, manufacture, testing and certification of chafing chain

4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements of W18.3, W18.4 and W18.5.

4.2 The arrangement at the end connected to the strongpoint and the dimensions of the chafing chain are determined by the type of ETA. The other end of the chafing chain is to be fitted with a pear-shaped open link allowing connection to a shackle corresponding to the type of ETA and chain cable grade. A typical arrangement of this chain end is shown in Figure 1.

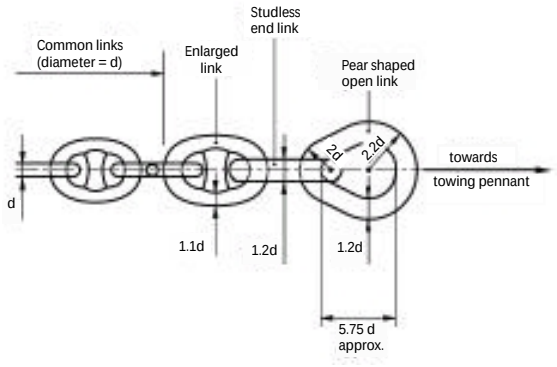
4.3 The common link is to be of stud link type grade 2 or 3.

4.4 The chafing chain is to be able to withstand a breaking load not less than twice the SWL. For each type of ETA, the nominal diameter of common link for chafing chains is to comply with the value indicated in Table 1.

Table 1 : Nominal diameter of common link for chafing chains

Type of ETA	Nominal diameter of common link, d min.	
	Grade 2	Grade 3
ETA1000	62mm	52mm
ETA2000	90mm	76mm

Figure 1: Typical outboard chafing chain end



TL- R W23 Approval of Welding Consumables for High Strength Steels for Welded Structures

1. General

1.1 Scope

1.1.1 These requirements supplement the TL- R W17 and give the conditions of approval and inspection of welding consumables used for high strength steels for welded structures according to TL- R W16 with yield strength levels from 420 N/mm^2 up to 960 N/mm^2, and impact grades A, D, E and F, except that impact grade F is not applicable for 890 N/mm^2 and 960 N/mm^2 yield strength levels.

Where no special requirements are given, those of TL- R W17 apply in analogous manner.

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

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

1.2 Grading, Designation

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

- Y42 - for welding steels with minimum yield strength 420 N/mm^2
- Y46 - for welding steels with minimum yield strength 460 N/mm^2
- Y50 - for welding steels with minimum yield strength 500 N/mm^2
- Y55 - for welding steels with minimum yield strength 550 N/mm^2
- Y62 - for welding steels with minimum yield strength 620 N/mm^2

* Wire-flux combinations for single or two-run technique are subject to special consideration of TL.

Note:

1. This requirement is implemented when an application for approval is dated on or after 1 July 2019.

- Y69 - for welding steels with minimum yield strength 690 N/mm^2

- Y89 - for welding steels with minimum yield strength 890 N/mm^2

- Y96 - for welding steels with minimum yield strength 960 N/mm^2

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

- Grade 3, test temperature -20^{o}C

- Grade 4, test temperature -40^{o}C

- Grade 5, test temperature -60^{o}C

1.2.3 Analogously to the designation scheme used in TL- R W17 the welding consumables for high strength steels are subject to classification designation and approval as follows:

- According to 1.2.2 with the quality grades **3, 4 or 5**

- With the added symbol, Y and an appended code number designating the minimum yield strength of the weld metal corresponding 1.2.1: Y42, Y46, Y50, Y55, Y62, Y69, Y89 and Y96.

- With the added symbol H10 or H5 for controlled hydrogen content of the weld metal,

- With the added symbol, **S** (= semi-automatic) for semi-mechanised welding,

- With the added symbol, **M** designating multi-run technique* (and is applicable only to welding consumables for fully mechanised welding).

1.2.4 Each higher quality grade includes the one (or those) below Grade A... and D... steels acc. to UR W16 are to be welded using welding consumables of at least quality grade 3, grade E... steels using at least quality grade 4 and grade F... steels using at least quality grade 5., see the following table:

Consumable Grade	Steel Grades covered
3Y..	D.. and A..
4Y..	E.., D.. and A..
5Y..	F.., E.., D.. and A..

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

* Wire-flux combinations for single or two-run technique are subject to special consideration of TL.

Welding consumables with grade Y89 are considered suitable for welding steels in the same strength level only. Welding consumables with grade Y96 are also considered suitable for welding steels in the one strength level below that for which they have been approved.

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

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

1.3 Manufacture, testing and approval procedure

1.3.1 Manufacturer's plant, production methods and quality control measures shall be such as to ensure reasonable uniformity in manufacture, see also TL- R W17.

1.3.2 Testing and approval procedure shall be in accordance with TL- R W17, sections 2 and 3 and as required in TL- R W17 for the individual categories (types) of welding consumables mentioned in 1.1.2 above.

2. Testing of the weld metal

2.1 For testing the deposited weld metal, test pieces analogous to those called for in TL- R W17, sections 4.2, 5.2, 6.2 or 6.3 respectively shall be prepared, depending on the type of the welding consumables (and according to the welding process). The base metal used shall be a fine-grained structural steel compatible with the properties of the weld metal, or the side walls of the weld shall be buttered with a weld metal of the same composition.

2.2 The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in TL- R W17, section 4.2.2. The results of the analysis shall not exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

2.3 Depending on the type of the welding consumables (and according to the welding process), the test specimens prescribed in TL- R W17, sections 3.1 and 4.2, 5.2, 6.2 or 6.3 respectively shall be taken from the weld metal test pieces in a similar manner.

2.4 The mechanical properties must meet the requirements stated in Tables 1 and 2. The provisions of TL- R W17 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperature in the notched bar impact test and the carrying out of results.

Table 1 Required toughness properties of the weld metal

Quality grade	Test temperature [°C]	Minimum notch impact energy [J][1)]
3	-20	Y42: ≥ 47 Y46: ≥ 47 Y50: ≥ 50 Y55: ≥ 55 Y62: ≥ 62 Y69: ≥ 69 Y89: ≥ 69[2)] Y96: ≥ 69[2)]
4	-40	
5	-60	

1) Charpy V-notch impact test specimen, mean value of three specimens; for requirements regarding minimum individual values and retests, see TL- R W17, section 3.3.2.

2) Quality grade 5 is not applicable for Y89 and Y96 grade consumables.

Table 2 Required strength properties of the weld metal

Symbols added to quality grade	Minimum yield strength or 0.2% proof stress [N/mm²]	Tensile Strength [N/mm²]	Minimum elongation [%]
Y42	420	520-680	20
Y46	460	540-720	20
Y50	500	590-770	18
Y55	550	640-820	18
Y62	620	700-890	18
Y69	690	770-940	17
Y89	890	940-1100	14
Y96	960	980-1150	13

3. Testing on welded joints

3.1 Depending on the type of the welding consumables (and according to the welding process), the testing on the welded joints shall be performed on butt-weld test pieces in analogous manner to TL- R W17, sections 4.3, 5.2, 6.2, 6.3, or 6.4 respectively.

3.2 Depending on the type of the welding consumables (and according to the welding process), the butt-weld test pieces called for in para. 3.1 shall be welded in a manner analogous to that prescribed in TL- R W17. The base metal used shall be a high-strength fine-grained structural steel with a minimum yield strength and tensile strength matching the consumable grade being approved and compatible with the added symbol for which application is made.

3.3 Depending on the type of the welding consumables (and according to the welding process), the test specimens described in TL- R W17 shall be taken from the butt-weld test pieces.

3.4 The mechanical properties must meet the requirements stated in Table 3. The provisions of TL- R W17 apply in analogous manner to the performance of the tests, including in particular the maintenance of the test temperatures in the notched bar impact test and the requirements regarding the retest specimens.

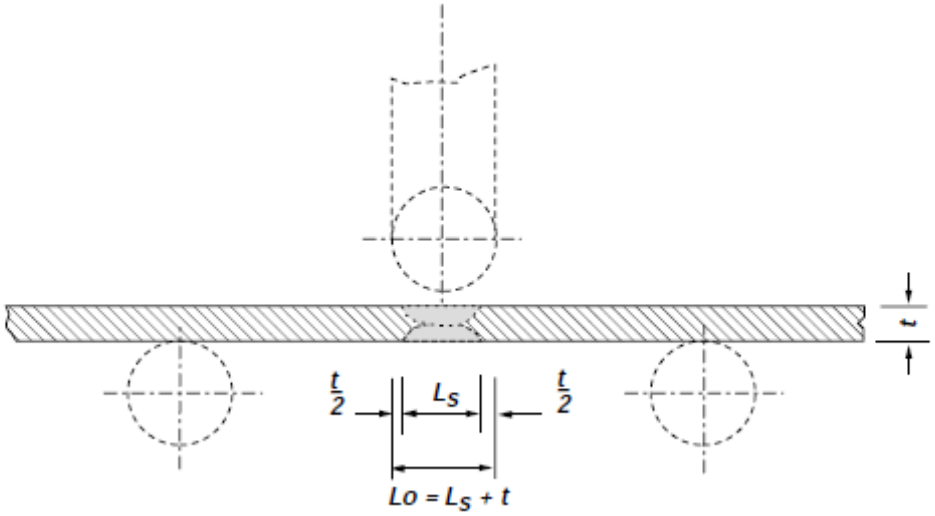
Table 3 Required properties of welded joints

Quality grade	Added symbol	Minimum tensile strength [N/mm²]	Minimum notch impact energy, test temperature	Minimum bending angle[1)]	Bend ratio D/t[2)]
3 to 5 accordance with Table 1	Y42	520	Depending on the quality grade & yield strength in accordance Table 1	120°	4
	Y46	540			4
	Y50	590			4
	Y55	640			5
	Y62	700			5
	Y69	770			5
	Y89	940			6
	Y96	980			7

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

2) D = Mandrel diameter, t = specimen thickness

3.5 Where the bending angle required in Table 3 is not achieved, the specimen may be considered as fulfilling the requirements, if the bending elongation on a gauge length Lo fulfills the minimum elongation requirements stated in Table 2. The gauge length Lo = Ls + t (Ls = width of weld, t = specimen thickness), see sketch below.



4. Hydrogen test

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

4.2 The diffusible hydrogen content of the weld metal determined in accordance with the provisions of TL- R W17, section 4.5 shall not exceed the limits given in table 4.

Table 4 Allowable diffusible hydrogen content

Yield strength group	Hydrogen symbol	Maximum hydrogen content [cm^3/100 g deposited weld metal]
Y42 Y46 Y50	H 10	10
Y55 Y62 Y69	H 5	5
Y89 Y96	H5	5

5. Annual repeat test

The annual repeat tests specified in TL- R W17 shall entail the preparation and testing of weld metal test pieces as prescribed under 2. For grades Y69 to Y96 annual hydrogen test is required. In special cases, TL may require more extensive repeat tests.

TL- R W28 Welding procedure qualification tests of steels for hull construction and marine structures

1. Scope

1.1 This document gives requirements for qualification tests of welding procedures intended for the use of weldable steels as specified in TL- R W7, TL- R W8, TL- R W11 and TL- R W16 for hull construction and marine structures.

1.2 This document specifically excludes the welding procedure specified in TL- R W1.

1.3 All new welding procedure qualification tests are to be carried out in accordance with this document from 1 July 2007.

1.4 This document does not invalidate welding procedure qualification tests made and accepted by TL before 1 July 2007 provided the welding procedure qualification tests are considered by TL to meet the technical intent of this requirement or have been qualified in accordance with the recognized standards such as ISO, EN, AWS, JIS or ASME.

2. General

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

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

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

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

Note:

1. This requirement is implemented on ships contracted for construction on or after 1 January 2013.

2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to TL- PR 29.

3 Welding procedure specification

3.1 Preliminary welding procedure specification and welding procedure specification

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

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

3.1.3 The WPS is to be used as a basis for the production welds, and upon satisfactory completion of the tests based on the pWPS, TL may approve it as a WPS. In case that a WPS is approved by TL the approval range is to be in compliance with section 5.

4. Qualification of welding procedures

4.1 General

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

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

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

4.2 Butt weld

4.2.1 Assembly of test pieces

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

- manual or semi-automatic welding:

  width = 2a, a = 3 x t, min 150 mm
  length b = 6 x t, min 350 mm

- automatic welding:

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

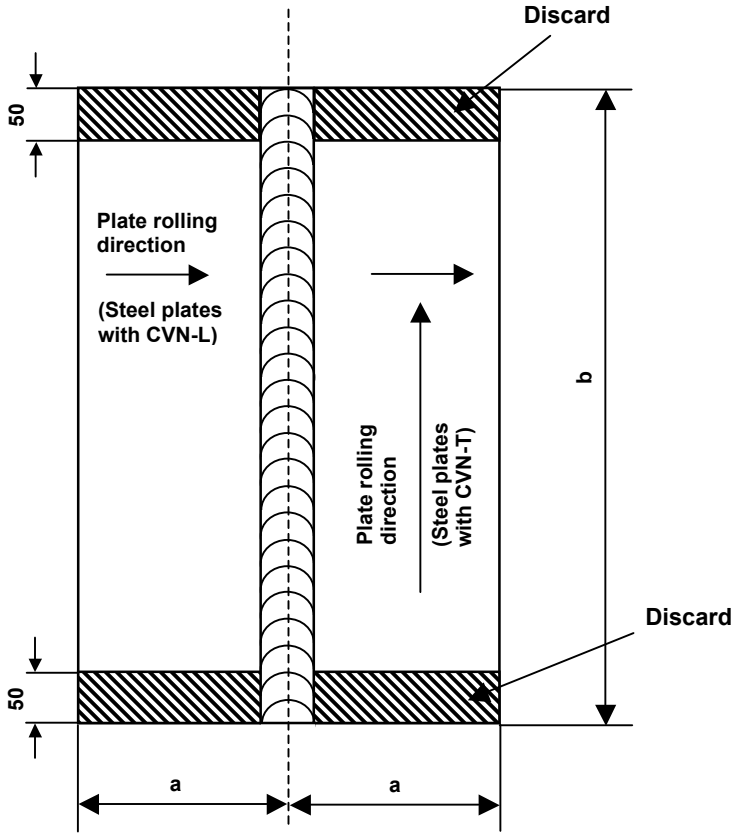


Fig.1 Test assembly for butt weld

For hull structural steel plates impact tested in the longitudinal direction (CVN-L) in UR W11, the butt weld of the test piece is perpendicular to the rolling direction of the two plates.

For high strength quenched and tempered steel plates impact tested in the transverse direction (CVN-T) in TL- R W16, the butt weld of the test piece is parallel to the rolling direction of the two plates.

4.2.2 Examinations and tests

Test assemblies are to be examined non-destructively and destructively in accordance with the following and Fig 2:

- Visual testing	100 %
- Surface crack detection	100 % (dye penetrant testing or magnetic particle testing)
- Radiographic or Ultrasonic testing	100 %
- Transverse tensile test	two specimens as per 4.2.2.2
- Longitudinal tensile test	required as per 4.2.2.3
- Transverse bend test	four specimens as per 4.2.2.4
- Charpy V-notch impact test	required as per 4.2.2.5
- Macro examination	one specimen as per 4.2.2.6
- Hardness test	required as per 4.2.2.7

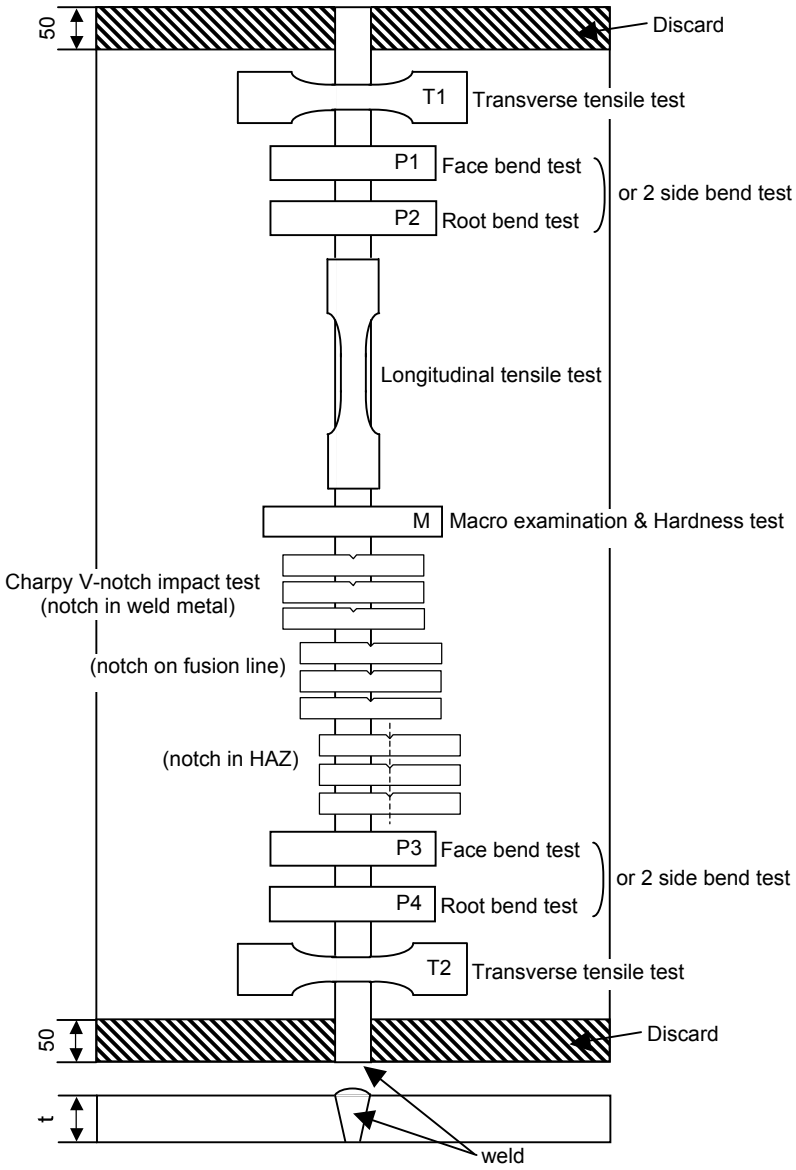


Fig.2 Test sampling

4.2.2.1 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified, non-destructive testing is to be performed after heat treatment. For steels according to TL- R W16 with specified minimum yield strength of 420 N/mm^2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with TL.

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

4.2.2.2 Transverse tensile test

The testing is to be carried out in accordance with TL- R W2.4. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal.

When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength.

4.2.2.3 Longitudinal tensile test

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

The testing is to be carried out in accordance with TL- R W2.4. The tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the appropriate grade of consumable.

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

4.2.2.4 Bend test

Transverse bend tests for butt joints are to be in accordance with TL- R W2.6.

The mandrel diameter to thickness ratio (i.e. D/t) is to be that specified for the welding consumable (TL- R W17, TL- R W23) approvals + 1.

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

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

For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

4.2.2.5 Impact test

a) Normal and higher strength hull structural steels according to TL- R W11

The positions of specimens are to be in accordance with these requirements. Dimensions and testing are to be in accordance with the requirements of TL- R W2.7.

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

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

Test temperature and absorbed energy are to be in accordance with Table 1.

Table 1 Impact test requirements for butt joints (t ≤ 50 mm)[(1),(2)]

Grade of steel	Testing Temperature (C°)	Value of minimum average absorbed energy (J)		
		For manually or semi-automatically welded joints		For automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A[(3)]	20	47	34	34
B[(3)], D	0			
E	-20			
A32, A36	20			
D32, D36	0			
E32, E36	-20			
F32, F36	-40			
A40	20		39	39
D40	0			
E40	-20			
F40	-40			

Note:

(1) For thickness above 50 mm impact test requirements are to be agreed by TL.

(2) These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.

(3) For Grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be minimum 27 J.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

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

The testing of sub - size specimen is to be in accordance with TL- R W2.7.2

b) High strength quenched and tempered steels according to TL- R W16

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

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

Test temperature and absorbed energy are to be in accordance with the requirements of base metal as specified in TL- R W16.

c) Weldable C and C-Mn hull steel castings and forgings according to TL- R W7 and TL- R W8

For base metal with specified impact values test temperature and absorbed energy are to be in accordance with the requirements of the base metal to be welded.

4.2.2.6 Macro examination

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

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

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

4.2.2.7 Hardness test

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

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

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

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

4.3 Fillet welds

4.3.1 Assembly of test pieces

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig. 3 with the minimum dimensions:

- manual and semi-automatic welding:

  width a = 3 x t, min. 150 mm
  length b = 6 x t, min. 350 mm

- automatic welding:

  width a = 3 x t, min. 150 mm
  length b = 1000 mm

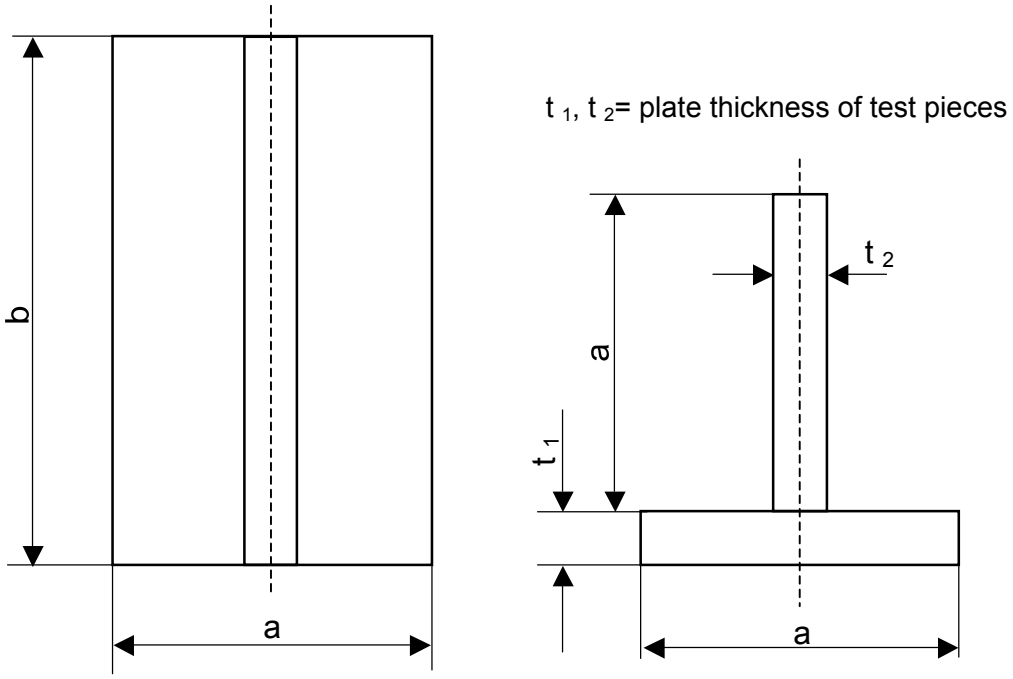


Fig.3 Test assembly for fillet weld

4.3.2 Welding of test pieces

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

4.3.3 Examinations and tests

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

- Visual testing	100 %
- Surface crack detection	100 % (dye penetrant testing or magnetic particle testing)
- Macro examination	two specimen as per 4.3.3.2
- Hardness test	required as per 4.3.3.3
- Fracture test	required as per 4.3.3.4

4.3.3.1 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified non-destructive testing is to be performed after heat treatment. For steels according to TL- R W16 with specified minimum yield strength of 420 N/mm^2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with TL.

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

4.3.3.2 Macro examination

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

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

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

4.3.3.3 Hardness test

Hardness test is required for steels with a specified minimum yield strength of $R_{eH} \geq 355$ N/mm^2. The Vickers method HV 10 is normally to be used. The indentations are to be made in the weld metal, the heat affected zone and the base metal measuring and recording the hardness values. At least two rows of indentations are to be carried out in accordance with Fig. 3, 4a and 4b of Annex B.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zone (both sides) and the base metal (both sides). A typical example is shown in Annex B.

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

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

4.3.3.4 Fracture test

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

4.4 Re-testing

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

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

4.4.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with TL- R W 2.4.3.

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

4.4.5 The re-testing of Charpy impact specimens are to be carried out in accordance with TL- R W 2.7.4.

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

4.5 Test record

4.5.1 Welding conditions for test assemblies and test results are to be recorded in welding procedure test record. Forms of welding procedure test records can be taken from TL's rules or from relevant standards.

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

4.5.3 A statement that the test piece was made according to the particular welding procedure is to be signed by the Surveyor witnessing the test and is to include TL´s identification.

5. Range of approval

5.1 General

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

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

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

5.2 Base metal

5.2.1 Normal and higher strength hull structural steels according to TL- R W11.

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

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

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

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

5.2.2 High strength quenched and tempered steels according to TL- R W16

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

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

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

5.2.3 Weldable C and C-Mn hull steel forgings according to TL- R W7

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

b) The approval of quenched and tempered hull steel forgings does not quality other delivery conditions and vice versa.

5.2.4 Weldable C and C-Mn hull steel castings according to TL- R W8

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

b) The approval of quenched and tempered hull steel castings does not quality other delivery conditions and vice versa.

5.3 Thickness

5.3.1 The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in Table 2.

Table 2 Approval range of thickness for butt and T-joint welds and fillet welds

Thickness of test piece T[(1)] (mm)	Range of approval	
	Butt and T-joint welds with single run or single run from both sides	Butt and T-joint welds with multi-run and fillet welds[(2)]
$3 < t \leq 12$	0.7 x t to 1.1 x t	3 to 2 x t
$12 < t \leq 100$	0.7 x t to 1.1 x t[(3)]	0.5 x t to 2 x t (Max. 150)

Note:

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

(2) For fillet welds, the range of approval is to be applied to both base metals.

(3) For high heat input processes over 50kJ/cm, the upper limit of range of approval is to be 1.0 x t.

5.3.2 In addition to the requirements of Table 2, the range of approval of throat thickness “a” for fillet welds is to be as follows:

- Single run ; “0.75 x a” to “1.5 x a”

- Multi-run ; as for butt welds with multi-run (i.e. a=t)

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

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

5.3.5 Notwithstanding the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated 4.2.2.7 and 4.3.3.3.

5.4 Welding position

Approval for a test made in any position is restricted to that position (see Annex C). To qualify a range of positions, test assemblies are to be welded for highest heat input position and lowest heat input position and all applicable tests are to be made on those assemblies.

5.5 Welding process

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

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

5.6 Welding consumable

Except high heat input processes over 50kJ/cm, welding consumables cover other approved welding consumables having the same grade mark including all suffixes specified in TL- R W17 and TL- R W23 with the welding consumable tested.

5.7 Heat input

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

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

5.8 Preheating and interpass temperature

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

5.8.2 The maximum interpass temperature is not to be higher than that used in the qualification test.

5.9 Post-weld heat treatment

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

5.10 Type of joint

5.10.1 Range of approval depending on type of welded joints for test assembly is to be specified in Table 3.

5.10.2 A qualification test performed on a butt weld will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 5.3 above.

Table 3 Range of approval for type of welded joint

Type of welded joint for test assembly			Range of approval	
Butt welding	One side	With backing	A	A, C
		Without backing	B	A, B, C, D
	Both side	With gouging	C	C
		Without gouging	D	C, D

5.11 Other variables

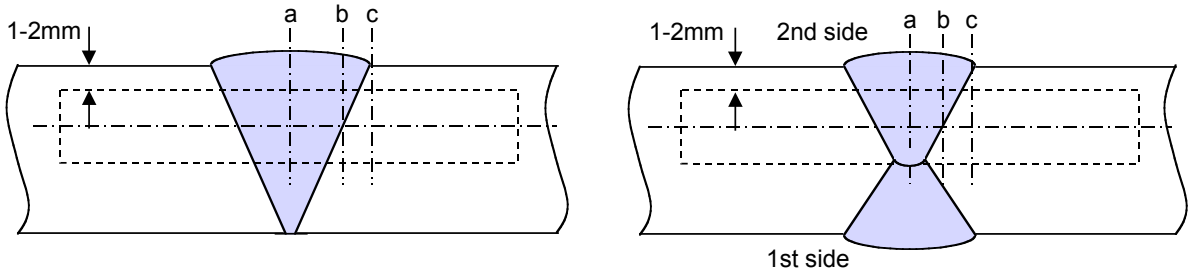
The range of approval relating to other variables may be taken according to TL

requirements.

Annex A

Location of Charpy V-notch impact test

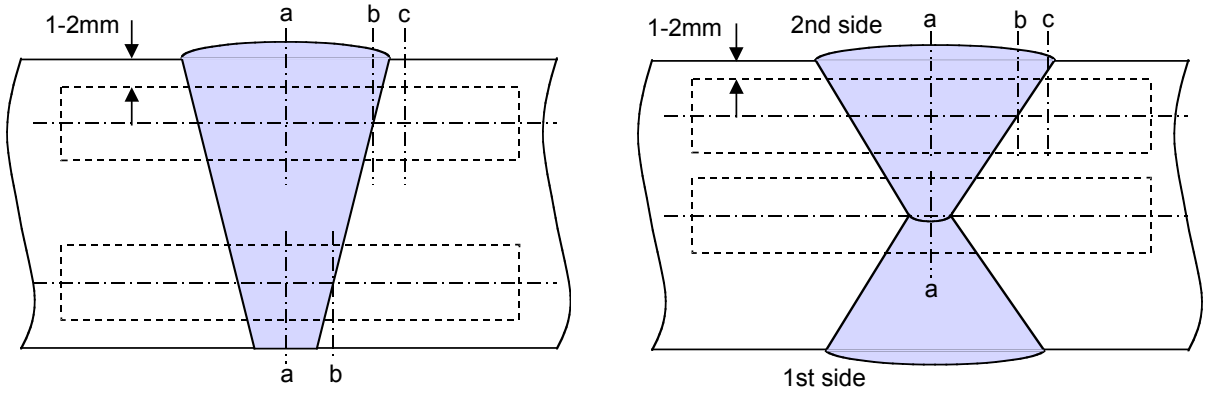
a) t≤50mm(1)



Note:

(1) For one side single run welding over 20mm notch location “a” is to be added on root side.

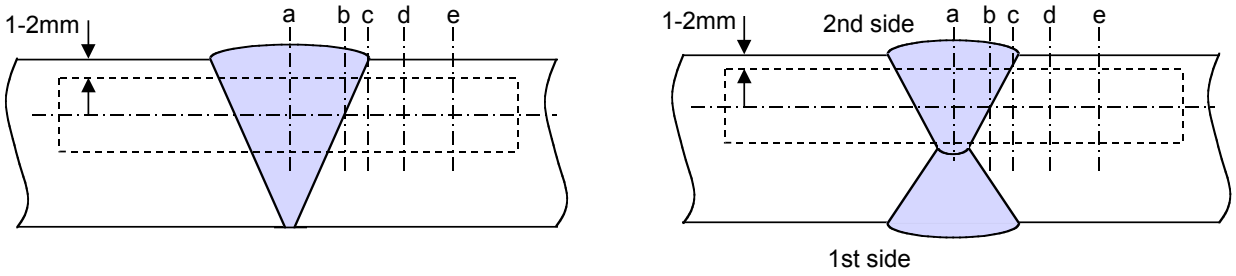
b) t>50mm



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

Fig. 1 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

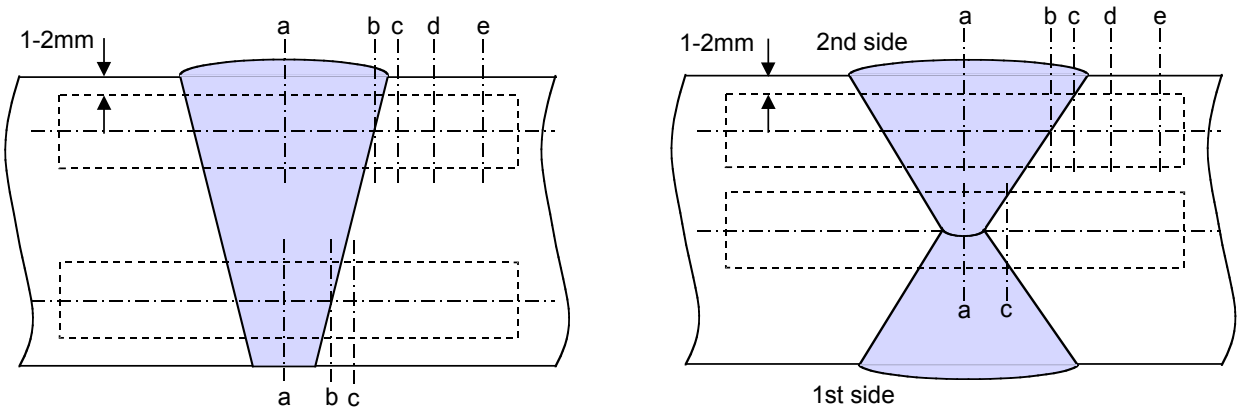
a) t≤50mm(1)



Note:

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

b) t>50mm



Notch locations:
a : center of weld “WM”
b : on fusion line “FL”
c : in HAZ, 2mm from fusion line
d : in HAZ, 5mm from fusion line
e : in HAZ, 10mm from fusion line in case of heat input > 200kJ/cm

Fig. 2 Locations of V-notch for butt weld of high heat input (heat input > 50kJ/cm)

Annex B

Hardness test

(Typical examples of hardness test)

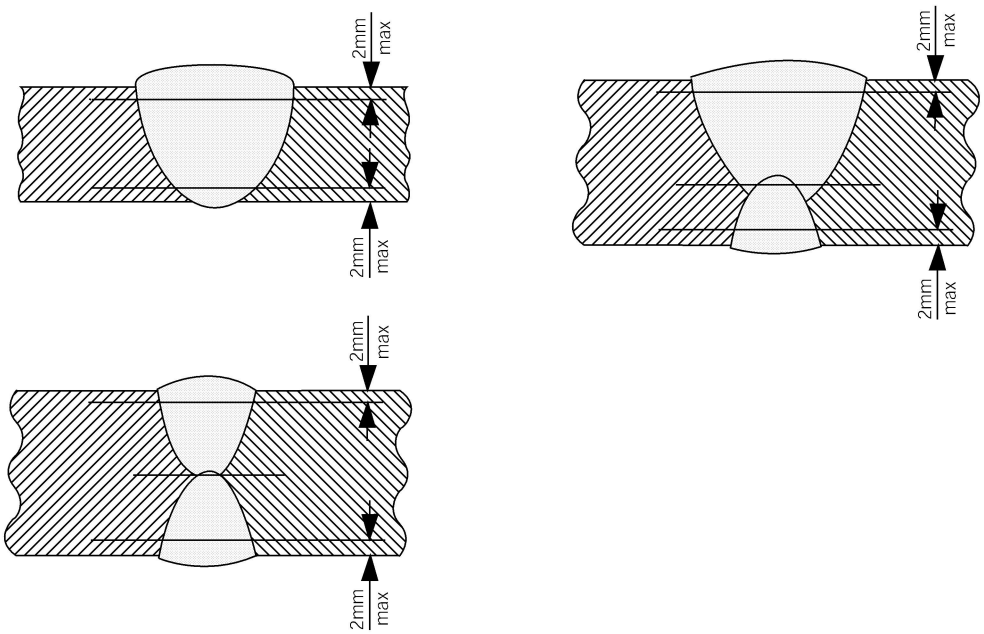


Fig. 1 Examples of hardness test with rows of indentations (R) in butt welds

Table 1 Recommended distances *l* between indentations for hardness test in the heat affected zone

Vickers hardness Symbol	Distance between indentations *l* (mm)
HV 10	1

The distance of any indentation from the previous indentation is not to be less than the value allowed for the previous indentation by ISO 6507/1.

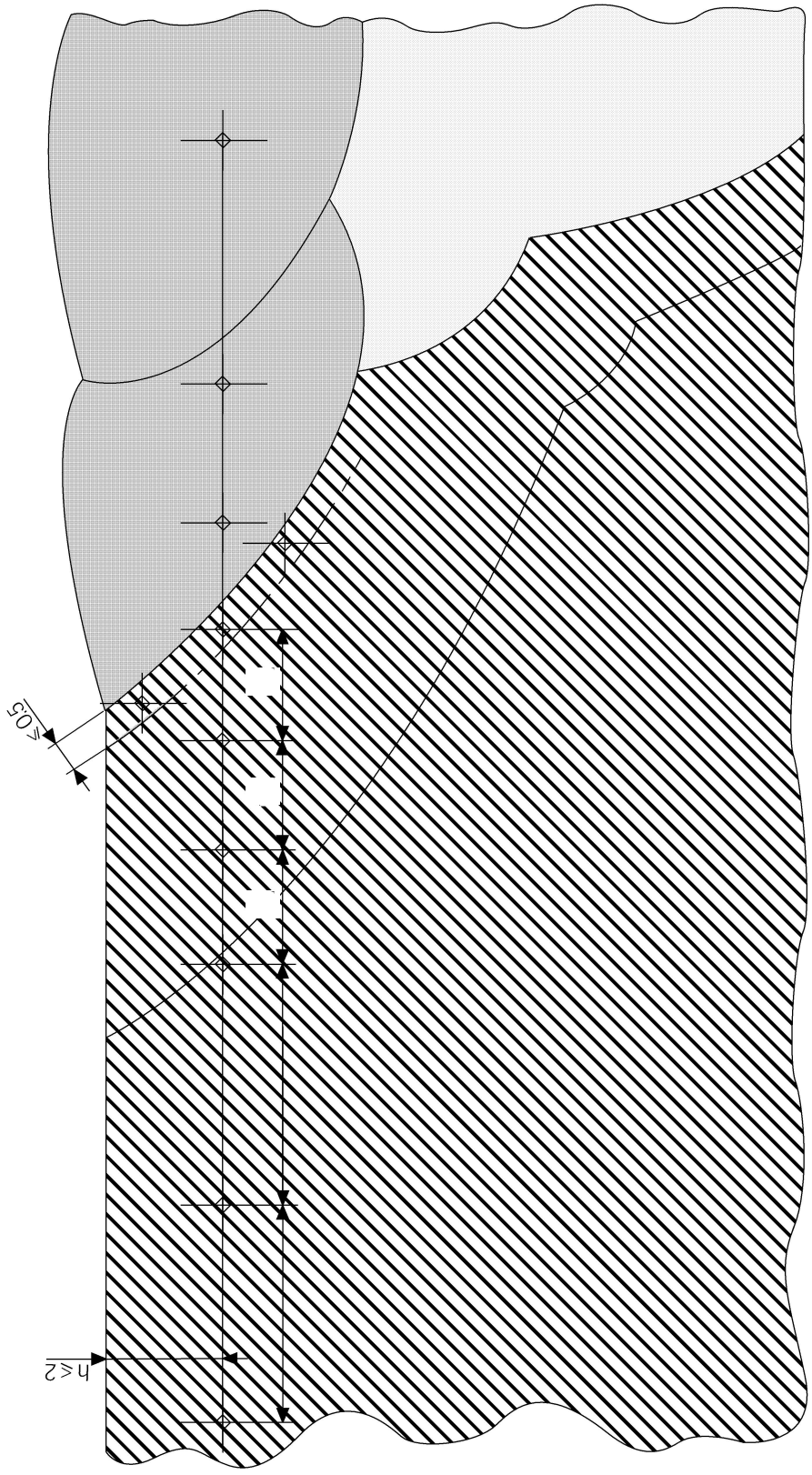
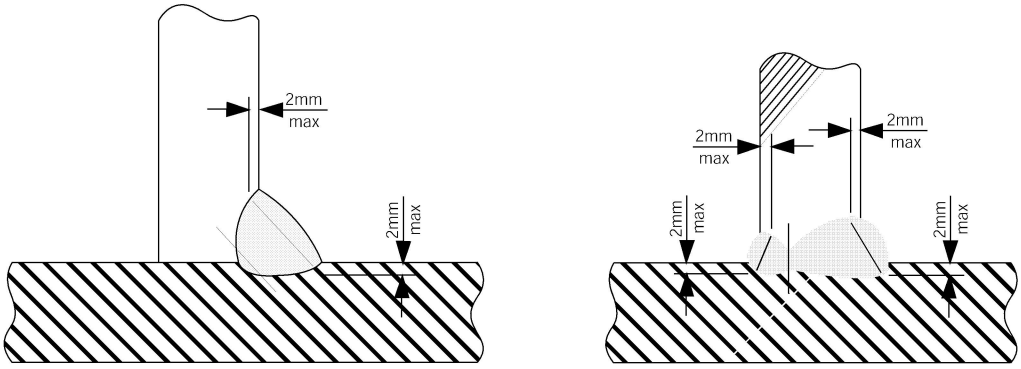


Fig. 2 Example showing the position of the indentations for hardness test in the weld metal, the heat affected zone and the base metal of a butt weld (dimensions in mm)



a) Fillet weld **b) T-joint weld**

Fig. 3 Examples of hardness test with row indentation (R) in fillet welds and in T-joint welds

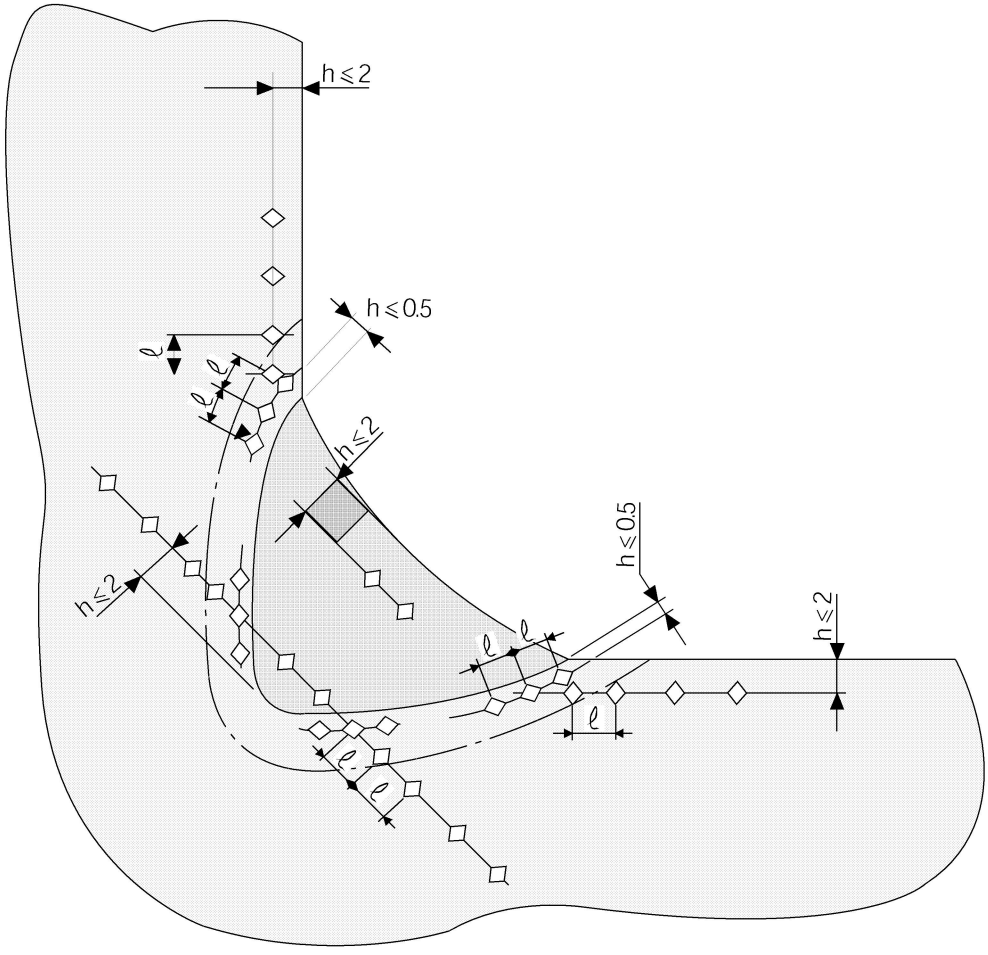


Fig. 4a Example showing the position of the indentations for hardness test in the weld metal, the heat affected zone and the base metal of a fillet weld (dimensions in mm)

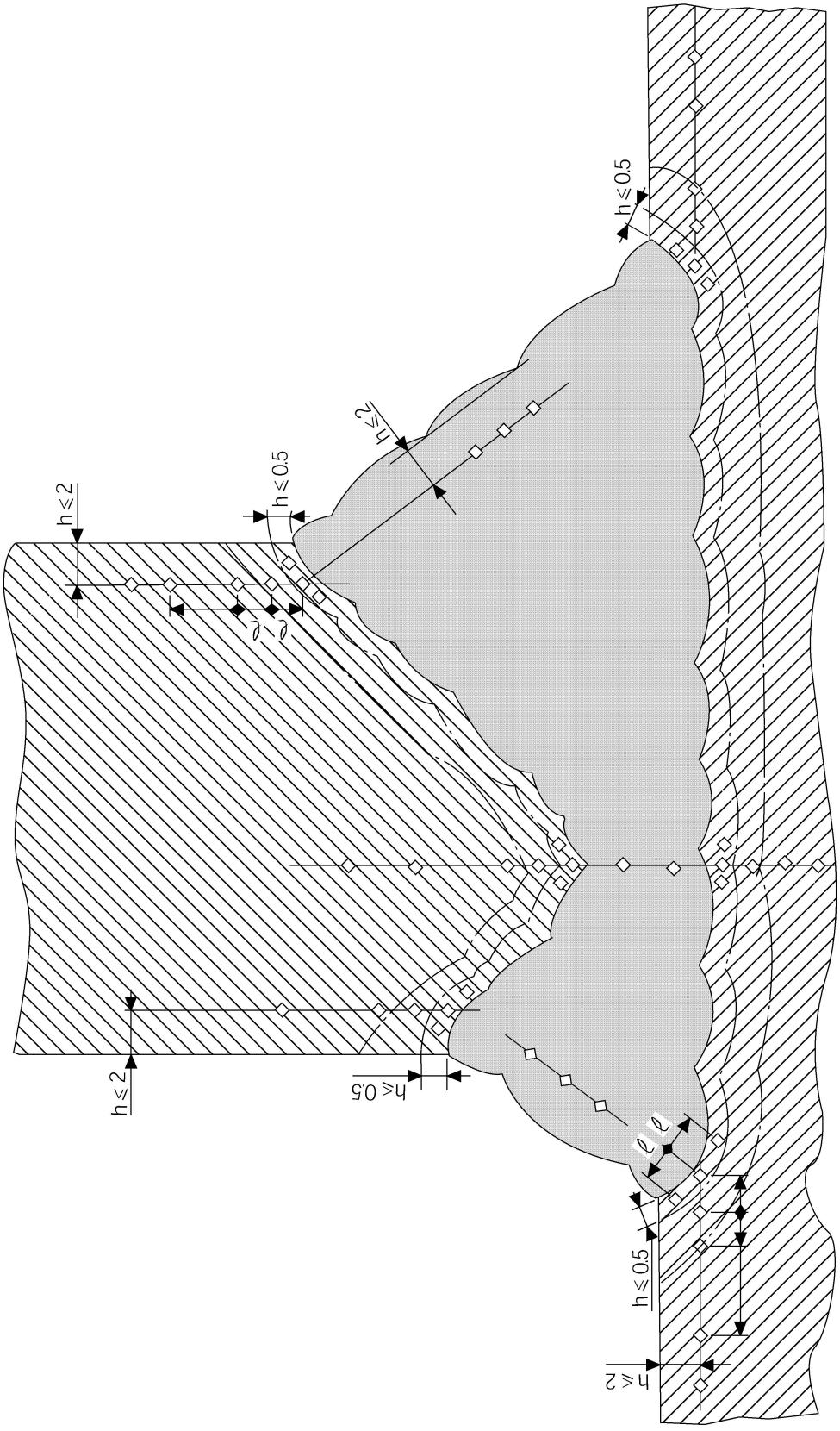
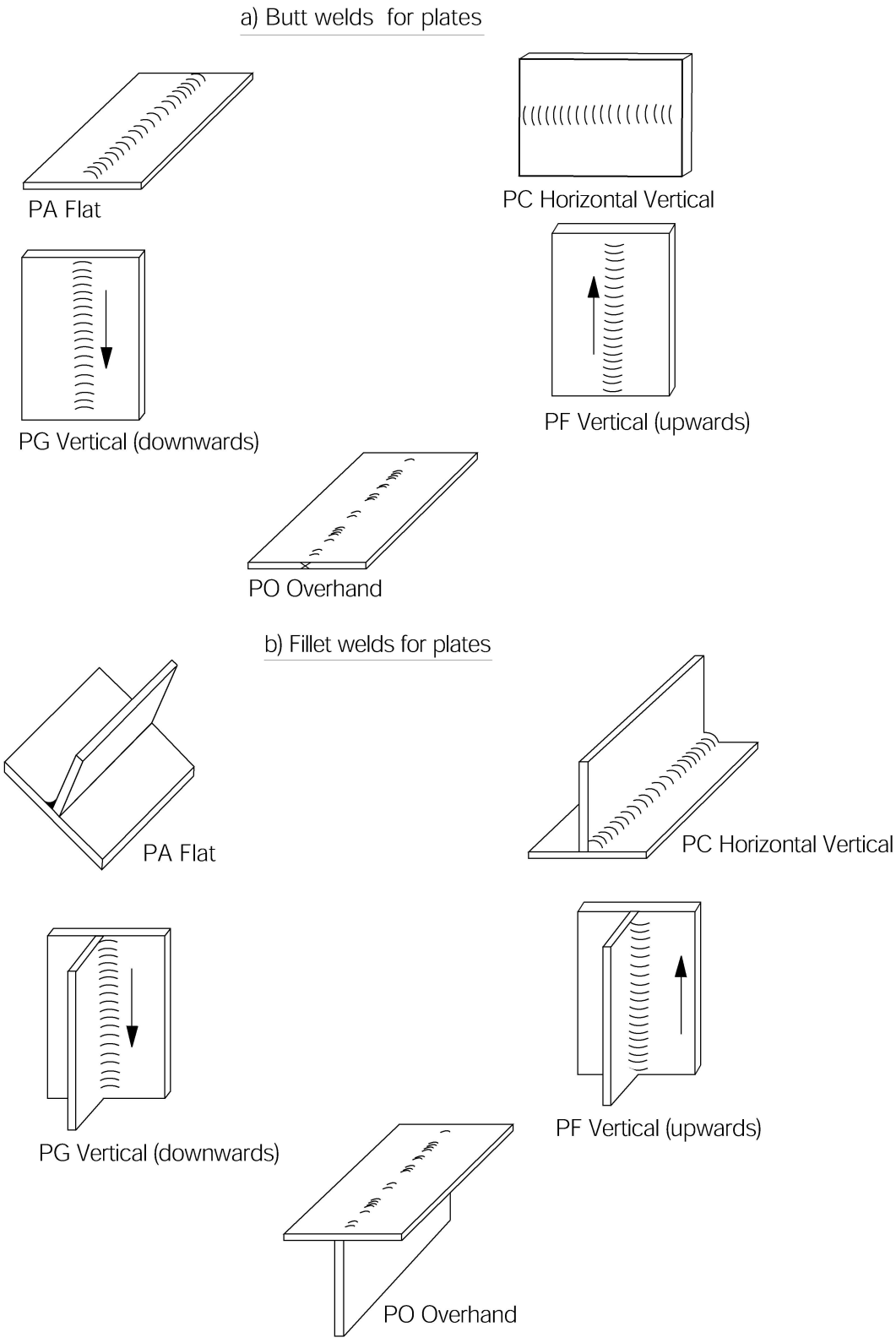


Fig. 4b Example showing the position of the indentations for hardness test on the weld metal, the heat affect zone and the base metal of a T-joint weld (dimensions in mm)

Annex C

Welding positions

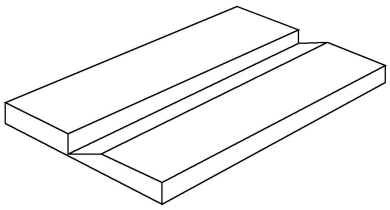
Annex C.1: Welding positions according to ISO Standard



Annex C.2: Welding positions according to AWS-Code

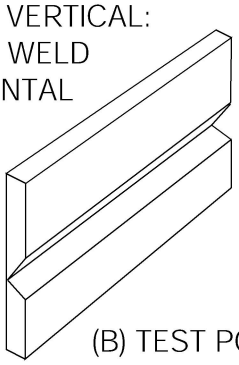
a) Butt weld for plates

PLATES HORIZONTAL

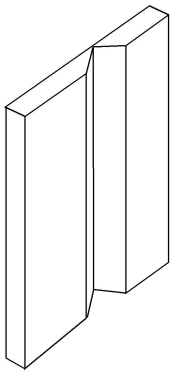


(A) TEST POSITION 1G

PLATES VERTICAL:
AXIS OF WELD
HORIZONTAL



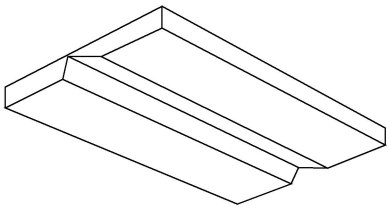
(B) TEST POSITION 2G



PLATES VERTICAL:
AXIS OF WELD
VERTICAL

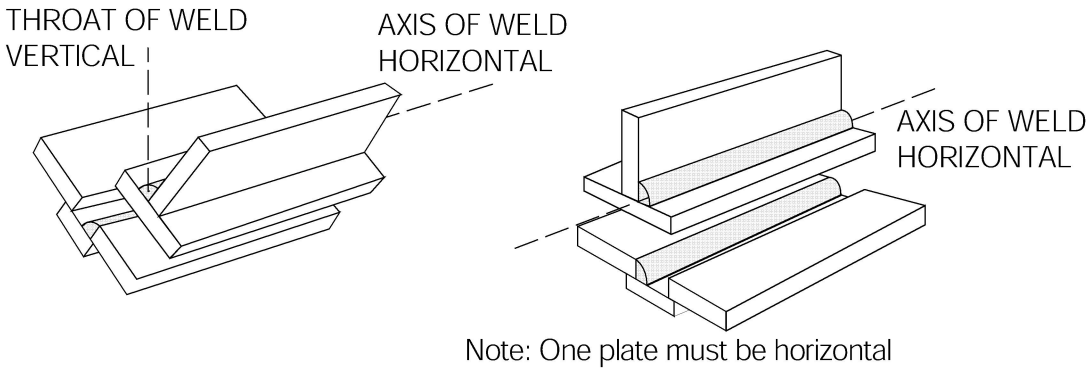
(C) TEST POSITION 3G

PLATES HORIZONTAL



(D) TEST POSITION 4G

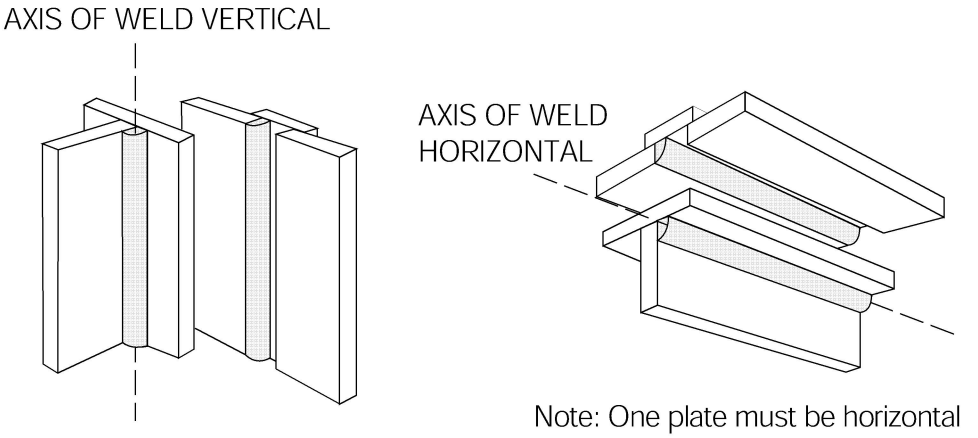
b) Fillet welds for plates



(A) FLAT POSITION 1F

Note: One plate must be horizontal

(B) HORIZONTAL POSITION 2F



(C) VERTICAL POSITION 3F

Note: One plate must be horizontal

(D) OVERHEAD POSITION 4F

TL- R W29 Requirements for manufacture of anchors

1. General requirements

1.1 Scope

These Rules apply to the materials, manufacture and testing, and certification of anchors, shanks and anchor shackles produced from cast or forged steel, or fabricated by welded rolled steel plate and bars. Frequent reference is made to TL- R A1.

With regard to holding power tests at sea for high holding power (HHP) and super high holding power (SHHP) anchors, refer to TL- R A1.

1.2 Types of anchor

The types of anchor covered include:

a) Ordinary anchors. Refer to TL- R A1.4.1.1
   i) Stockless anchors
   ii) Stocked anchors

b) HHP anchors. Refer to TL- R A1.4.1.2

c) SHHP anchors, not exceeding 1500kg in mass. Refer to TL- R A1.4.1.3

Any changes to the design made during manufacture are to have prior written agreement from TL.

2. Materials

2.1 Materials for anchors

All anchors are to be manufactured from materials meeting the requirements of the TL- R Ws as indicted below:

a) Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of TL- R W8 and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with Aluminium. If test programme B is selected in Section 4.2 then Charpy V notch (CVN) impact testing of cast material is required. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

b) Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of TL- R W7. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

Note: This requirement is implemented in respect of anchors, the manufacturing of which is commenced on or after 1 January 2007.

c) Rolled billets, plate and bar for fabricated steel anchors are to be manufactured and tested in accordance with the requirements of TL- R W11.

d) Rolled bar intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements of TL- R W7 or TL- R W11.

2.2 Materials for SHHP anchors

In addition to the requirements of 2.1 above, SHHP anchors are to be produced in accordance with the material toughness requirements of TL- R A1.4.4.

3. Manufacture of anchors

3.1 Tolerance

If not otherwise specified on standards or on drawings demonstrated to be appropriate, the following assembly and fitting tolerance are to be applied.

The clearance either side of the shank within the shackle jaws is to be no more than 3mm for small anchors up to 3 tonnes weight, 4mm for anchors up to 5 tonnes weight, 6mm for anchors up to 7 tonnes weight and is not to exceed 12 mm for larger anchors.

The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0.5mm for pins up to 57mm and 1.0mm for pins of larger diameter.

The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3 degrees, see Figure 1.

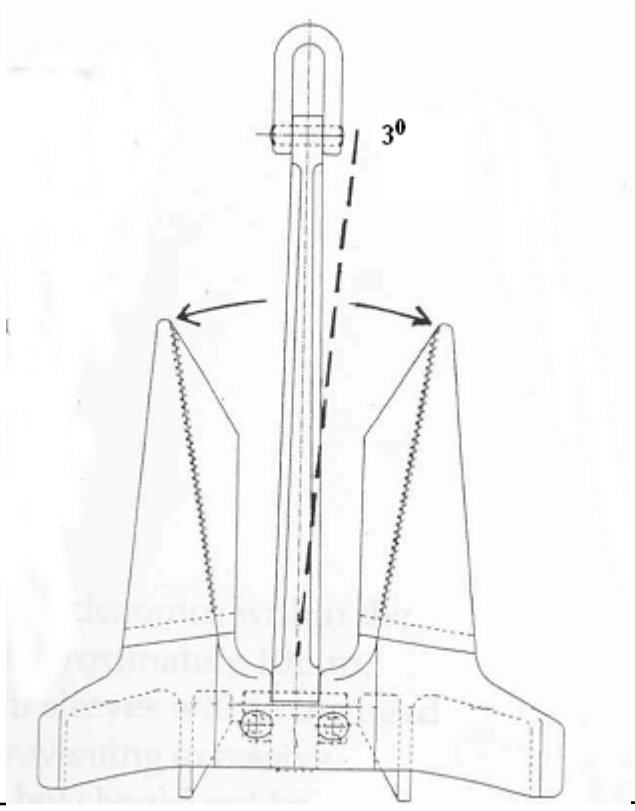


Figure 1 Allowable lateral movement of shank

3.2 Welding of anchors

Welded construction of fabricated anchors is to be done in accordance with procedures approved by TL. Welding is to be carried out by qualified welders, following the approved welding procedures qualified in accordance with TL- R W28, using consumables manufactured in accordance with the requirements of TL- R W17. NDE is to be carried in accordance with the requirements of 4.2 Product tests.

3.3 Heat treatment

Components for cast or forged anchors are to properly heat treated; fully annealed; normalised or normalised and tempered in accordance with TL- R W7 and TL- R W8.

Fabricated anchors may require stress relief after welding depending upon weld thickness. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

3.4 Freedom from defects

All parts are to have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects that would impair the performance of the product.

3.5 Repairs

Any necessary repairs to forged and cast anchors are to be agreed by the Surveyor and carried out in accordance with the repair criteria indicated in TL- R W7 and TL- R W8. Repairs to fabricated anchors are to be agreed by the Surveyor and carried out in accordance with qualified weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

3.6 Anchor assembly

Assembly and fitting are to be done in accordance with the design details.

Securing of the anchor pin, shackle pin or swivel nut by welding is to be done in accordance with an approved procedure.

4. Testing and certification

4.1 Proof load test

Proof load tests are to be carried out by an approved testing facility.

Proof load testing for Ordinary, HHP and SHHP anchors is to be carried out in accordance with the pertinent requirements of TL- R A1.4.3.

4.2 Product tests

4.2.1 Product Test Programmes

TL can request that either programme A or programme B be applied.

Table 1 Applicable programmes for each product form

Product test	Product form		
	Cast components	Forged components	Fabricated/Welded components
Programme A	Applicable	Not applicable	Not applicable
Programme B	Applicable (1)	Applicable	Applicable

Notes : (1) CVN impact tests are to be carried out to demonstrate at least 27 joules average at 0ºC. Refer to 2.1 a).

Table 2 Product test requirements for programme A and B

Programme A	**Programme B**
Drop test	—
Hammering test	—
Visual inspection	Visual inspection
General NDE	General NDE
—	Extended NDE

4.2.2 Drop test

Each anchor fluke and shank is individually raised to a height of 4m and dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

4.2.3 Hammering test

After the drop test, hammering tests are carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3kg mass is to be used.

4.2.4 Visual inspection

After proof loading visual inspection of all accessible surfaces is to be carried out.

4.2.5 General non-destructive examination

After proof loading general NDE is to be carried out as indicated in the following Tables 3 and 4.

Table 3 General NDE for Ordinary and HHP anchors

Location	Method of NDE
Feeders of castings	PT or MT
Risers of castings	PT or MT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Table 4 General NDE for SHHP anchors

Location	Method of NDE
Feeders of castings	PT or MT and UT
Risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

TL- G 69 “Guidelines for non-destructive examination of marine steel castings” is regarded as an example of an acceptable standard for surface and volumetric examination.

4.2.6 Extended non-destructive examination

After proof loading general NDE is to be carried out as indicated in the following Table 5.

Table 5 Extended NDE for Ordinary, HHP and SHHP anchors

Location	Method of NDE
Feeders of castings	PT or MT and UT
Risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Random areas of castings	UT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

TL- G 69 “Guidelines for non-destructive examination of marine steel castings” is regarded as an example of an acceptable standard for surface and volumetric examination.

4.2.7 Repair criteria

If defects are detected by NDE, repairs are to be carried out in accordance with 3.5. For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.

4.3 Mass and dimensional inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless this is an integral component.

4.4 Retests

Mechanical retest are permitted in accordance with the requirements of TL- R W2.

4.5 Marking

Anchors which meet the requirements are to be stamped on the shank and the fluke. The markings on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the center line of the crown on the right hand fluke looking from the crown towards the shank. The markings are to include:

- Mass of anchor
- Identification, e.g. test No. or certificate No.
- TL’s stamp
- Manufacturer’s mark

Additionally the unique cast identification is to be cast on the shank and the fluke.

4.6 Certification

Anchors which meet the requirements are to be certified by TL at least with the following items:

- Manufacturer's name
- Type
- Mass
- Fluke and Shank identification numbers
- Grade of materials
- Proof test loads
- Heat treatment
- Marking applied to anchor

4.7 Painting

All types of anchor are not to be painted until all tests and inspections have been completed.

TL- R W31 YP47 Steels and Brittle Crack Arrest Steels

1. Scope

1.1 General

1.1.1 This Requirement defines the requirements on YP47 steels and brittle crack arrest steels as required by TL-R S33.

1.1.2 Unless otherwise specified in this Requirement, TL-R W11 is to be followed.

1.2 YP47 steels

1.2.1 Steels designated as YP47 refer to steels with a specified minimum yield point of 460 N/mm^2.

1.2.2 The YP47 steels 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, etc.). Special consideration is to be given to the application of YP47 steels for other hull structures.

1.2.3 This Requirement gives the requirements for YP47 steels in thickness greater than 50mm and not greater than 100mm intended for the upper deck region of container carriers. For YP47 steels outside scope of the said thickness range, special consideration is to be given by TL.

1.3 Brittle crack arrest steels

1.3.1 The brittle crack designation can be assigned to YP36 and YP40 steels specified in TL-R W11 and YP47 steels specified in this Requirement, which meet the additional brittle crack arrest requirements and properties defined in this Requirement.

1.3.2 The application of brittle crack arrest steels is to comply with TL-R S33, which covers longitudinal structural members in the upper deck region of container carriers (such as hatch side coaming, upper deck, hatch coaming top and the attached longitudinals, etc.).

Notes:

1. This Requirement is to be implemented on ships contracted for construction on or after 01 January 2021.

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 TL-PR 29.

1.3.3 The thickness range of brittle crack arrest steels is over 50mm and not greater than 100mm as specified in Table 3 of this Requirement.

2 Material specifications

2.1 YP47 steels

Material specifications for YP47 steels are specified in Table 1 and Table 2.

Table 1 Chemical composition and deoxidation practice for YP47 steels without specified brittle crack arrest properties

Grade	EH47
Deoxidation Practice	Killed and fine grain treated
Chemical Composition % (ladle samples)(6)(7)	
C max.	0.18
Mn	0.90 – 2.00
Si max.	0.55
P max.	0.020
S max.	0.020
Al (acid soluble min)	0.015 (1)(2)
Nb	0.02 – 0.05 (2)(3)
V	0.05 – 0.10 (2)(3)
Ti max.	0.02(3)
Cu max.	0.35
Cr max.	0.25
Ni max.	1.0
Mo max.	0.08
C_{eq} max.(4)	0.49
P_{cm} max.(5)	0.22

Notes:

1. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0.020%.
2. 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.
3. The total niobium, vanadium and titanium content is not to exceed 0.12%.
4. The carbon equivalent C_{eq} value is to be calculated from the ladle analysis using the following formula:

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

5. Cold cracking susceptibility P_{cm} value is to be calculated using the following formula:

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

6. Where additions of any other element have been made as part of the steelmaking practice subject to approval by TL, the content is to be indicated on product inspection certificate.

7. Variations in the specified chemical composition may be allowed subject to approval of TL.

Table 2 Conditions of supply, grade and mechanical properties for YP47 steels without specified brittle crack arrest properties (1)

Supply condition	Grade	Tensile test			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
						Longitudinal	Longitudinal	Longitudinal
TMCP(2)	EH47	460	570 - 720	17	-40	53	64	75

t: thickness (mm)

Notes:
1. The additional requirements for YP47 steel with brittle crack arrest properties is specified in 2.2 of this Requirement.
2. Other conditions of supply are to be in accordance with TL's procedures.

2.2 Brittle crack arrest steels

2.2.1 Brittle crack arrest steels are defined as steel plate with the specified brittle crack arrest properties measured by either the brittle crack arrest toughness K_{ca} or Crack Arrest Temperature (CAT).

2.2.2 In addition to the required mechanical properties of TL-R W11 for YP36 and YP40 and Table 2 of this Requirement for YP47, brittle crack arrest steels are to comply with the requirements specified in Table 3 and Table 4 of this Requirement .

2.2.3 The brittle crack arrest properties specified in Table 3 are to be evaluated for the products in accordance with the procedure approved by TL. Test specimens are to be taken from each piece (means "the rolled product from a single slab or ingot if this is rolled directly into plates" as defined in TL-RW11), unless otherwise agreed by TL.

Table 3 Requirement of brittle crack arrest properties for brittle crack arrest steels

Suffix to the steel grade(1)	Thickness range (mm)	Brittle crack arrest properties(2)(6)	
		Brittle Crack Arrest Toughness K_{ca} at -10 °C ($N/mm^{3/2}$) (3)	Crack Arrest Temperature CAT (°C) (4)
BCA1	50 < t ≤ 100	6,000 min.	-10 or below
BCA2	80 < t ≤ 100(7)	8,000 min.	(5)

t: thickness (mm)

Notes:
1. Suffix "BCA1" or "BCA2" is to be affixed to the steel grade designation (e.g. EH40-BCA1, EH47-BCA1, EH47-BCA2, etc.).
2. Brittle crack arrest properties for brittle crack arrest steels are to be verified by either the brittle crack arrest toughness K_{ca} or Crack Arrest Temperature (CAT).
3. K_{ca} value is to be obtained by the brittle crack arrest test specified in Annex 3 of this UR.
4. CAT is to be obtained by the test method specified in Annex 4 of this UR.
5. Criterion of CAT for brittle crack arrest steels corresponding to Kca=8,000 $N/mm^{3/2}$ is to be approved by TL
6. Where small-scale alternative tests are used for product testing (batch release testing), these test methods are to be approved by TL.
7. Lower thicknesses may be approved at the discretion of TL.

Table 4 Chemical composition and deoxidation practice for brittle crack arrest steels

Grade	EH36-BCA	EH40-BCA	EH47-BCA
Deoxidation Practice	Killed and fine grain treated		
Chemical Composition % (1)(7)(8) (ladle samples)			
C max.	0.18		0.18
Mn	0.90 – 2.00		0.90 – 2.00
Si max.	0.50		0.55
P max.	0.020		0.020
S max.	0.020		0.020
Al (acid soluble min)	0.015 (2) (3)		0.015 (2) (3)
Nb	0.02 – 0.05 (3) (4)		0.02 – 0.05 (3) (4)
V	0.05 – 0.10 (3) (4)		0.05 – 0.10 (3) (4)
Ti max.	0.02(4)		0.02(4)
Cu max.	0.50		0.50
Cr max.	0.25		0.50
Ni max.	2.0		2.0
Mo max.	0.08		0.08
C_{eq} max.(5)	0.47	0.49	0.55
P_{cm} max.(6)	-		0.24

Notes:

1. Chemical composition of brittle crack arrest steels shall comply with Table 4 of this Requirement , regardless of chemical composition specified in TLR W11 and Table 1 of this Requirement .
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0.020%.
3. 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.
4. The total niobium, vanadium and titanium content is not to exceed 0.12%.
5. The carbon equivalent C_{eq} value is to be calculated from the ladle analysis using the following formula:

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

6. Cold cracking susceptibility P_{cm} value is to be calculated using the following formula:

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

7. Where additions of any other element have been made as part of the steelmaking practice subject to approval by TL, the content is to be indicated on product inspection certificate.

8. Variations in the specified chemical composition may be allowed subject to approval of TL.

3 Manufacturing approval scheme

3.1 YP47 steels

Manufacturing approval scheme for YP47 steels is to be in accordance with Annex 1 of this Requirement.

3.2 Brittle crack arrest steels

Manufacturing approval scheme for brittle crack arrest steels is to be in accordance with Annex 2 of this Requirement.

4 Welding procedure qualification test

4.1 YP47 steels

4.1.1 General

Approval test items, test methods and acceptance criteria not specified in this Requirement are to be in accordance with TL's procedures.

4.1.2 Approval range

TL-R W28 is to be followed for approval range.

4.1.3 Impact test

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

4.1.4 Hardness

HV10, as defined in TL-R W28, is to be not more than 350. Measurement points are to include mid-thickness position in addition to the points required by TL-R W28.

4.1.5 Tensile test

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

4.1.6 Brittle fracture initiation test

Deep notch test or CTOD test may be required.

Test method and acceptance criteria are to be considered appropriate by TL.

4.2 Brittle crack arrest steels

4.2.1 General

Where Welding Procedure Specification (WPS) for the non-BCA steels has been approved by TL, the said WPS is applicable to the same welding procedure applied to the same grade with suffix "BCA1" or "BCA2" specified in Table 3 of this Requirement except high heat input processes over 50kJ/cm.

The requirements for welding procedure qualification test for brittle crack arrest steels is to be in accordance with the relevant requirements for each steel grade excluding suffix “BCA1” or “BCA2” specified in Table 3 of this Requirement, except for 4.2.2 below.

4.2.2 Hardness

For YP47 steels with brittle crack arrest properties, HV10, as defined in TL-R W28, is to be not more than 380. Measurement points are to include mid-thickness position in addition to the points required by TL-R W28.

5 Production welding

5.1 YP47 steels

5.1.1 Welder

Welders engaged in YP47 welding work are to possess welder’s qualifications specified in TL-R W32.

5.1.2 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 TL.

5.1.3 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 and the air temperature is below 5°C but above 0°C, alternative preheating requirements may be adopted with approval of TL.

5.1.4 Welding consumable

Approval procedure, approval test items, test methods and acceptance criteria not specified in this Requirement are to be in accordance with TL-R W17.

Specifications of welding consumables for YP47 steel plates are to be in accordance with Table 5.

Table 5 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	64

Consumable tests for butt weld assemblies are to be in accordance with Table 6.

Table 6 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 absorbed energy (J) min.
570 - 720	4	- 20	64

5.1.5 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 TL.

5.2 Brittle crack arrest steels

Welding work (such as relevant welder's qualification, short bead, preheating, selection of welding consumable, etc.) for brittle crack arrest steels is to be in accordance with the relevant requirements for each steel grade excluding suffix "BCA1" or "BCA2" specified in Table 3 of this Requirement.

Annex 1 Manufacturing Approval Scheme for YP47 Steels

1. Scope

1.1 This Annex specifies, as given in 3.1 of this Requirement, the manufacturing approval scheme for YP47 steels of grade EH47.

1.2 Unless otherwise specified in this Annex, Appendix A2 of TL-R W11 is to be followed.

2. Approval tests

2.1 Extent of the approval tests

3.1 (c) and (d), Appendix A2 of TL-R W11 are not applied to manufacturing approval of YP47 steels.

2.2 Type of tests

2.2.1 Brittle fracture initiation test

Deep notch test or Crack Tip Opening Displacement (CTOD) test is to be carried out. Test method is to be in accordance with TL's practice.

2.2.2 Weldability test

(a) Y-groove weld cracking test (Hydrogen crack test)

The test method is to be in accordance with recognized national standards such as JIS Z 3158-2016 or CB/T 4364-2013. Acceptance criteria are to be in accordance with TL's practice.

(b) 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 TL.

2.2.3 Other tests

In addition to the requirement specified in 2.2.1 and 2.2.2 above, the approval tests required for steels specified in Appendix A2 of TL-R W11 are to be carried out. Additional tests may be required when deemed necessary by TL.

Annex 2 Manufacturing Approval Scheme for Brittle Crack Arrest Steels

1. Scope

1.1 This Annex specifies, as given in 3.2 of this Requirement, the manufacturing approval scheme for brittle crack arrest steels.

1.2 Unless otherwise specified in this Annex, Appendix A2 of TL-R W11 and/or Annex1 of this Requirement are to be followed.

2. Approval Application

2.1 Documents to be submitted

The manufacturer is to submit to TL the following documents together with those required in 2.1, Appendix A2 of TL-R W11:

a) In-house test reports of the brittle crack arrest properties of the steels intended for approval
b) Approval test program for the brittle crack arrest properties (see 3.1 below)
c) Production test procedure for the brittle crack arrest properties.

3. Approval tests

3.1 Extent of the approval tests

3.1.1 The extent of the test program is specified in 3.2, 3.3 and 3.4 of this Annex.
If the manufacturing process and mechanism to ensure the brittle crack arrest properties for the steels intended for approval are same, 3.1, Appendix A2 of TL-R W11 is to be followed for the extent of the approval tests.

3.1.2 The number of test samples and test specimens may be increased when deemed necessary by TL, based on the in-house test reports of the brittle crack arrest properties of the steels intended for approval specified in 2.1 a).

3.2 Type of tests

3.2.1 Brittle crack arrest tests are to be carried out in accordance with 3.3 of this Annex in addition to the approval tests specified in Appendix A2 of TL-R W11 and/or Annex 1 of this Requirement.
3.2.2 In the case of applying for addition of the specified brittle crack arrest properties for YP36, YP40 and YP47 steels of which, manufacturing process has been approved by TL (i.e. The aim analyses, method of manufacture and condition of supply are similar and the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same), brittle crack arrest tests, chemical analyses, tensile test and Charpy V-notch impact test are to be carried out in accordance with Annex 2 of this Requirement and Appendix A2 of TL-R W11.

3.3 Test specimens and testing procedure of brittle crack arrest tests

3.3.1 The test specimens of the brittle crack arrest tests are to be taken with their longitudinal axis parallel to the final rolling direction of the test plates.

W31 (cont)

3.3.2 The loading direction of brittle crack tests is to be parallel to the final rolling direction of the test plates.

3.3.3 The thickness of the test specimens of the brittle crack arrest tests is to be the full thickness of the test plates.

3.3.4 The test specimens and repeat test specimens are to be taken from the same steel plate.

3.3.5 The thickness of the test specimen is to be the maximum thickness of the steel plate requested for approval.

3.3.6 In the case where the brittle crack arrest properties are evaluated by K_{ca}, the brittle crack arrest test method is to be in accordance with Annex 3 of this Requirement. In the case where the brittle crack arrest properties are evaluated by CAT, the test method is to be in accordance with Annex 4 of this Requirement.

3.4 Other tests

Additional tests may be required when deemed necessary by TL in addition to the tests specified in 3.3.

4. Results

Appendix A2 of TL-R W11 is to be followed for the results.

Additionally, results of test items and the procedures shall comply with the test program approved by TL. In the case where the brittle crack arrest properties are evaluated by K_{ca} or CAT, the manufacturer also is to submit to TL the brittle crack arrest test reports in accordance with Annex 3 for Kca and Annex 4 for CAT of this Requirement.

5. Approval and Certification

Upon satisfactory completion of the survey and tests, approval is granted by TL with the grade designation having the suffix “BCA1” or “BCA2” (e.g. EH40-BCA1, EH47-BCA1, EH47-BCA2, etc.).

6. Renewal of approval

The manufacturer is also to submit to TL actual manufacturing records of the approved brittle crack arrest steels within the term of validity of the manufacturing approval certificate.

Note: Chemical composition, mechanical properties, brittle crack arrest properties (e.g. brittle crack arrest test results or small-scale alternative test results) and nominal thickness are to be described in the form of histogram or statistics.

Annex 3 Test Method for Brittle Crack Arrest Toughness, K_{ca}

Setting a temperature gradient in the width direction of a test specimen, and applying uniform stress to the test specimen, strike the test specimen to initiate a brittle crack from the mechanical notch at the side of the test specimen and causes crack arrest (temperature gradient type arrest testing). Using the stress intensity factor, calculate the brittle crack arrest toughness, K_{ca}, from the applied stress and the arrest crack length. This value is the brittle crack arrest toughness at the temperature of the point of crack arrest (arrest temperature). To obtain K_{ca} at a specific temperature followed by the necessary evaluation, the method specified in Appendix A of this Annex 3 can be used.

As a method for initiating a brittle crack, a secondary loading mechanism can also be used (see Appendix B of this Annex 3 “Double tension type arrest test”).

1. Scope

This Annex 3 specifies the test method for brittle crack arrest toughness (i.e. K_{ca}) of steel using fracture mechanics parameter. This Annex 3 is applicable to hull structural steels with the thickness over 50mm and not greater than 100mm specified in TLR W11 or this TL-R.

2. Symbols and their significance

The symbols and their significance used in this standard are shown in Table A3-1.

Table A3-1 Symbols and their significance

Symbol	Unit	Significance
a	mm	Crack length or arrest crack length
E	N/mm^2	Modulus of longitudinal elasticity
E_i	J	Impact energy
E_s	J	Strain energy stored in a test specimen
E_t	J	Total strain energy stored in tab plates and pin chucks
F	MN	Applied load
K	$N/mm^{3/2}$	Stress intensity factor
K_{ca}	$N/mm^{3/2}$	Arrest toughness
L	mm	Test specimen length
L_p	mm	Distance between the loading pins
L_{pc}	mm	Pin chuck length
L_{tb}	mm	Tab plate length
T	°C	Temperature or arrest temperature
t	mm	Test specimen thickness

Table A3-1 Symbols and their significance (cont'd)

Symbol	Unit	Significance
t_{tb}	mm	Tab plate thickness
t_{pc}	mm	Pin chuck thickness
W	mm	Test specimen width
W_{tb}	mm	Tab plate width
W_{pc}	mm	Pin chuck width
x_a	mm	Coordinate of a main crack tip in the width direction
x_{br}	mm	Coordinate of the longest branch crack tip in the width direction
y_a	mm	Coordinate of a main crack tip in the stress loading direction
y_{br}	mm	Coordinate of the longest branch crack tip in the stress loading direction
σ	N/mm^2	Applied stress
σ_{Y0}	N/mm^2	Yield stress at room temperature

3. Testing equipment

The following specifies the testing machine needed for conducting the brittle crack arrest test. Testing machine is used to apply tensile force to an integrated specimen, and impact equipment is used to generate a brittle crack on the test specimen.

3.1 Testing machine

3.1.1 Loading method

Tensile load to an integrated specimen shall be hydraulically applied.
The loading method to an integrated specimen using the testing machine shall be of a pin type. The stress distribution in the plate width direction shall be made uniform by aligning the centres of the loading pins of both sides and the neutral axis of the integrated specimen.

3.1.2 Loading directions

The loading directions shall be either vertical or horizontal. In the case of the horizontal direction, test specimen surfaces shall be placed either perpendicular to the ground.

3.1.3 Distance between the loading pins

The distance between the loading pins shall be approximately 3.4W or more, where W is the width of the test specimen. Since the distance between the loading pins sometimes has an effect on the load drop associated with crack propagation, the validity of the test results is determined by the judgment method described in 7.1.

3.2 Impact equipment

3.2.1 Impact methods

Methods to apply an impact load to an integrated specimen shall be of a drop weight type or of an air gun type.

The wedge shall be hard enough to prevent significant plastic deformation caused by the impact. The wedge thickness shall be equal to or greater than that of the test specimen, and the wedge angle shall be greater than that of the notch formed in the test specimen and have a shape capable of opening up the notch of the test specimen.

4. Test specimens

4.1 Test specimen shapes

The standard test specimen shape is shown in Figure A3-1. Table A3-2 shows the ranges of test specimen thicknesses, widths and width-to-thickness ratios.

The test specimen length shall be, in principle, equal to or greater than its width.

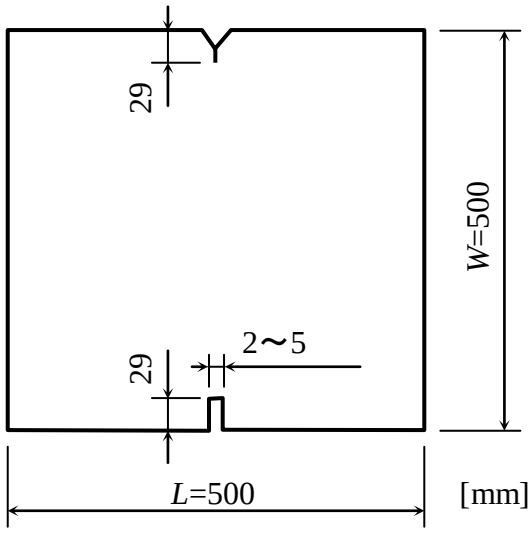


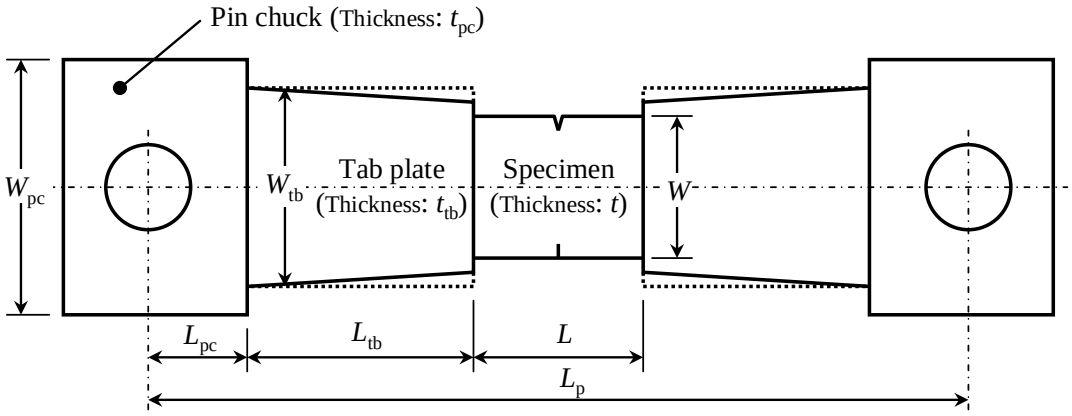
Figure A3-1 Standard test specimen shape

Table A3-2 Dimensions of test specimens

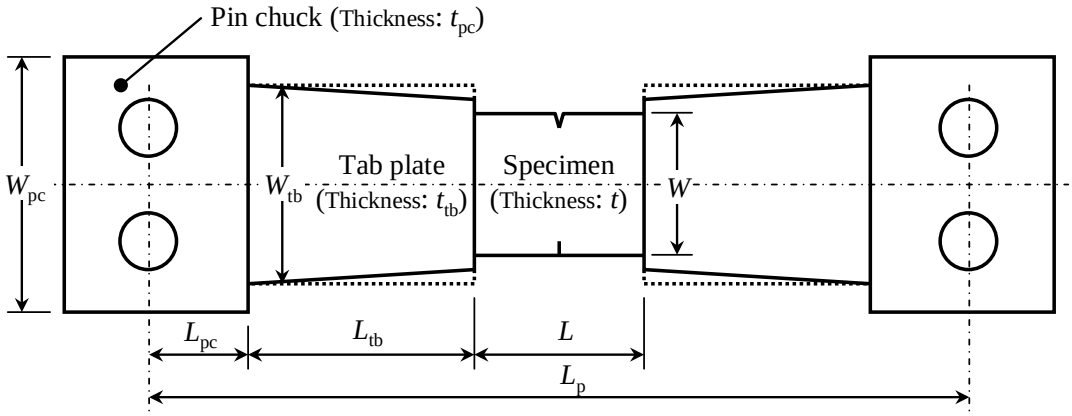
Test specimen thickness, t	50 mm ≤ t ≤ 100 mm
Test specimen width, W	350 mm ≤ W ≤ 1000 mm (Standard width: W = 500 mm)
Test specimen width/test specimen thickness, W/t	W/t ≥ 5

4.2 Shapes of tab plates and pin chucks

The definitions of the dimensions of the tab plates and pin chucks are shown in Figure A3-2. Typical examples are shown in Figure A3-3.

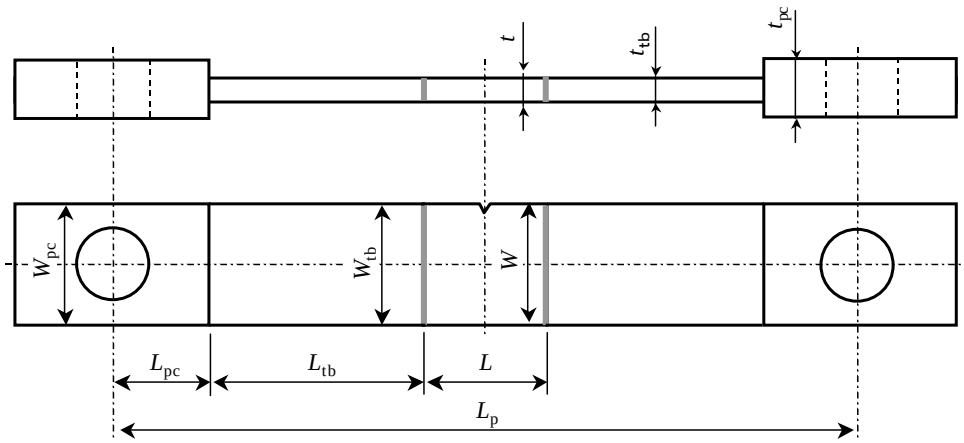


(a) Single-pin type

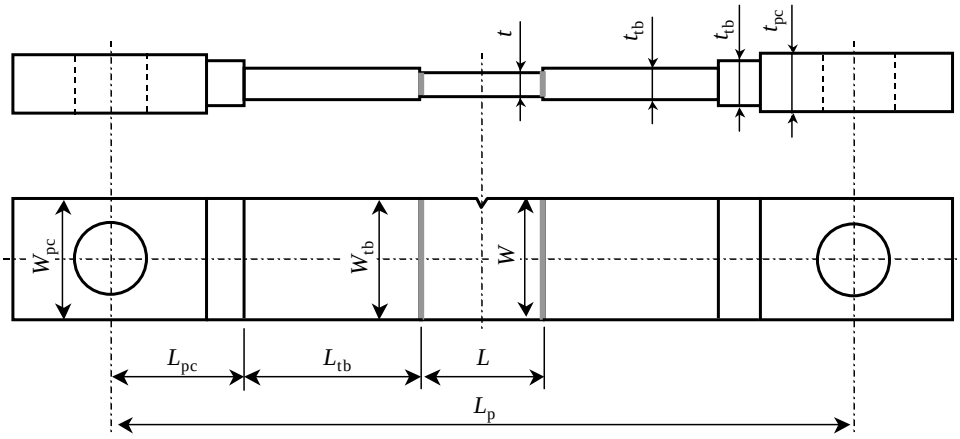


(b) Double-pin type

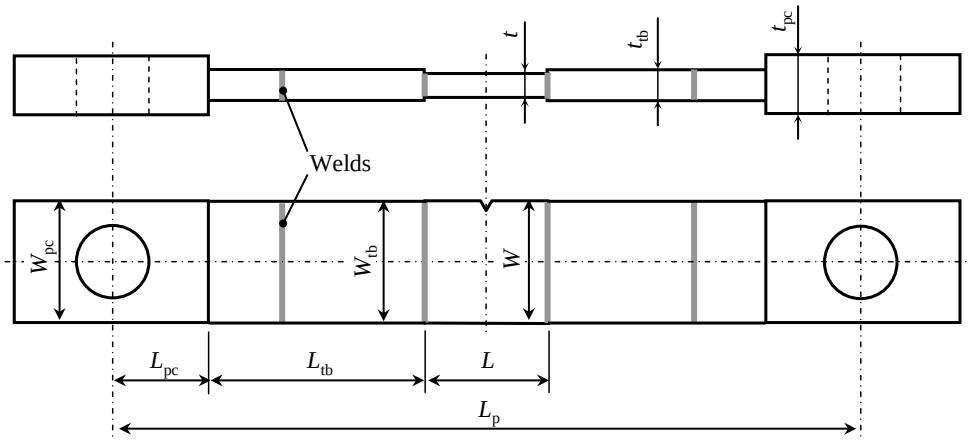
Figure A3-2 Definitions of dimensions of tab plates and pin chucks



(a) Example 1

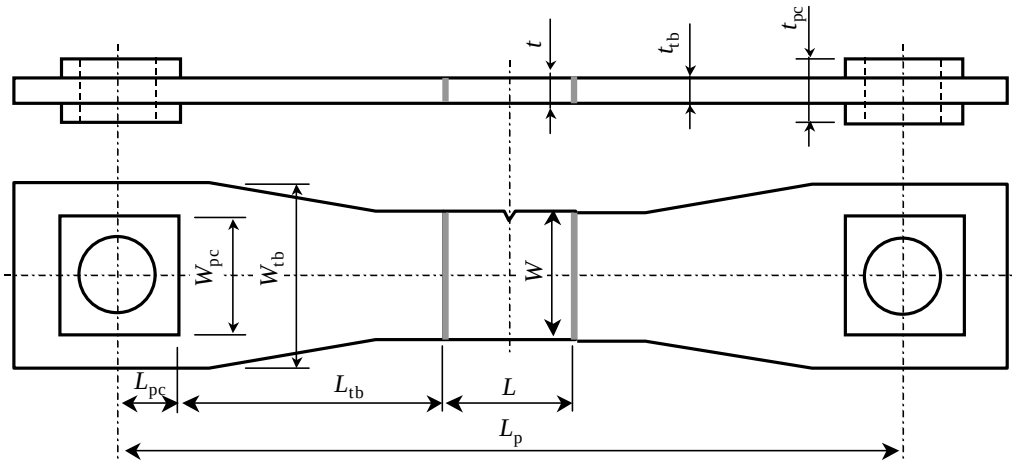


(b) Example 2

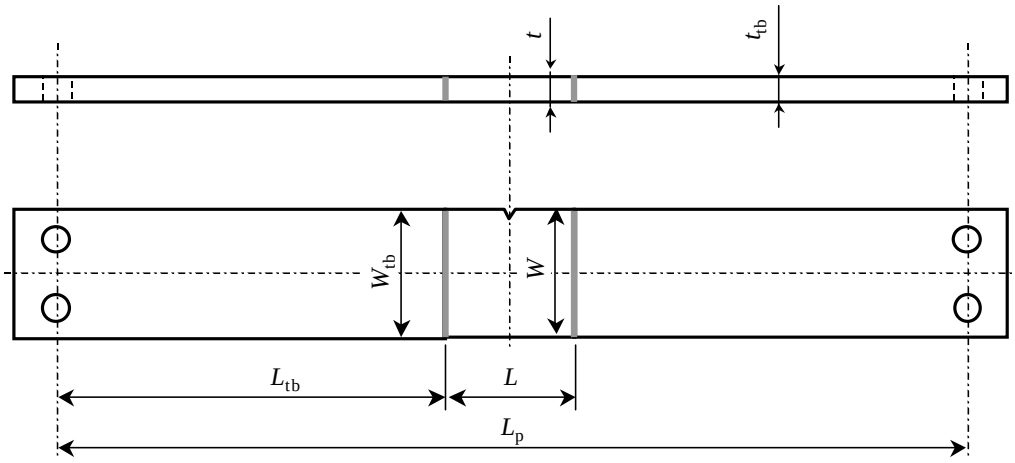


(c) Example 3

Figure A3-3 Examples of the shapes of tab plates and pin chucks



(d) Example 4



(e) Example 5

Figure A3-3 Examples of shapes of tab plates and pin chucks (cont'd)

4.2.1 Tab plates

The tolerances of tab plate dimensions are shown in Table A3-3. When the lengths of the tab plates attached to both ends of a test specimen are different, the shorter length shall be used as the tab length, L_{tb}.

Table A3-3 Tolerances of tab plate dimensions

Tab plate thickness, t_{tb}	$0.8t \le t_{tb} \le 1.5t$
Tab plate width, W_{tb}	$W \le W_{tb} \le 2.0W$
Total length of a test specimen and tab plates, $L + 2L_{tb}$ (Total length of a test specimen and a single tab plate $L + L_{tb}$)	$L + 2L_{tb} \ge 3.0W$ ($L + L_{tb} \ge 2.0W$)
Tab plate length (L_t)/Tab plate width, (W)	$L_{tb}/W \ge 1.0$

4.2.2 Pin chucks

The pin chuck width, W_{pc}, shall be in principle equal to or more than the tab plate width, W_{tb}.

The pin chucks shall be designed to have a sufficient load bearing strength. When pin chucks attached to both ends of an integrated specimen are asymmetric, the length of the shorter one shall be used as the pin chuck length, L_{pc}.

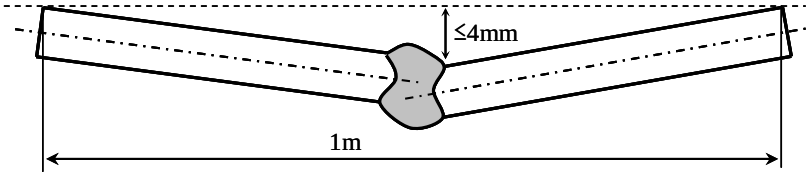
The distance between the pins, L_p, is obtained from the equation (1). In the case as shown in Figure A3-3 (e), Example 5, L_p is obtained by setting $L_{pc} = 0$.

$$L_{\mathrm{p}} = L + 2L_{\mathrm{tb}} + 2L_{\mathrm{pc}} \quad \cdots\cdots (1)$$

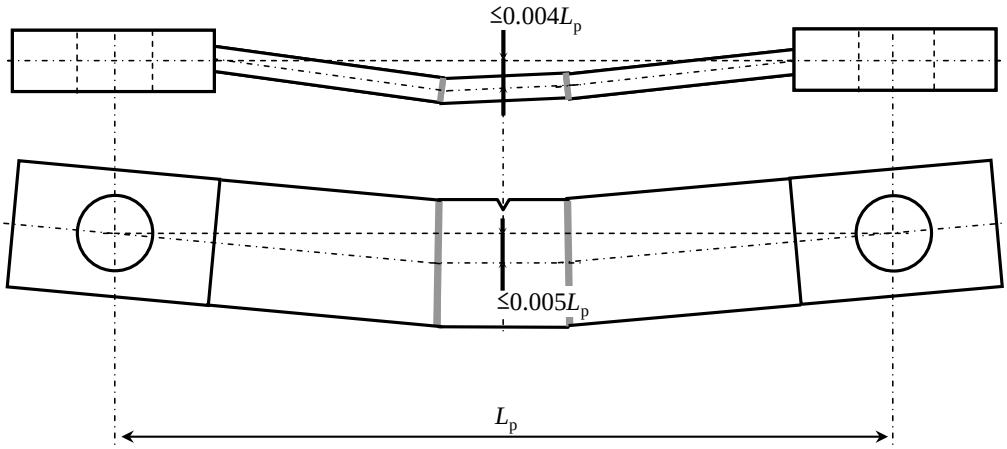
4.3 Welding of test specimen and tab plates

Test specimen, tab plates, and pin chucks shall be connected by welding. The welds shall have a sufficient force bearing strength.

As shown in Figure A3-4 (a), the flatness (angular distortion, linear misalignment) of the weld between a test specimen and a tab plate shall be 4 mm or less per 1 m. In the case of preloading, however, it is acceptable if the value after preloading satisfies this condition. As shown in Figure A3-4 (b), the accuracy of the in-plane loading axis shall be 0.5% or less of the distance between the pins, and the accuracy of the out-of-plane loading axis shall be 0.4% or less of the distance between the pins.



(a) Flatness of weld between test specimen and tab plate



(b) Accuracy of in-plane and out-of-plane loading axes

Figure A3-4 Dimensional accuracy of weld between test specimen and tab plate

5. Test methods

The following specifies methods for conducting the arrest toughness test.

5.1 Temperature control methods

A predetermined temperature gradient shall be established across a test specimen width by soldering at least nine thermocouples to the test specimen for temperature measurement and control.

Temperature gradient shall be established in accordance with the following conditions (1) through (3).

(1) A temperature gradient of 0.25 - 0.35°C/mm shall be established in a test specimen width range of 0.3*W* - 0.7*W*. When measuring the temperatures at the centre position of the test specimen thickness, it shall be kept within ±2°C for 10 minutes or more, whereas when measuring the temperatures on the front and back surface positions of the test specimen, it shall be kept within ±2°C for (10＋0.1*t* [mm]) minutes or more taking account of the time needed for soaking to the centre. If the temperature gradient at 0,3*W* - 0,7*W* is less than 0.25°C/mm, crack arrest may become difficult, and if the gradient is larger than 0.35°C/mm, the obtained arrest toughness may be too conservative.

(2) At the test specimen width centre position (i.e., 0.5*W*), and in the range of ±100 mm in the test specimen length direction, the deviation from the temperature at the centre position in the length direction shall be controlled within ±5°C. However, when temperature measurement is not performed at the centre position in the length direction, the average temperature at the closest position shall be used as the temperature at the centre position in the length direction.

(3) At the same position in the width direction, the deviation of the temperature on the front and back surfaces shall be controlled within ±5°C.

5.2 Crack initiation methods

Impact energy shall be applied to a test specimen to initiate a crack. However, if the energy is excessive, it may influence on the test results. In that case, the results shall be treated as invalid data in accordance with the judgment criteria specified in 7.2. It is desirable to use equation (2) and Figure A3-5 as guides for obtaining valid data.

$$\frac{E_{\mathrm{i}}}{t} \leq min\,(1.2\sigma - 40\,,200\,) \quad \cdots\cdots (2)$$

Where the variables have the following units: E_{i} [J], t [mm], and σ [N/mm^2], and *min* means the minimum of the two values.

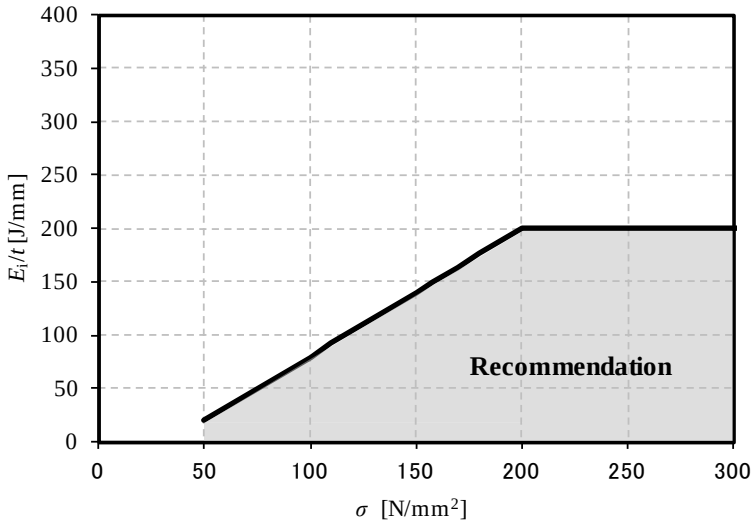


Figure A3-5 Recommended range of impact energy

6. Test procedures

The following specifies the procedures for testing brittle crack arrest toughness.

6.1 Pretest procedures

(1) Install an integrated specimen in the testing machine.

(2) Mount a cooling device on the test specimen. A heating device may also be mounted on the test specimen.

(3) Install an impact apparatus specified in 3.2, on the testing machine. Place an appropriate reaction force receiver as necessary.

Note: The above procedures (1) through (3) do not necessarily specify the order of implementation, and they may be completed, for example, on the day before the test.

(4) After checking that all measured values of the thermocouples indicate room temperature, start cooling. The temperature distribution and the holding time shall be as provided in the specifications in 5.1.

(5) Set an impact apparatus, as specified in 3.2 so that it can supply predetermined energy to the test specimen.

(6) Apply force to the test specimen until it reaches the predetermined value. This force is applied after temperature control to prevent autonomous crack initiation during force increase. Alternatively, temperature control may be implemented after loading. The loading rate and applied stress shall satisfy the conditions (a) and (b) described below, respectively.

(a) Loading rate
There is no specification of loading rate, but it shall be determined considering that an excessively slow loading rate may prolong the temperature control period, thereby allowing the temperature distribution to depart from the desired condition and an

excessively fast loading rate may cause over-shooting of the load.

(b) Applied stress/yield stress ratio
Applied stress shall be within the range shown by equation.

$$\sigma \leq \frac{2}{3}\sigma_{Y0} \quad \cdots\cdots (3)$$

As a guide, a value equal to 1/6 of σ_{Y0} or more is desirable. If applied stress is larger than that specified by equation (3), the test may give a non-conservative result.

(7) To initiate a crack, the notch may be cooled further immediately before impact on the condition that the cooling does not disturb the temperature in the range of 0.3*W* - 0.7*W*. The test temperature in this case shall be the measured temperature obtained from the temperature record immediately before the further notch cooling.

(8) Record the force value measured by a force recorder.

6.2 Loading procedures

(1) After holding a predetermined force for 30 seconds or more, apply an impact to the wedge using the impact apparatus. If a crack initiates autonomously and the exact force value at the time of the crack initiation cannot be obtained, the test is invalid.

(2) After the impact, record the force value measured by the force recorder.

(3) When the force after the impact is smaller than the test force, consider that crack initiation has occurred.

Note: An increase in the number of times of impact may cause a change in the shape of the notch of the test specimen. Since the number of impact has no effect on the value of brittle crack arrest toughness, no limit is specified for the number of impact. However, because the temperature gradient is often distorted by impact, the test shall be conducted again, beginning from temperature control when applying repeated impact to the wedge.

(4) When crack initiation, propagation, and arrest are observed, remove the force.

6.3 Procedures after testing

(1) Remove the impact apparatus.

(2) Remove the cooling device, thermocouples, and strain gauges.

(3) Return the temperature of the test specimen to room temperature. For that purpose, the test specimen may be heat-tinted using a gas burner or the like. If it is necessary to prevent heating of the fracture surface, this method shall be avoided.

(4) After gas-cutting an uncracked ligament, use the testing machine to cause ductile fracture, as necessary. Alternatively, it is also possible to gas-cut the uncracked ligament after using the testing machine to develop a ductile crack to a sufficient length.

6.4 Observation of fracture surfaces

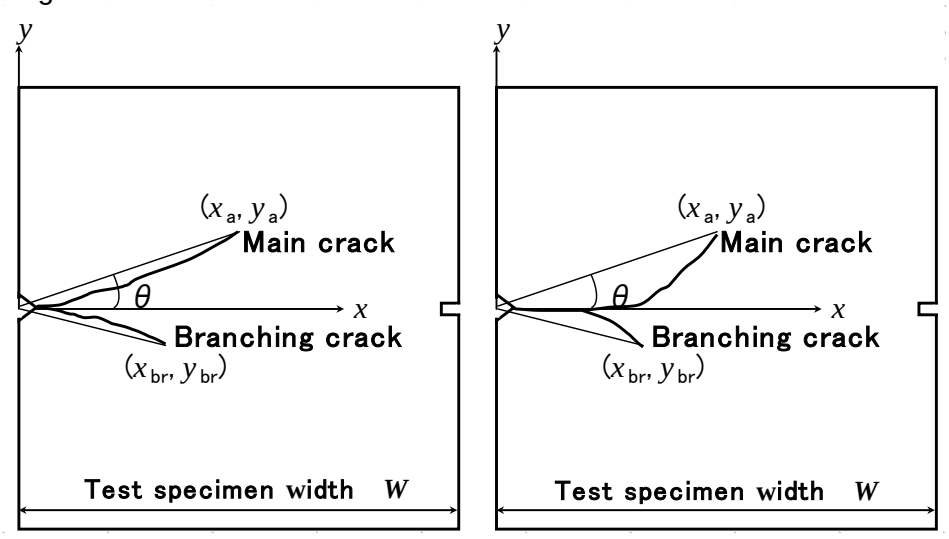
(1) Photograph the fracture surfaces and propagation path.

(2) Measure the longest length of the arrest crack tip in the plate thickness direction, and record the result as the arrest crack length. The arrest crack length shall include the notch length. In the case where a crack deviates from the direction vertical to the loading direction, the length projected to the plane vertical to the loading line is defined as the arrest crack length. In the following cases, however, judge the results according to the methods described for each case.

(a) Crack re-initiation
In the case where a brittle crack has re-initiated from an arrested crack, the original arrest position is defined as the arrest crack position. Here re-initiation is defined as the case where a crack and re-initiated cracks are completely separated by a stretched zone and brittle crack initiation from the stretched zone can be clearly observed. In the case where a crack continuously propagates partially in the thickness direction, the position of the longest brittle crack is defined as the arrest position.

(b) Crack branching
In the case where a crack deviates from the direction vertical to the loading direction, the length projected to the plane vertical to the loading line is defined as the arrest crack length. Similarly, in the case of crack branching, the length of the longest branch crack projected to the plane vertical to the loading line is defined as the branch crack length. More specifically, from the coordinates (x_a, y_a) of the arrest crack tip position and the coordinates (x_{br}, y_{br}) of the branch crack tip position shown in Figure A3-6, obtain the angle θ from the x-axis and define x_a as the arrest crack length, a. Here, x is the coordinate in the test specimen width direction, and the side face of the impact side is set as $x = 0$; y is the coordinate in the test specimen length direction, and the notch position is set as $y = 0$.

(3) Prepare a temperature distribution curve (line diagram showing the relation between the temperature and the distance from the test specimen top side) from the thermocouple measurement results, and obtain the arrest temperature T corresponding to the arrest crack length.



(a) Case of branching from notch brittle crack propagation **(b) Case of branching during**

Figure A3-6 Measurement methods of main crack and branch crack lengths

7. Determination of arrest toughness

7.1 Judgment of arrested crack

When an arrested crack satisfies all of the conditions (a) through (d) below as shown in Figure A3-7, the length of the arrested crack determined by 6.4 is valid. If any of the conditions is not met, the arrest toughness calculated from 7.3 is invalid.

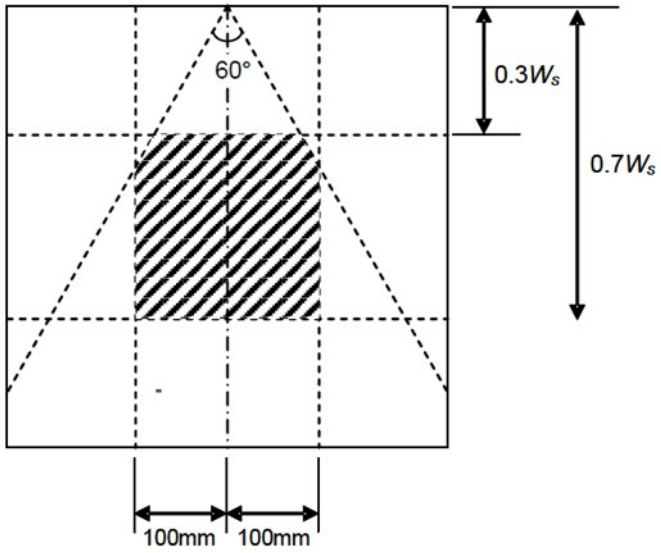


Figure A3-7 Necessary conditions of arrest crack position

(a) Conditions for crack propagation path:

All of the crack path from crack initiation to arrest shall be within the range shown in Figure A3-8. However, in the case where a main crack tip lies within this range but a part of the main crack passes outside the range, the arrest toughness may be assessed as valid if the temperature at the most deviated position of the main crack in the *y* direction is lower than that at $y = 0$, and also K for the main crack falls within ± 5% of K for a straight crack of the same a. The calculation method of Ks for the main crack and a straight crack is obtained from equation (4).

$$K = K_{\mathrm{I}} \cos^3\left(\frac{\phi}{2}\right) + 3K_{\mathrm{II}} \cos^2\left(\frac{\phi}{2}\right) \sin\left(\frac{\phi}{2}\right) \quad \cdots\cdots (4)$$

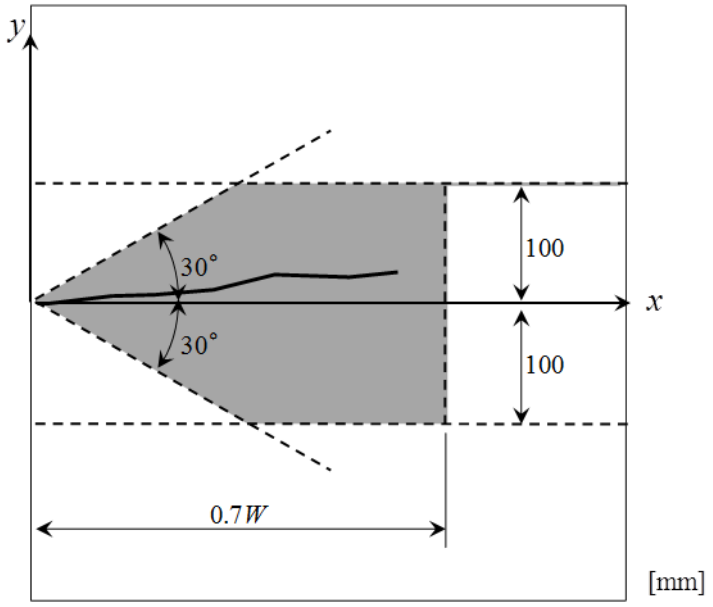


Figure A3-8 Allowable range of main crack propagation path

(b) Conditions for arrest crack length:

$$0.3 \le \left(\frac{a}{W}\right) \le 0.7 \quad \cdots\cdots (5)$$

$$\left(\frac{a}{t}\right) \ge 1.5 \quad \cdots\cdots (6)$$

$$\left(\frac{a}{L_p}\right) \le 0.15 \quad \cdots\cdots (7)$$

Note: Equation (7) ensures minimal influence of force drop at the centre of the specimen which might be caused by crack propagation and reflection of the stress wave at the two ends of the specimen. However, application of equation (7) is not necessarily required if the strain and the crack length have been dynamically measured and the value of the strain at the time of arrest is 90% or more of the static strain immediately before crack initiation.

(c) Conditions for crack straightness:

$$\left|y_a\right| \le 50 \text{ mm} \quad \cdots\cdots (8)$$

In the case where 50 mm $< \left|y_a\right| \le$ 100 mm and $\left|\theta\right| \le 30°$, the result is valid only when the temperature at $x = 0.5W$ and $y = \pm 100$ mm falls within ± 2.5°C of that at $x = 0.5W$ and $y = 0$.

(d) Conditions for crack branching:

$$\left(\frac{x_{br}}{x_a}\right) \le 0.6 \quad \cdots\cdots (9)$$

7.2 Assessment of impact energy

Impact energy shall satisfy equation (10). If it does not satisfy the equation, the value of arrest toughness calculated from the equations in 7.3 is invalid.

Conditions for impact energy:

$$\frac{E_{\mathrm{i}}}{E_{\mathrm{s}}+E_{\mathrm{t}}} \le \frac{5a-1050+1.4W}{0.7W-150} \quad \text{where} \quad 0.3 \le \left(\frac{a}{W}\right) \le 0.7 \quad \cdots\cdots\cdots (10)$$

where the variables have the following units: a [mm], and W [mm]. E_{i} is impact energy calculated from the equation (11). E_{s} and E_{t} are calculated from equations (12) and (13), respectively.

Note1: If equation (10) is not satisfied, the influence of impact energy on the stress intensity factor is too large to obtain an accurate arrest toughness.

Note2: In the case where the tab plates are multistage as shown in Figure A3-3 (b), calculate and total the strain energy of each tab plate using equation (12).

Note3: In the case where tab plate widths are tapered as shown in Figure A3-3 (d), calculate the strain energy based on elastostatics.

$$E_{\mathrm{i}} = m\,g\,h \quad \cdots\cdots\cdots (11)$$

$$E_{\mathrm{s}} = \frac{10^9 F^2}{2E}\frac{L}{W\,t} \quad \cdots\cdots\cdots (12)$$

$$E_{\mathrm{t}} = \frac{10^9 F^2}{E}\left(\frac{L_{\mathrm{tb}}}{W_{\mathrm{tb}}\,t_{\mathrm{tb}}}+\frac{L_{\mathrm{pc}}}{W_{\mathrm{pc}}\,t_{\mathrm{pc}}}\right) \quad \cdots\cdots\cdots (13)$$

where the variables have the following units: E_{s} [J], E_{t} [J], F [MN], E [N/mm^2], L [mm], W [mm], and t [mm].

7.3 Calculation of arrest toughness

The arrest toughness, K_{ca}, at the temperature, T, shall be calculated from equation (14) using the arrest crack length, a, and the applied stress, σ, judged by 7.1. Calculate σ from equation (15).

$$K_{\mathrm{ca}} = \sigma\sqrt{\pi a}\left[\frac{2W}{\pi a}\tan\left(\frac{\pi a}{2W}\right)\right]^{1/2} \quad \cdots\cdots\cdots (14)$$

$$\sigma = \frac{10^6 F}{W\,t} \quad \cdots\cdots\cdots (15)$$

where the variables have the following units: F [MN], W [mm], and t [mm].

If the conditions specified in 7.1 and 7.2 are not satisfied, the K_{ca} calculated from equation (14) is invalid.

8. Reporting

Using Table A3-4, the following items shall be reported:

(1) Test material: Steel type and yield stress at room temperature

(2) Testing machine: Capacity of the testing machine

(3) Test specimen dimensions: Thickness, width, length, angular distortion, and linear misalignment

(4) Integrated specimen dimensions: Tab plate thickness, tab plate width, integrated specimen length including the tab plates, and distance between the loading pins

(5) Test conditions: Applied force, applied stress, temperature gradient, impact energy, and the ratio of impact energy to the strain energy stored in the integrated specimen (sum of test specimen strain energy and tab plate strain energy)

(6) Test results

  (a) Judgment of arrest: Crack length, presence or absence of crack branching, main crack angle, presence or absence of crack re-initiation, and arrest temperature

  (b) Arrest toughness value

(7) Temperature distribution at moment of impact: Thermocouple position, temperature value, and temperature distribution

(8) Test specimen photographs: Crack propagation path (one side), and brittle crack fracture surface (both sides)

(9) Dynamic measurement results: History of crack propagation velocity, and strain change at pin chucks

  Note: Item (9) shall be reported as necessary.

Table A3-4 Report sheet for brittle crack arrest test results

Item	Details		Symbol	Conditions/ Results	Unit	Valid/ Invalid
(1) Test material	Steel type		—		—	—
	Yield stress at room temperature		σ_{Y0}		N/mm^2	—
(2) Test equipment	Testing machine capacity		—		MN	—
(3) Test specimen dimensions	Thickness		t		mm	
	Width		W		mm	
	Length		L		mm	
	Angular distortion + linear misalignment		—		mm/m	
(4) Integrated specimen dimensions	Tab plate thickness		t_{tb}		mm	
	Tab plate width		W_{tb}		mm	
	Test specimen length including a tab plate		$L + L_{tb}$		mm	
	Distance between loading pins		L_p		mm	
(5) Test conditions	Applied force		F		MN	
	Applied stress		σ		N/mm^2	
	Temperature gradient		—		°C /mm	
	Impact energy		E_i		J	
	Ratio of impact energy to strain energy stored in integrated specimen		$E_i/(E_s+E_t)$		—	
(6) Test results	Judgment of crack propagation/arrest	Crack length	a		mm	
		Presence/absence of crack branching	—		—	—
		Ratio of branch crack length to main crack	x_{br}/x_a		—	
		Main crack angle	θ		degree (°)	
		Presence/absence of crack re-initiation	—		—	
		Temperature at crack arrest position	T		°C	
	Arrest toughness value		K_{ca}		N/mm$^{3/2}$	
(7) Temperature distribution at moment of impact	Temperature measurement position		—	Attached	—	—
	Temperature at each temperature measurement position		—	Attached	°C	—
	Temperature distribution curve		—	Attached	—	
(8) Test specimen photographs	Crack propagation path		—	Attached	—	
	Brittle crack fracture surface (both sides)		—	Attached	—	
(9) Dynamic measurement results	History of crack propagation velocity		—	Attached	—	
	Strain change at pin chucks		—	Attached	—	

Annex 3 - Appendix A

Method for obtaining K_{ca} at a specific temperature and the evaluation

A.1 General

This Appendix specifies the method for conducting multiple tests specified in Annex 3 of this UR to obtain K_{ca} value at a specific temperature T_D.

A.2 Method

A number of experimental data show dependency of K_{ca} on arrest temperature, as expressed by equation (A.1), where T_K [K] (= T [°C]＋273), c and K_0 are constants.

$$K_{\mathrm{ca}} = K_0 \exp\left(\frac{c}{T_{\mathrm{K}}}\right) \quad \text{..... (A.1)}$$

The arrest toughness at a required temperature T_D [K] can be obtained by following the procedures below.

(1) Obtain at least four valid K_{ca} data.

(2) Approximating log K_{ca} by a linear expression of $1/T_K$, determine the coefficients log K_0 and c for the data described in paragraph (1) by using the least square method.

$$\log K_{\mathrm{ca}} = \log K_0 + c\frac{1}{T_{\mathrm{K}}} \quad \text{..... (A.2)}$$

(3) Obtain the value of $(K_{ca}/K_0)\exp(c/T_K)$ for each data item. When the number of data outside the range of 0.85 through 1.15 does not exceed, the least square method used in paragraph (2) is considered valid. Here is an integer obtained by rounding down the value of (number of all data divided by 6). If this condition is not met, conduct additional tests to add at least two data and apply the procedure in paragraph (2) to the data.

(4) The value of $K_0 \exp(c/T_D)$ is defined as the estimated value of K_{ca} at T_D. The estimated value for the temperature corresponding to a specific value of K_{ca} can be obtained from $T_K = c/\log(K_{ca}/K_0)$. If the condition specified in paragraph (3) is not met, these estimated values are treated as reference values.

A.3 Evaluation

The straight-line approximation of arrhenius plot for valid K_{ca} data by interpolation method are to comply with either the following (1) or (2):

(1) The evaluation temperature of K_{ca} (i.e. - 10 degree C) is located between the upper and lower limits of the arrest temperature, with the K_{ca} corresponding to the evaluation temperature not lower than the required K_{ca} (e.g. 6,000 N/mm$^{3/2}$ or 8,000 N/mm$^{3/2}$), as shown in Fig. A3-A.1.

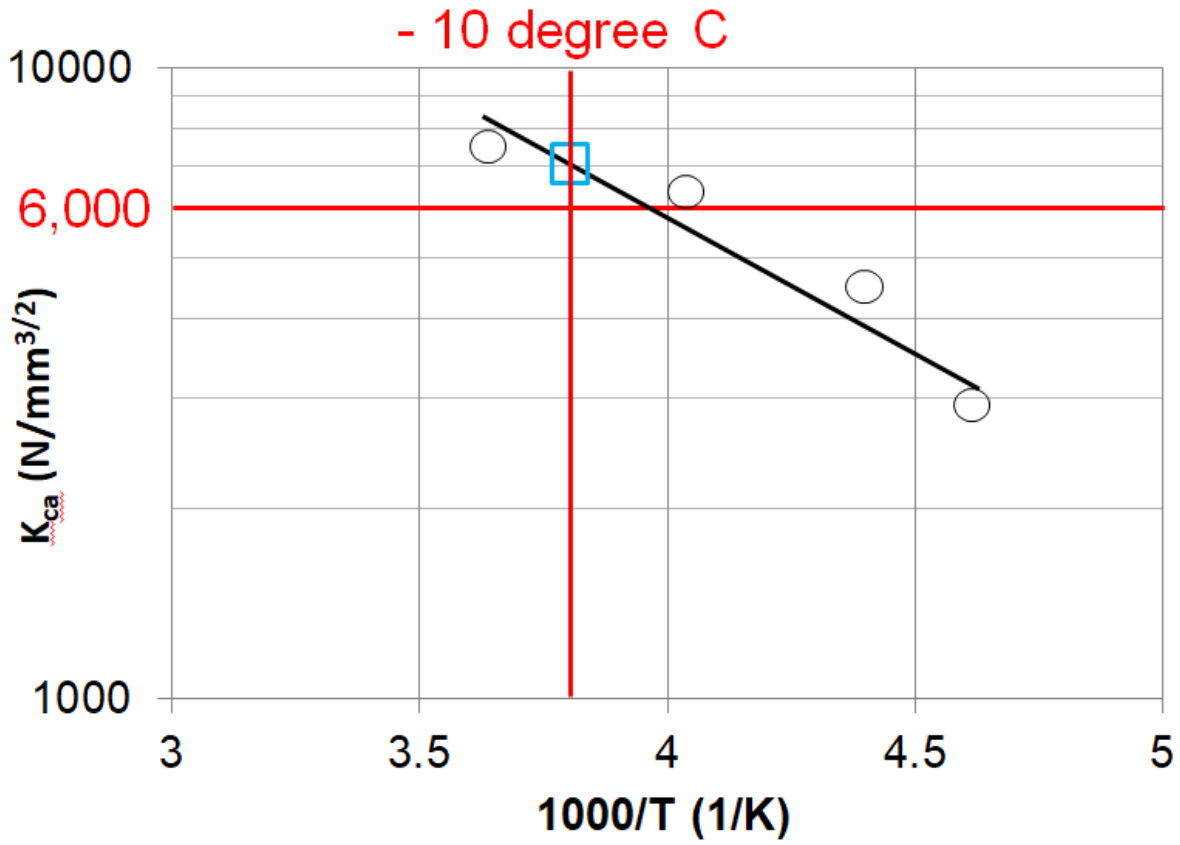


Fig. A3-A.1 Example for evaluation of K_{ca} at - 10 degree C

(2) The temperature corresponding to the required K_{ca} (e.g. 6,000 N/mm$^{3/2}$ or 8,000 N/mm$^{3/2)}$ is located between the upper and lower limits of the arrest temperature, with the temperature corresponding to the required K_{ca} not higher than the evaluation temperature (i.e. -10 degree C), as shown in Fig. A3-A.2.

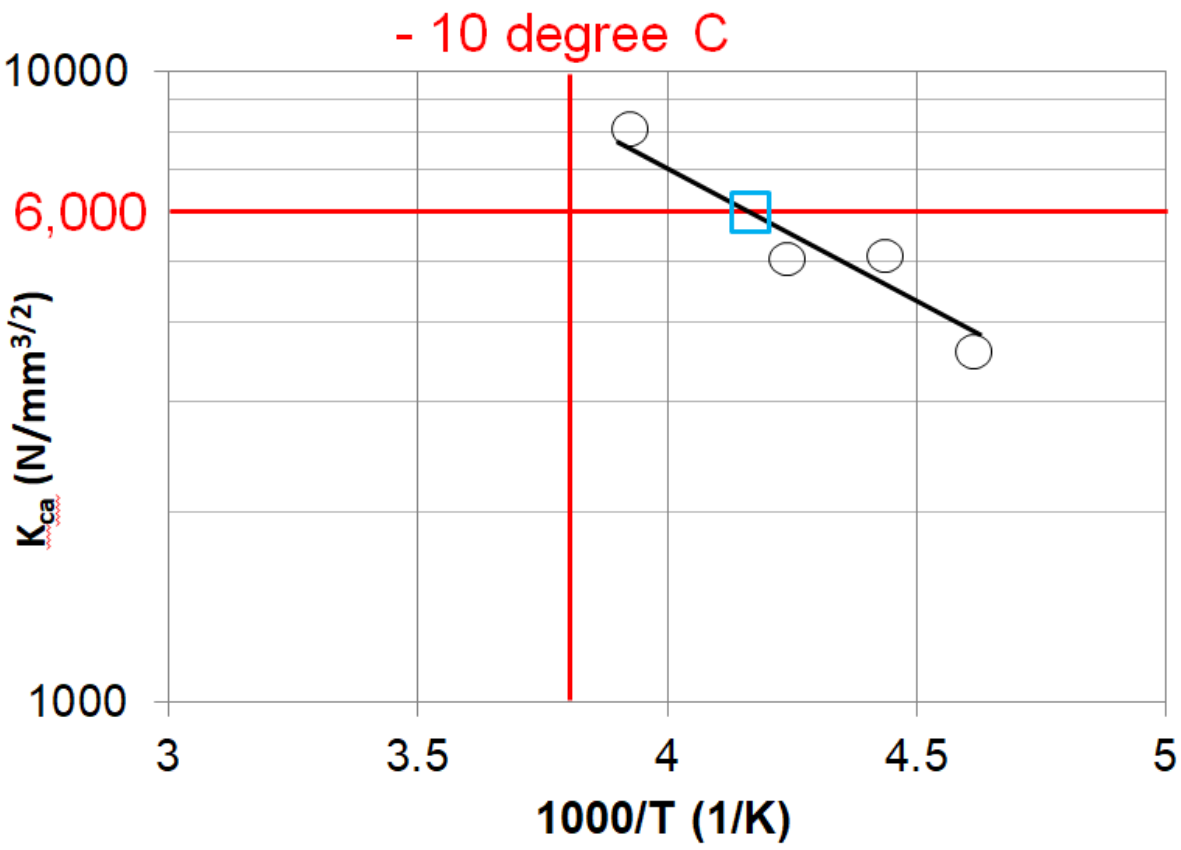


Fig. A3-A.2 Example for evaluation of temperature corresponding to the required K_{ca}

If both of (1) and (2) above are not satisfied, conduct additional tests to satisfy this condition.

Annex 3 - Appendix B

Double tension type arrest test

B.1 Features of this test method

A double tension type arrest test specimen consists of a main plate and a secondary loading tab. The main plate is a test plate for evaluating brittle crack arrest toughness. The secondary loading tab is a crack starter plate for assisting a brittle crack to run into the main plate. After applying a predetermined tension force and a temperature gradient to the main plate, a secondary force is applied to the secondary loading tab by a secondary loading device to cause a brittle crack to initiate and run into the main plate. The arrest toughness is evaluated from the arrest temperature and the crack length in the main plate.

The narrow connection part of the main plate and the secondary loading tab in this test suppress the flow of the tension stresses of the secondary loading tab into the main plate. The values of arrest toughness obtained by this method can be considered the same as the results obtained by the brittle crack arrest toughness test specified in Annex 3 of this TL-R.

The specifications described in Annex 3 of this TL-R shall be applied to conditions not mentioned in this Appendix B.

B.2 Test specimen shapes

The recommended shapes of the entire double tension type arrest test specimen and the secondary loading tab are shown in Figures A3-B.1 and A3-B.2, respectively. Clause 4.2 of Annex 3 of this TL-R is applied to the shapes of the tab plates and pin chucks.

Note: Because of the narrowness of the connection part, slight crack deviation may lead to failure of the crack to enter the main plate. The optimum shape design of the secondary loading tab depends on the type of steel and testing conditions.

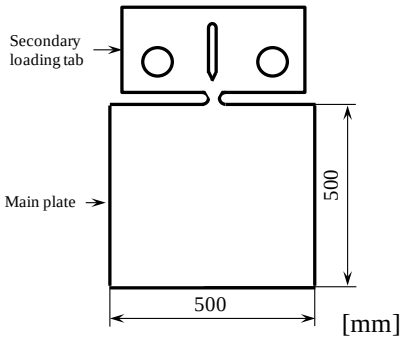


Figure A3-B.1 Example of shape of entire test specimen

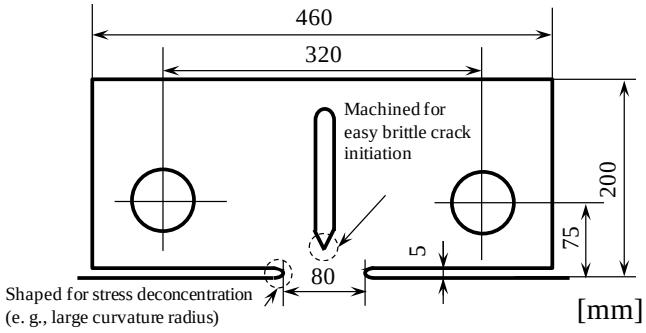


Figure A3-B.2 Example of shape of secondary loading tab

B.3 Temperature conditions and temperature control methods

Establish a temperature gradient in the main plate in order to evaluate its brittle crack arrest toughness. The specifications for temperature gradients and methods for establishing the temperature gradient are described in clause 5**,** Annex 3 of this TL-R. In addition, in the double tension type arrest test, the secondary loading tab must be cooled. The secondary loading tab is cooled without affecting the temperature gradient of the main plate. As in the cooling method for test specimens described in Annex 3 of this TL-R, cooling may be applied using a cooling box and a coolant. The temperature of the secondary loading tab can be measured using thermocouples as described in Annex 3 of this TL-R.

B.4 Secondary loading method

A secondary loading device is used to apply force to the secondary loading tab. The secondary loading device shall satisfy the conditions below.

B.4.1 Holding methods of secondary loading device

To avoid applying unnecessary force to the integrated specimen, the secondary loading device must be held in an appropriate way. Suspension type or floor type holding methods can be used. In the suspension type method, the secondary loading device is suspended and held by using a crane or a similar device. In the floor type method, the secondary loading device is lifted and held by using a frame or a similar device.

B.4.2 Loading system

A hydraulic type loading system is most suitable for applying a force to the secondary loading tab. However, other methods may be used. Clause 4.2 of Annex 3 of this TL-R is applied to the shapes of the tab plates and pin chucks.

B.4.3 Loading method

The method of loading the secondary loading tab shall be a pin type loading method. A loading method other than a pin type may be used by agreement among the parties concerned. The loading rate is not specifically specified because it does not have a direct influence on the crack arrest behavior of the main plate.

Annex 4 Outline of requirements for undertaking isothermal Crack Arrest Temperature (CAT) test

1. Scope of application

1.1 Annex 4 is to be applied according to the scope defined in TL-R W31.

1.2 Annex 4 specifies the requirements for test procedures and test conditions when using the isothermal crack arrest test to determine a valid test result under isothermal conditions and in order to establish the crack arrest temperature (CAT). Annex 4 is applicable to steels with thickness over 50mm and not greater than 100mm.

1.3 This method uses an isothermal temperature in the test specimen being evaluated. Unless otherwise specified in this Annex 4, the other test parameters are to be in accordance with Annex 3.

1.4 Table 3 of TL-R W31 gives the relevant requirements for the brittle crack arrest property described by the crack arrest temperature (CAT).

1.5 The manufacturer is to submit the test procedure to TL for review prior to testing.

2 Symbols and their significance

2.1 Table A4-1 supplements Table A3-1 in Annex 3 with specific symbols for the isothermal test.

Table A4-1 Nomenclature supplementary to Table A3-1

Symbol	Unit	Significance
t	mm	Test specimen thickness
L	mm	Test specimen length
W	mm	Test specimen width
a_{MN}	mm	Machined notch length on specimen edge
L_{SG}	mm	Side groove length on side surface from the specimen edge. L_{SG} is defined as a groove length with constant depth except a curved section in depth at side groove end.
d_{SG}	mm	Side groove depth in section with constant depth
$L_{EB\ -\ min}$	mm	Minimum length between specimen edge and electron beam re-melting zone front
$L_{EB\text{-}s1,\ -s2}$	mm	Length between specimen edge and electron beam re-melting zone front appeared on both specimen side surfaces
L_{LTG}	mm	Local temperature gradient zone length for brittle crack runway
a_{arrest}	mm	Arrested crack length
T_{target}	°C	Target test temperature
T_{test}	°C	Defined test temperature
T_{arrest}	°C	Target test temperature at which valid brittle crack arrest behaviour is observed
σ	N/mm^2	Applied test stress at cross section of W x t
SMYS	N/mm^2	Specified minimum yield strength of the tested steel grade to be approved
CAT	°C	Crack arrest temperature, the lowest temperature, T_{arrest}, at which running brittle crack is arrested

3 Testing equipment

3.1 The test equipment to be used is to be of the hydraulic type of sufficient capacity to provide a tensile load equivalent to ⅔ of SMYS of the steel grade to be approved.

3.2 The temperature control system is to be equipped to maintain the temperature in the specified region of the specimen within ±2°C from T_{target}.

3.3 Methods for initiating the brittle crack may be of drop weight type, air gun type or double tension tab plate type.

3.4 The detailed requirements for testing equipment are specified in 3 of Annex 3.

4 Test specimens

4.1 Impact type crack initiation

4.1.1 Test specimens are to be in accordance with 4 of Annex 3, unless otherwise specified in this Annex.

4.1.2 Specimen dimensions are shown in Figure A4-1. The test specimen width, W shall be

500mm. The test specimen length, *L* shall be equal to or greater than 500mm.

4.1.3 V-shape notch for brittle crack initiation is machined on the specimen edge of the impact side. The whole machined notch length shall be equal to 29mm with a tolerance range of ±1mm.

4.1.4 Requirements for side grooves are described in 4.4.

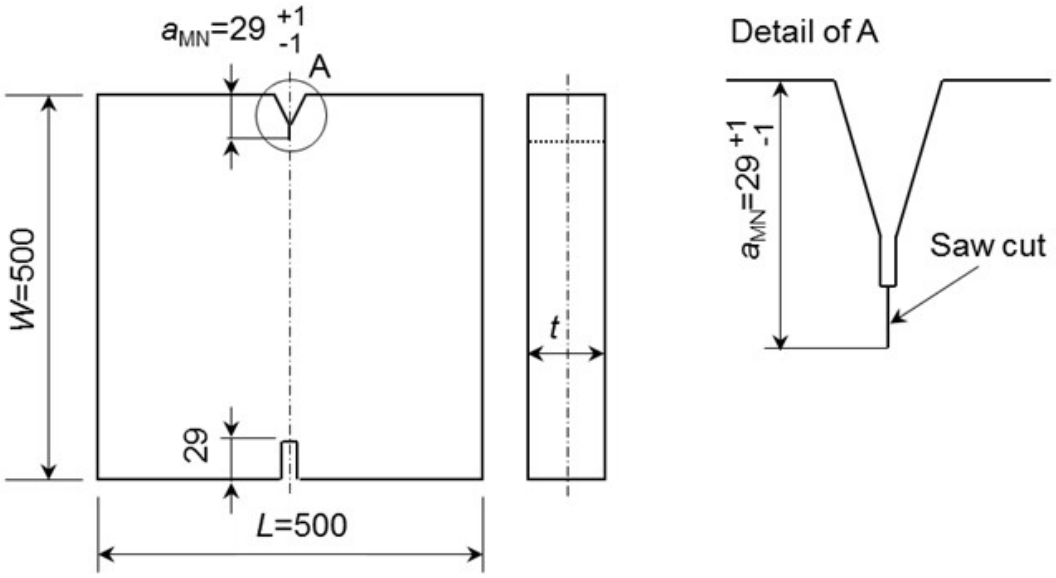


Figure A4-1 Test specimen dimensions for an impact type specimen

NOTE: Saw cut notch radius may be machined in the range 0.1mmR and 1mmR in order to control a brittle crack initiation at test.

4.2 Double tension type crack initiation

4.2.1 Reference shall be made to Appendix B in Annex 3 for the shape and sizes in secondary loading tab and secondary loading method for brittle crack initiation.

4.2.2 In a double tension type test, the secondary loading tab plate may be subject to further cooling to enhance an easy brittle crack initiation.

4.3 Embrittled zone setting

4.3.1 An embrittled zone shall be applied to ensure the initiation of a running brittle crack. Either Electron Beam Welding (EBW) or Local Temperature Gradient (LTG) may be adopted to facilitate the embrittled zone.

4.3.2 In EBW embrittlement, electron beam welding is applied along the expected initial crack propagation path, which is the centre line of the specimen in front of the machined V- notch.

4.3.3 The complete penetration through the specimen thickness is required along the embrittled zone. One side EBW penetration is preferable, but dual sides EB penetration may be also adopted when the EBW power is not enough to achieve the

complete penetration by one side EBW.

4.3.4 The EBW embrittlement is recommended to be prepared before specimen contour machining.

4.3.5 In EBW embrittlement, zone shall be of an appropriate quality.

Note: EBW occasionally behaves in an un-stable manner at start and end points. EBW line is recommended to start from the embrittled zone tip side to the specimen edge with an increasing power control or go/return manner at start point to keep the stable EBW.

4.3.6 In LTG system, the specified local temperature gradient between machined notch tip and isothermal test region is regulated after isothermal temperature control. LTG temperature control is to be achieved just before brittle crack initiation, nevertheless the steady temperature gradient through the thickness shall be ensured.

4.4 Side grooves

4.4.1 Side grooves on side surface can be machined along the embrittled zone to keep brittle crack propagation straight. Side grooves shall be machined in the specified cases as specified in this section.

4.4.2 In EBW embrittlement, side grooves are not necessarily mandatory. Use of EBW avoids the shear lips. However, when shear lips are evident on the fractured specimen, e.g. shear lips over 1mm in thickness in either side then side grooves should be machined to suppress the shear lips.

4.4.3 In LTG embrittlement, side grooves are mandatory. Side grooves with the same shape and size shall be machined on both side surfaces.

4.4.4 The length of side groove, L_{SG} shall be no shorter than the sum of the required embrittled zone length of 150mm.

4.4.5 When side grooves would be introduced, the side groove depth, the tip radius and the open angle are not regulated, but are adequately selected in order to avoid any shear lips over 1mm thickness in either side. An example of side groove dimensions are shown in Figure A4-2.

4.4.6 Side groove end shall be machined to make a groove depth gradually shallow with a curvature larger than or equal to groove depth, d_{SG}. Side groove length, L_{SG} is defined as a groove length with constant depth except a curved section in depth at side groove end.

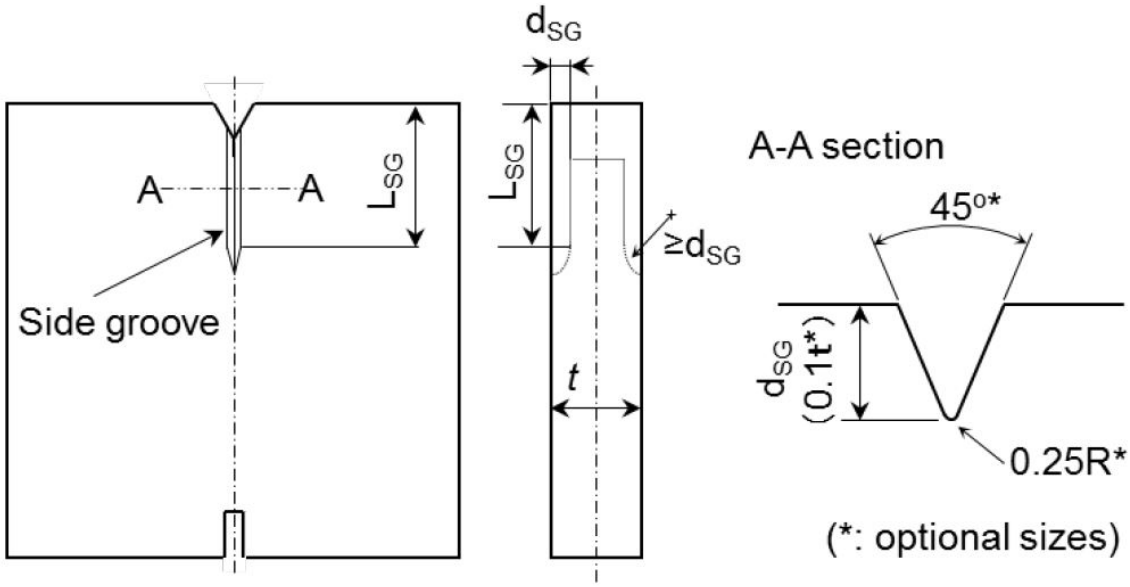


Figure A4-2 Side groove configuration and dimensions

4.5 Nominal length of embrittled zone

4.5.1 The length of embrittled zone shall be nominally equal to 150mm in both systems of EBW and LTG.

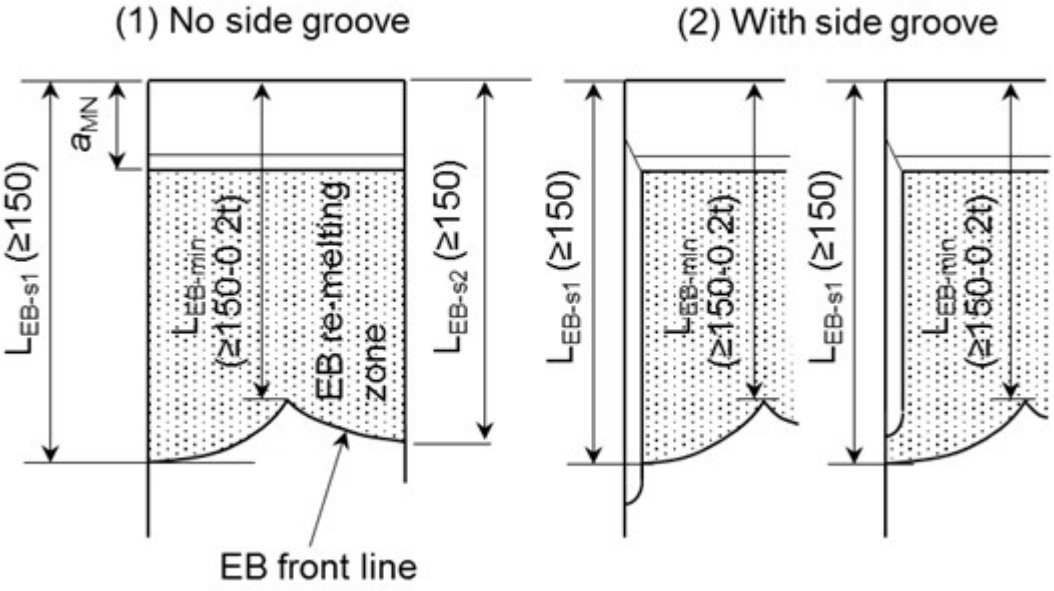


Figure A4-3 Definition of EBW length

4.5.2 EBW zone length is regulated by three measurements on the fracture surface after test as shown in Figure A4-3, L_{EB-min} between specimen edge and EBW front line, and L_{EB-s1} and L_{EB-s2}.

4.5.3 The minimum length between specimen edge and EBW front line, $L_{EB\text{-}min}$ should be no smaller than 150mm. However, it can be acceptable even if $L_{EB\text{-}min}$ is no smaller than 150mm-0.2t, where t is specimen thickness. When $L_{EB\text{-}min}$ is smaller than 150mm, a temperature safety margin shall be considered into T_{test} (See 8.1.2).

4.5.4 Another two are the lengths between specimen edge and EBW front appeared on both side surfaces, as denoted with $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$. Both of $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$ shall be no smaller than 150mm.

4.5.5 In LTG system, L_{LTG} is set as 150mm.

4.6 Tab plate / pin chuck details and welding of test specimen to tab plates

4.6.1 The configuration and size of tab plates and pin chucks shall be referred to 4.2 of Annex 3. The welding distortion in the integrated specimen, which is welded with specimen, tab plates and pin chucks, shall be also within the requirement in 4.3 of Annex 3.

5 Test method

5.1 Preloading

5.1.1 Preloading at room temperature can be applied to avoid unexpected brittle crack initiation at test. The applied load value shall be no greater than the test stress. Preloading can be applied at higher temperature than ambient temperature when brittle crack initiation is expected at preloading process. However, the specimen shall not be subjected to temperature higher than 100°C.

5.2 Temperature measurement and control

5.2.1 Temperature control plan showing the number and position of thermocouples is to be in accordance with this section.

5.2.2 Thermocouples are to be attached to both sides of the test specimen at a maximum interval of 50mm in the whole width and in the longitudinal direction at the test specimen centre position (0.5 W) within the range of ±100mm from the centreline in the longitudinal direction, refer to Figure A4-4.

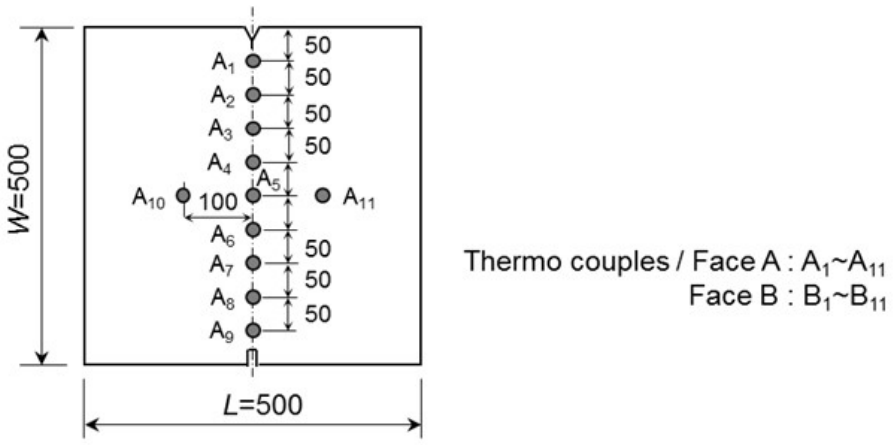


Figure A4-4 Locations of temperature measurement

5.2.3 For EBW embrittlement

5.2.3.1 The temperatures of the thermocouples across the range of 0.3*W*~0.7*W* in both width and longitudinal directions are to be controlled within ± 2°C of the target test temperature, T_{target}.

5.2.3.2 When all measured temperatures across the range of 0.3*W*~0.7*W* have reached T_{target}, steady temperature control shall be kept at least for 10 + 0.1 x *t* [mm] minutes to ensure a uniform temperature distribution into mid-thickness prior to applying test load.

5.2.3.3 The machined notch tip can be locally cooled to easily initiate brittle crack. Nevertheless, the local cooling shall not disturb the steady temperature control across the range of 0.3*W*~0.7*W*.

5.2.4 For LTG embrittlement:

5.2.4.1 In LTG system, in addition to the temperature measurements shown in Figure A4-4, the additional temperature measurement at the machine notch tip, A_0 and B_0 is required. Thermocouples positions within LTG zone are shown in Figure A4-5.

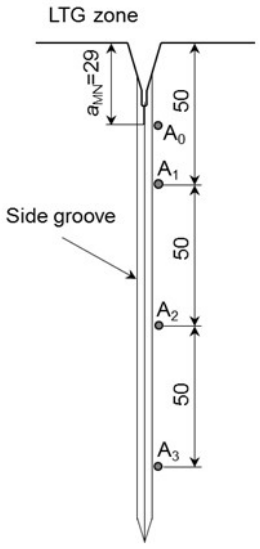


Figure A4-5 Detail of LTG zone and additional thermocouple A_0

5.2.4.2 The temperatures of the thermocouples across the range of 0.3*W*~0.7*W* in both width and longitudinal directions are to be controlled within ± 2°C of the target test temperature, T_{target}. However, the temperature measurement at 0.3*W* (location of A_3 and B_3) shall be in accordance with 5.2.4.6 below.

5.2.4.3 Once the all measured temperatures across the range of 0.3*W*~0.7*W* have reached T_{target}, steady temperature control shall be kept at least for 10 + 0.1 x *t* [mm] minutes to ensure a uniform temperature distribution into mid-thickness, then the test load is applied.

5.2.4.4 LTG is controlled by local cooling around the machined notch tip. LTG profile shall be recorded by the temperature measurements from A_0 to A_3 shown in Figure A4-6.

5.2.4.5 LTG zone is established by temperature gradients in three zones, Zone I, Zone II and Zone III. The acceptable range for each temperature gradient is listed Table A4-2.

5.2.4.6 Two temperature measurements at A_2, B_2 and A_3, B_3 shall be satisfied the following requirements:

T at A_3, T at $B_3 < T_{target} - 2^oC$

T at $A_2 < T$ at $A_3 - 5^oC$

T at $B_2 < T$ at $B_3 - 5^oC$

5.2.4.7 No requirements for T at A_0 and T at A_1 temperatures when T at A_3 and T at A_2 satisfy the requirements above. Face B is the same.

5.2.4.8 The temperatures from A_0, B_0 to A_3, B_3 should be decided at test planning stage refer to Table A4-2 which gives the recommended temperature gradients in three zones, Zone I, Zone II and Zone III in LTG zone.

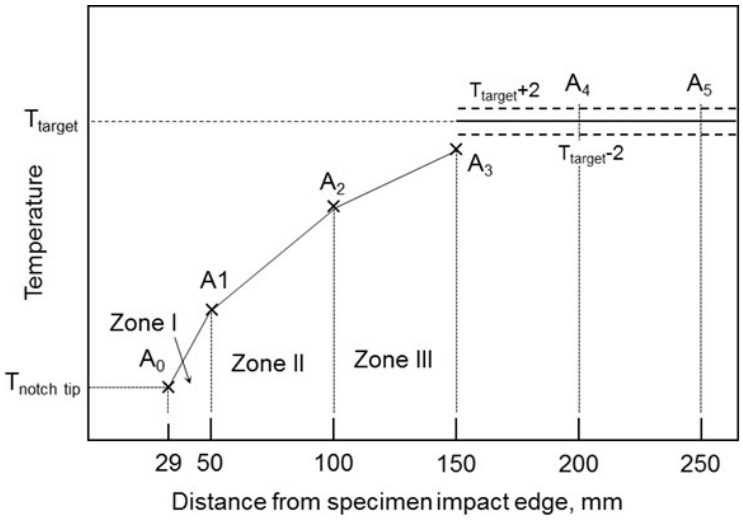


Figure A4-6 Schematic temperature gradient profile in LTG zone

Table A4-2 Acceptable LTG range

Zone	Location from edge	Acceptable range of temperature gradient
Zone I	29mm – 50mm	2.00 ˚C/mm – 2.30 ˚C/mm
Zone II	50mm – 100mm	0.25 ˚C/mm – 0.60 ˚C/mm
Zone III[1)]	100mm – 150mm	0.10 ˚C/mm – 0.20 ˚C/mm

Note 1: The Zone III arrangement is mandatory

5.2.4.9 The temperature profile in LTG zone mentioned above shall be ensured after holding time at least for 10 + 0.1 x t [mm] minutes to ensure a uniform temperature distribution into mid-thickness before brittle crack initiation.

5.2.4.10 The acceptance of LTG in the test shall be decided from Table A4-2 based on the measured temperatures from A_0 to A_3.

5.2.5 For double tension type crack initiation specimen:

5.2.5.1 Temperature control and holding time at steady state shall be the same as the case of EBW embrittlement specified in 5.2.3 or the case of LTG embrittlement specified in Section 5.2.4.

5.3 Loading and brittle crack initiation

5.3.1 Prior to testing, a target test temperature (T_{target}) shall be selected.

5.3.2 Test procedures are to be in accordance with 6 of Annex 3 except that the applied stress is to be ⅔ of SMYS of the steel grade tested.

5.3.3 The test load shall be held at the test target load or higher for a minimum of 30 seconds prior to crack initiation.

5.3.4 Brittle crack can be initiated by impact or secondary tab plate tension after all of the temperature measurements and the applied force are recorded.

6. Measurements after test and test validation judgement

6.1 Brittle crack initiation and validation

6.1.1 If brittle crack spontaneously initiates before the test force is achieved or the specified hold time at the test force is not achieved, the test shall be invalid.

6.1.2 If brittle crack spontaneously initiates without impact or secondary tab tension but after the specified time at the test force is achieved, the test is considered as a valid initiation. The following validation judgments of crack path and fracture appearance shall be examined.

6.2 Crack path examination and validation

6.2.1 When brittle crack path in embrittled zone deviates from EBW line or side groove in LTG system due to crack deflection and/or crack branching, the test shall be considered as invalid.

6.2.2 All of the crack path from embrittled zone end shall be within the range shown in Figure A4-7. If not, the test shall be considered as invalid.

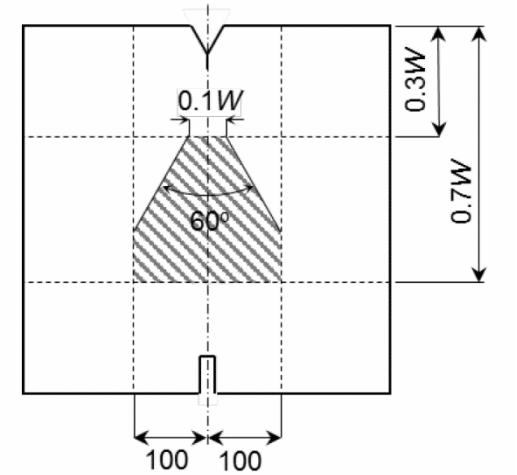


Figure A4-7 Allowable range of main crack propagation path

6.3 Fracture surface examination, crack length measurement and their validation

6.3.1 Fracture surface shall be observed and examined. The crack “initiation” and “propagation” are to be checked for validity and judgements recorded. The crack “arrest” positions are to be measured and recorded.

6.3.2 When crack initiation trigger point is clearly detected at side groove root, other than the V-notch tip, the test shall be invalid.

6.3.3 In EBW embrittlement setting, EBW zone length is quantified by three measurements of $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ and $L_{EB\text{-}min}$, which are defined in 4.5. When either or both of $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$ are smaller than 150mm, the test shall be invalid. When $L_{EB\text{-}min}$ is smaller than 150mm-0.2t, the test shall be invalid.

6.3.4 When the shear lip with thickness over 1mm in either side near side surfaces of embrittled zone are visibly observed independent of the specimens with or without side grooves, the test shall be invalid.

6.3.5 In EBW embrittlement setting, the penetration of brittle crack beyond the EBW front line shall be visually examined. When any brittle fracture appearance area continued from the EB front line is not detected, the test shall be invalid.

6.3.6 The weld defects in EBW embrittled zone shall be visually examined. If detected, it shall be quantified. A projecting length of defect on the thickness line through EB weld region along brittle crack path shall be measured, and the total occupation ratio of the projected defect part to the total thickness is defined as defect line fraction (See Figure A4-8). When the defects line fraction is larger than 10 %, the test shall be invalid.

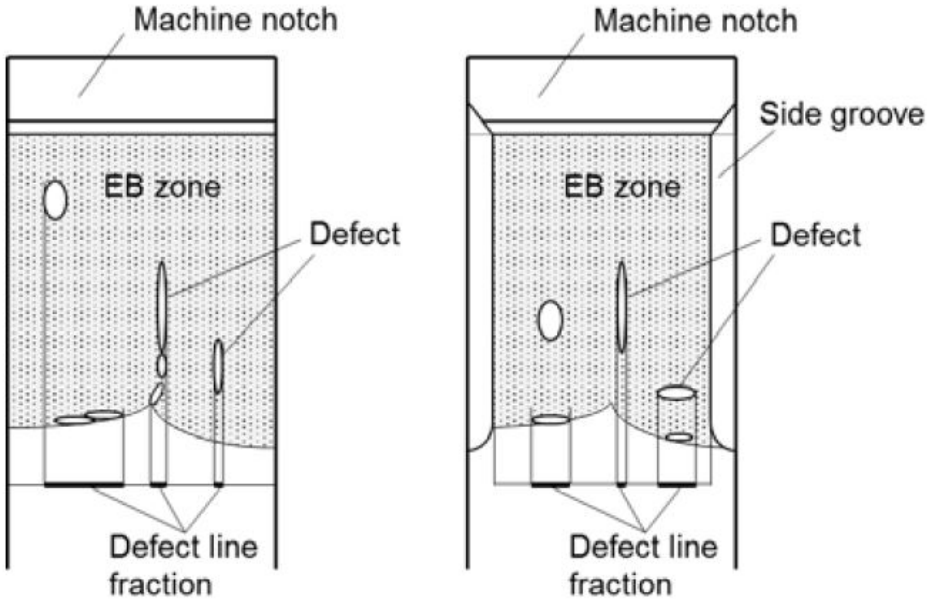


Fig. A4-8 Counting procedure of defect line fraction

6.3.7 In EBW embrittlement by dual sides’ penetration, a gap on embrittled zone fracture surface which is induced by miss meeting of dual fusion lines is visibly detected at an overlapped line of dual side penetration, the test shall be invalid.

7 Judgement of “arrest” or “propagate”

7.1 The final test judgment of “arrest”, “propagate” or “invalid” is decided by the following requirements of 7.2 through 7.6.

7.2 If initiated brittle crack is arrested and the tested specimen is not broken into two pieces, the fracture surfaces should be exposed with the procedures specified in 6.3 and 6.4 of Annex 3.

7.3 When the specimen was not broken into two pieces during testing, the arrested crack length, a_{arrest} shall be measured on the fractured surfaces. The length from the specimen edge of impact side to the arrested crack tip (the longest position) is defined as a_{arrest}.

7.4 For LTG and EBW, a_{arrest} shall be greater than L_{LTG} and $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ or $L_{EB\text{-}min}$. If not, the test shall be considered as invalid.

7.5 Even when the specimen was broken into two pieces during testing, it can be considered as “arrest” when brittle crack re-initiation is clearly evident. Even in the fracture surface all occupied by brittle fracture, when a part of brittle crack surface from embrittled zone is continuously surrounded by thin ductile tear line, the test can be judged as re-initiation behaviour. If so, the maximum crack length of the part surrounded tear line can be measured as a_{arrest}. If re-initiation is not visibly evident, the test is judged as “propagate”.

7.6 The test is judged as “arrest” when the value of a_{arrest} is no greater than 0.7W. If not, the test is judged as “propagate”.

8 T_{test}, T_{arrest} and CAT determination

8.1 T_{test} determination

8.1.1 It shall be ensured on the thermocouple measured record that all temperature measurements across the range of 0.3W ~ 0.7W in both width and longitudinal direction are in the range of T_{target} ±2°C at brittle crack initiation. If not, the test shall be invalid. However, the temperature measurement at 0.3W (location of A_3 and B_3) in LTG system shall be exempted from this requirement.

8.1.2 If $L_{EB\text{-}min}$ in EBW embrittlement is no smaller than 150mm, T_{test} can be defined to equal with T_{target}. If not, T_{test} shall be equaled with T_{target} + 5˚C.

8.1.3 In LTG embrittlement, T_{test} can be equaled with T_{target}.

8.1.4 The final arrest judgment at T_{test} is concluded by at least two tests at the same test condition which are judged as “arrest”.

8.2 T_{arrest} determination

8.2.1 When at least repeated two “arrest” tests appear at the same T_{target}, brittle crack arrest behaviour at T_{target} will be decided (T_{arrest} = T_{target}).When a “propagate” test result is included in the multiple test results at the same T_{target}, the T_{target} cannot to be decided as T_{arrest}.

8.3 CAT determination

8.3.1 When CAT is determined, one “propagate” test is needed in addition to two “arrest” tests. The target test temperature, T_{target} for “propagate” test is recommended to select 5^{o}C lower than T_{arrest}. The minimum temperature of T_{arrest} is determined as CAT.

8.3.2 With only the “arrest” tests, without “propagation” test, it is decided only that CAT is lower than T_{test} in the two “arrest” tests, i.e. not deterministic CAT.

9 Reporting

The following items are to be reported:

(i) Test material: grade and thickness

(ii) Test machine capacity

(iii) Test specimen dimensions: thickness t; width W and length L; notch details and length a_{MN}, side groove details if machined;

(iv) Embrittled zone type: EBW or LTG embrittlement

(v) Integrated specimen dimensions: Tab plate thickness, tab plate width, integrated specimen unit length including the tab plates, and distance between the loading pins, angular distortion and linear misalignment

(vi) Brittle crack trigger information: impact type or double tension. If impact type, drop weight type or air gun type, and applied impact energy.

(vii) Test conditions; Applied load; preload stress, test stress
- Judgements for preload stress limit, hold time requirement under steady test stress.

(viii) Test temperature: complete temperature records with thermocouple positions for measured temperatures (figure and/or table) and target test temperature.

- Judgements for temperature scatter limit in isothermal region.

- Judgement for local temperature gradient requirements and holding time requirement after steady local temperature gradient before brittle crack trigger, if LTG system is used.

(ix) Crack path and fracture surface: tested specimen photos showing fracture surfaces on both sides and crack path side view; Mark at “embrittled zone tip” and “arrest” positions.

- Judgment for crack path requirement.

- Judgment for cleavage trigger location (whether side groove edge or V-notch edge).

(x) Embrittled zone information:

When EBW is used: $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ and $L_{EB\text{-}min}$

- Judgement for shear lip thickness requirement

- Judgment whether brittle fracture appearance area continues from the EBW front line

- Judgement for EBW defects requirement

- Judgement for EBW lengths, $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ *and* $L_{EB\text{-}min}$ requirements

When LTG is used: L_{LTG}

- Judgment for shear lip thickness requirement

Test results:

When the specimen did not break into two pieces after brittle crack trigger, arrested crack length a_{arrest}

When the specimen broke into two pieces after brittle crack trigger,

- judgement whether brittle crack re-initiation or not.

If so, arrested crack length a_{arrest}:

- Judgement for a_{arrest} in the valid range ($0.3W < a_{arrest} \leq 0.7W$)

- Final judgement either “arrest”, “propagate” or “invalid”

(xi) Dynamic measurement results: History of crack propagation velocity, and strain change at pin chucks, if needed

10 Use of test for material qualification testing

Where required, the method can also be used for determining the lowest temperature at which a steel can arrest a running brittle crack (the determined CAT) as the material property characteristic in accordance with 8.3.