PART III CONSTRUCTION COMPONENTS

TITLE 61 MATERIALS AND PROCEDURES FOR THE HULL

SECTION 2 STRUCTURE

CHAPTERS

CONTENT

CHAPTER A
APPROACH

CHAPTER CONTENTS

A1. APPLICATION

100. Materials classified

101. These requirements apply to materials used in construction or repair of parts of vessels covered under these Rules for classification.

102. Other materials not listed may be used provided they are approved by RBNA which, if any, will establish the process for approval. This also applies to materials for which there is official control or established practice in countries where the material is produced, in view of its application.

A2. CONTROL OF STEEL

100. Manufacturing Process

101. The steel to be used shall be manufactured by one of the following:

a. Thomas;

b. Basic Oxygen;

c. Siemens Martin;

d. Electric oven, and

e. Another method approved by RBNA.

200. Witness testing

201. All tests should be performed in the presence of the Surveyor, in factories before shipment for delivery.

202. Manufacturers must put in good order the necessary facilities for inspection and give free access to services and local authorities.

203. Requests for inspection should be made in time by the Builders or Owners, providing full identification of the material being inspected.

204. The machines used for testing should have their accuracy, sensitivity and precision recognized by RBNA. A record of periodic calibration must be kept.

205. Parts inspected will be stamped with the RBNA seal in such a place as to be as much as possible visible after installation and will be surrounded by a painted circle.

206. After inspection, the Surveyor will be forwarded a report with full identification of the material / equipment and results.

300. Defects and re-testing

301. The material should be free of surface defects, lamination, and other inclusions of a similar nature.

302. Surface defects can be corrected with approval of the Surveyor, in view of the importance of the part and in principle the following procedure should be followed:

a. Grinding, provided that at no point the thickness is reduced to less than 93%, this reduction may not exceed 3 mm, and provided that the affected area no greater than 20% of the total number when the depth is at most 0 , 8 mm and no greater than 10% when the depth is greater than 0.8 mm;

b. Welding according to procedures and classified welders, provided that the thickness after preparation for welding has not been reduced by over 20% at any point. This preparation must be submitted to the Surveyor prior to welding, provided that the affected area is not greater than 20% of the total area of the part.

303. Defects beyond those specified above shall result in partial or complete rejection of parts.

A3. TEST SPECIMENS

100. SPECIMENS [IACS UR W.2.1]

101. This chapter gives the requirements for test specimens when testing ferrous and non-ferrous metals.

102. The corresponding testing procedures generally are to follow established practice as laid down in international and national standards. The main testing procedures are given in this chapter.

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

200. General
[IACS UR W.2.2]

201. 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). The samples necessary to prepare the specimens will be chosen and punch marked in the presence of the Surveyor.

202. 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.

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

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

300. Testing machines
[IACS UR W.2.3]

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

302. 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.

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

400. Tolerances
[IACS UR W2.4.2.10]

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

500. Retest Procedure
[IACS UR W 2.4.3]

501. When the tensile test fails to meet the requirements, two further tests may be made from the same piece.

502. 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.

503. 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.

A4. TENSILE TEST SPECIMENS

100. Designations
[IACS UR W.2.4.1]

101. The following designations are used:

a. d = diameter

b. a = thicknes

c. b = width

d. $L0$ = original gauge length

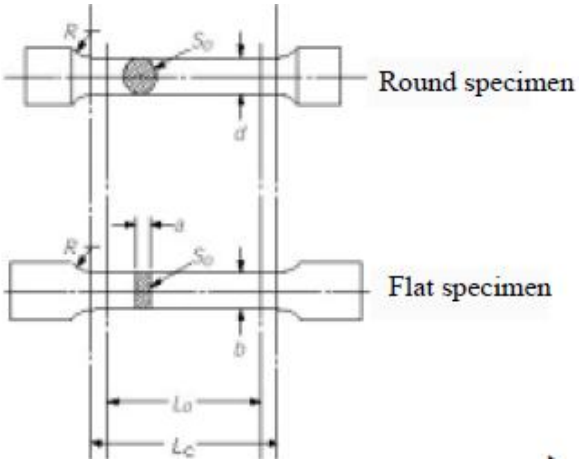
e. Lc = parallel length

f. $S0$ = original cross sectional area

g. R = transition radius

h. D = external tube diameter

i. t = plate thickness



200. Dimensions
[IACS UR W.2.4.2.1]

201. Proportional test specimens with a gauge length or = 5 d should preferably be used as the minimum percentage elongation values specified in the W Unified Requirements refer to this gauge length, L0 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.

202. **Plates, strips and sections:** Flat specimens are usually to be used with dimensions as specified below

Proportional flat specimen

a = t

b = 25 mm

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

$$Lc = Lo + 2\sqrt{S_0}$$

R = 25 mm

Non-proportional flat specimen

a = t

b = 25 mm

Lo = 200 mm

Lc > 212.5 mm

R = 25 mm

a. 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.

b. Alternatively, for materials over about 40 mm thick, proportional round test specimens with dimensions as specified below, may be used.

203. **Round specimen**

d ≥ 10 mm to 20 mm, preferably 14 mm
Lo = 5d

R = 10 mm (for nodular cast iron and materials with a specified elongation less than 10%, R ≥ 1,5 d)

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

300. Test specimens for aluminium alloys [IACS UR W.2.14.2.3]

301. 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.

302. For thicknesses exceeding 12.5mm, round tensile test specimens will be used.

303. 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.

304. 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.

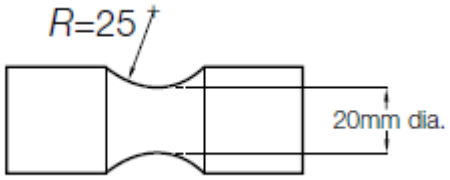
400. Forgings, castings (excluding grey cast iron) [IACS UR W.2.4.2.4]

401. Proportional round test specimens with dimensions as specified above in Part III, Title 61, Section 2, sub-chapter A4.203 are usually to be used.

402. 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.

500. Test specimens for grey cast iron [IACS UR W.2.4.2.7]

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



600. Test specimens for tubes [IACS UR W.2.4.2.5]

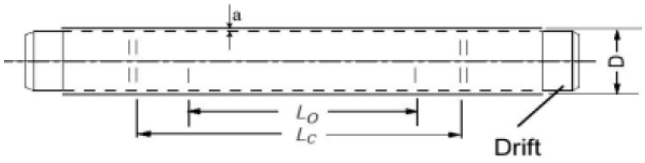
601. The test specimen shall conform with the following:

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.



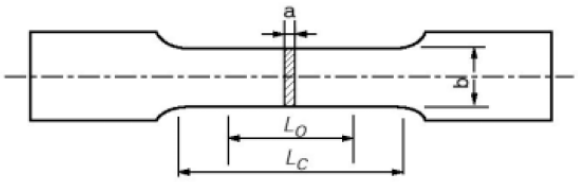
b. Strips cut longitudinally

a = t
b ≥ 12 mm

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

$$Lc = Lo + 2b$$

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



603. 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 Part III, Title 61, Section 2, Chapter A4, item 203, with their axes located at the midwall thickness.

700. Test specimen for wires [IACS UR W.2.4.2.6]

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

Lo = 200 mm

Lc = Lo + 50 mm

A5. WELDMENTS [IACS UR W2.4.2.8]

100. Deposited metal tensile test

101. Round specimen with the following dimensions is to be used :

d = 10 mm

Lo = 50 mm

Lc > 55 mm

R ≥ 10 mm

102. For specially small or large dimensions other specimens may be used after agreement with the RBNA, provided they conform with the geometrical relationship given in Part III, Title 61, Section 2, Sub-chapter A4. item 203.

103. 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:

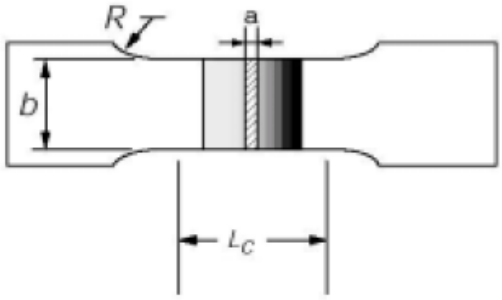
a = t

b = 12 for t<2

b = 25 for t>2

Lc = width of weld + 60 mm

R > 25 mm



200. Through thickness tensile test specimen

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

A6. TENSILE PROPERTIES AT AMBIENT TEMPERATURE [IACS UR W2.5]

100. Yield stress (yield point) [IACS UR W.2.5.1]

101. 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:

TABLE T.A6.101.1 – LIMITS OF ELASCTIC STRESS

Modulus of Elasticity of the Material (E) N/mm^2	Rate of stressing N/mm^2	
	Min	Max
< 150 000	2	20
≥ 150 000	6	60

200. Proof stress (yield strength) [IACS UR W.2.5.2]

201. 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*.

202. The rate of loading shall be as stated in Table T.A6.101.1 above.

300. Tensile strength *(Rm)*
[IACS UR W.2.5.3]

301. 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.

400. Fracture elongation *(A)*
[IACS UR W.2.5.4]

401. 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.

402. The elongation generally means elongation *A*5 determined on a proportional gauge length, but may also be given for other specified gauge lengths.

$$5.65\sqrt{So} = 5d$$

403. 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:

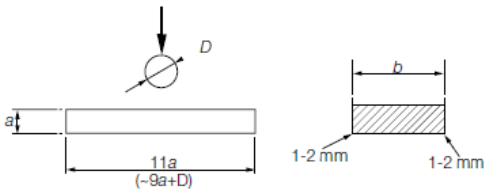
$$A_0 = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0,40}$$

404. For tables and graphs see ISO/DIS 2566.

A7. BEND TEST SPECIMENS
[IACS UR W2.6]

100. Flat bend test specimen
[IACS UR W2.6.1]

101. 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.



200. Forgings, castings, and semi finished products
[IACS UR W2.6.2]

201. Forgings, castings and semi-finished products

a = 20 mm

b = 25 mm

202. Plates, structural sections, sheets: [**IACS UR W2.6.**3]

a= *t*

b = 30 mm

300. Butt welds, transverse specimen
[IACS UR W2.6.4]

301. Face and root bend

a= *t*

b = 30 mm

302. 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.

303. Side bend

a = 10 mm

b = *t*

304. If *t* ≥ 40 mm, the side-bend specimen may be subdivided, each part being at least 20 mm wide.

305. The test specimens, for longitudinal face and root test, are to be in accordance with an appropriate recognised standard. [**IACS UR W2.6.5]**

A8. TOUGHNESS TESTING
[IACS UR W2.7]

100. Charpy V-notch impact test specimens
[IACS UR W2.7.1]

101. The dimensions and tolerances are as follows:

TABLE T.A3.401.1 – V – NOTCH TEST SPECIMEN

ITEM	NOMINAL DIMENSIONS AND TOLERANCES (mm)
Length	55 ± 0,6
Height	10 ± 0,11
Width Standard specimen Subsize specimen Subsize speciment	 10 ± 0,11 7,5 ± 0,11 5,0 ± 0,06
Angle of notch	$45^o \pm 2^o$
Thickness	10 ± 0,06
Depth of notch below	8 ± 0,06
Root radius	0,25 ± 0,025
Distance of notch from end of test specimen	27,5 ± 0,42
Angle between plane of symmetry of notch and longitudinal axisx of test specimen	$90^o \pm 2^o$

TABELA T.A3.401.2 – TEST SPECIMENT WITH "U" NOTCH

ITEM	NOMINAL DIMENSIONS AND TOLERANCES (mm)
Notch angle	-
Thicknes of the remaining notch	5 ± 0,09
Radius at bottom of notch	1 ± 0,07

402. The distances between supports is 40 mm, the velocity at impact 4.5 to 5.5 m / s and impact energy, at least 150 Nm (15 kgf.m).

200. Sub size Charpy requirements [IACS UR W2.7.2]

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

TABLE T.A8.201.1 – TABLE FOR SUBSIZED SPECIMENTS

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 mm	2E/3

where:

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

202. All other dimensions and tolerances are to be as specified in Part III, Title 61, Section 2, Chapter A8, item 101.

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

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

300. Testing machines and temperature control in Charpy V-notch impact testing [IACS UR W2.7.3]

301. 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.

302. 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.

400. Charpy re-test procedure [IACS UR W2.7.4]

401. 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.

A9. DROPWEIGHT SPECIMENS

100. Dropweight specimens [IACS UR W2.7.5]

101. 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):

a. Type P-1: 25 by 90 by 360

b. Type P-2 19 by 50 by 130

c. Type P-3 16 by 50 by 130

Guidance

-The ASTM E208 drop weight test is used primarily to determine the Nil-ductility transition temperature or NDT of

ferritic steels of 5/8 in thickness and over. This particular drop weight test was initially developed by the Navel Research Laboratory in 1952 and published as Department of the Navy document NAVSHIPS-250-634-3. Current specifications are available from ASTM at: ASTM E208-06 Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels.

- Nil-ductility transition temperature is the temperature at which the fracture mode of the steel changes from ductile to brittle. Above the NDT a piece of steel typically will stretch or deform 20% - 40% before fracture when loaded to its ultimate tensile strength. However, below the NDT the same piece of steel will fracture in a brittle manner like glass when only loaded to yield strength (about half of the ultimate strength). Once it begins to crack in this manner the crack will continue to propagate at the speed of sound. It will only stop when it runs out of steel, the load is released, or until the crack is interrupted by steel that is behaving in a ductile manner due to different qualities in the steel or different temperatures present.

-The drop-weight test consists of beam specimens prepared according to ASTM E208 specifications to initiate a material crack in a selected area of their tensile surfaces at the start of the test. During the test a series of specimens is subjected to a single impact load at a progression of selected temperatures to determine the maximum temperature at which a specimen breaks. The impact load is delivered by a guided, free-falling weight with an energy of 250 to 1200 ft-lb (340 to 1630 J) according to the yield strength of the steel to be tested. A stop is employed to prevent deflection of more than a few tenths of an inch.

- After the specimen is prepared properly for the crack initiation, and conditioned to the proper temperature, the test begins. The initial test is conducted at a temperature estimated to be near the NDT temperature. The remaining specimens are then tested at a progression of temperature intervals to determine the break and no-break performance temperatures within 10°F or (5°C).

End of guidance

102. The following is to be noted if not otherwise specified:

a. the specimen sides shall be saw-cut or machined (minimum 25 mm to flame-cut surface)

b. the machining of the plate to prescribed specimen thickness shall be on one side only

c. the specimens may be of any orientation, but the orientation shall be the same for all specimens.

CHAPTER B
NORMAL AND HIGH STRENGTH HULL STRUCTURAL STEEL

CHAPTER CONTENTS

B1. DEFINITIONS

100. Definitions of applicable rolling procedures and the schematic diagrams

101. **Critical temperatures**

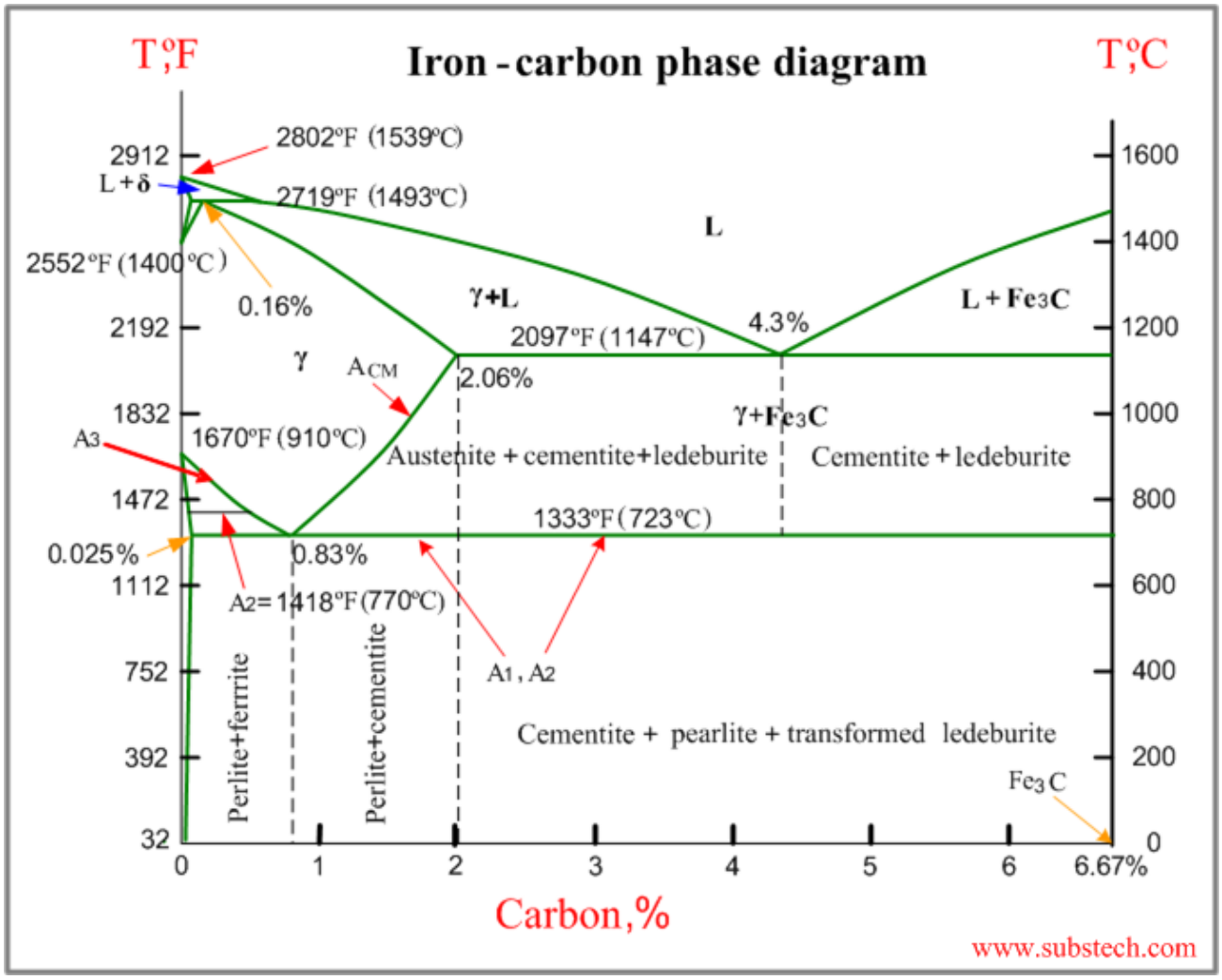
a. **Upper critical temperature (point) A3** is the temperature, below which ferrite starts to form as a result of ejection from austenite in the hypoeutectoid alloys.

b. **Upper critical temperature (point) ACM** is the temperature, below which cementite starts to form as a result of ejection from austenite in the hypereutectoid alloys.

c. **Lower critical temperature (point) A1** is the temperature of the austenite-to-pearlite eutectoid transformation. Below this temperature austenite does not exist.

d. **Magnetic transformation temperature A2** is the temperature below which α-ferrite is ferromagnetic.

FIGURE F.B1.101.1 – IRON CARBON PHASE DIAGRAM



102. Phase compositions of the iron-carbon alloys at room temperature:

a. **Hypoeutectoid steels** (carbon content from 0 to 0.83%) consist of primary (proeutectoid) ferrite (according to the curve A3) and pearlite.

b. **Eutectoid steel** (carbon content 0.83%) entirely consists of pearlite.

c. **Hypereutectoid steels** (carbon content from 0.83 to 2.06%) consist of primary (proeutectoid)cementite (according to the curve A_{CM}) and pearlite.

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

104**. Normalising, N**: normalising involves heating rolled steel above the critical temperature, Ac3, and in the lower end of the austenite recrystallization region followed by air cooling. The process improves the mechanical properties of as rolled steel by refining the grain size.

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

106. **Quenching and Tempering, QT:** quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the Ac3 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 Ac1 to restore toughness properties by improving the microstructure.

107. **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 Ar3 temperature and may involve the rolling in the dual phase temperature region. Unlike controlled rolled (normalised rolling) the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM-rolling may also be accepted subject to the special approval of the RBNA. The same applies for the use of tempering after completion of the TM-rolling.

108. **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.

B2. QUALITY SCOPE AND APPROVAL [IACS UR W11]

100. Scope [IACS UR W11.1]

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

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

a. For steel plates and wide flats;

a.1. - All Grades: Up to 100mm in thickness

b. For sections and bars;

b.1. - All Grades: Up to 50mm in thickness

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

103. 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.

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

200. Approval [IACS UR W11.2]

201. All materials are to be manufactured at works which have been approved by the RBNA 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 Part III, Title 61, Section 2, Sub-chapter B.9 and B10. 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 Part III, Title 61, Section 2, Sub-chapter B.11.

202. 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.

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

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

205. 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.

206. Notes:

a. 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.

b. 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.

300. Method of Manufacture [IACS UR W11.3]

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

302. The deoxidation practice used for each grade is to comply with the appropriate requirements of T.B2.101.1.

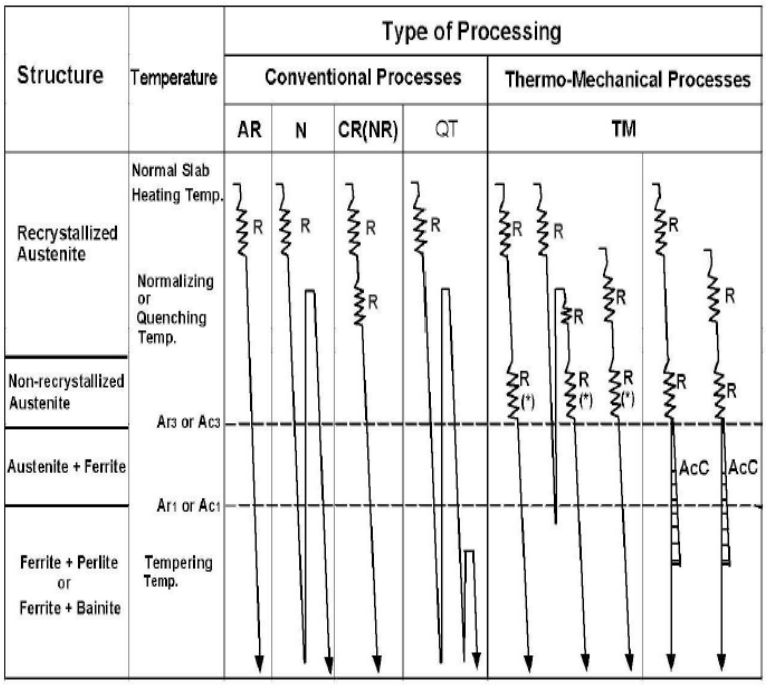
303. The rolling practice applied for each grade is to comply with the appropriate condition of supply of T.B2.101.4 and T.B2.101.5

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

305. Where CR and TM with/without AcC are applied, the programmed rolling schedules are to be verified by the RBNA 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 item B2.202. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

306. 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 item B2.202 to the Surveyor's satisfaction.

FIGURE F.B2.300.1 – 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

TABLE T.B2.101.1 – MECHANICAL PROPERTIES FOR NORMAL STRENGTH STEEL

GRADES			A	B	D	E
Method of manufacture			Basic oxygen, open heart or electric furnace	Basic oxygen, open heart or electric furnace	Basic oxygen, open heart or electric furnace	Basic oxygen, open heart or electric furnace
Deoxidation parctice			For t ≤ 50 mm Any method except rimmed steel (1) For t > 50 mm Killed	For t ≤ 50 mm Any method except rimmed steel 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 (%)	Carbon (máx)		0, 21 (2)	0, 21	0, 21	0, 18
	Manganese (máx)		≥ 2, 50 C	0, 80 (3)	≥ 0, 60	≥ 0, 70
	Sulphur (máx)		0,035	0,035	0,035	0,035
	Phosphorus (máx)		0,035	0,035	0,035	0,035
	Silício (máx)		-0,50	0, 35	- 0, 35	- 0, 35
	Aluminium (acid soluble minimum)		-	-	0,015 (5) (6)	0,015 (6)
	Other		C + Mn / 6 ≤ 0, 40	C + Mn / 6 ≤ 0, 40	C + Mn / 6 ≤ 0, 40	Al ≥ 0, 015 C + Mn / 6 ≤ 0, 40
Condition of supply IACS TABLE 4			≤50 mm: Any > 50 mm ≤ 100 mm: Normalized, controlled rolled or thermo mechanically rolled	≤50 mm: Any > 50 mm ≤ 100 mm: Normalized, controlled rolled or thermo mechanically rolled	≤ 35 mm: Any > 35 mm ≤ 100 mm: Normalized, controlled rolled or thermo mechanically rolled (3)	≤ 100 mm: Normalized or thermo mechanically rolled
Mechanical properties IACS TABLE6	Tensile strength (N/ mm²)		400 – 520 (9)	400 - 520	400 - 520	400 - 520
	Yield strangth (N / mm²)		235 mín (5)	235 mín	235 mín	235 mín
	Elongation at 5, 65 √ S_0 (%)		≥ 21 (10)	≥ 21 (10)	≥ 21 (10)	≥ 21 (10)
	Impact Test Charpy V notch	Temperature (C)	20	0 (7)	- 10	- 40
		Espessura (mm)	≤ 50	≤ 50	≤ 50	E
		Average impact energy (J) mín	Longitudinal (11) E ≤ 50 - E ≥ 50 ≤ 70 34 (13) E ≥ 70 ≤ 100 41 (13) Transverse (11) E ≤ 50 - E ≥ 50 ≤ 70 24 (13)	Longitudinal (11 E ≤ 50 27 (12) E ≥ 50 ≤ 70 34 E ≥ 70 ≤ 100 41 Transverse (11 E ≤ 50 20 (12) E ≥ 50 ≤ 70 24 E ≥ 70 ≤ 100 27	Longitudinal (11 E ≤ 50 27 E ≥ 50 ≤ 70 34 E ≥ 70 ≤ 100 41 Transverse (11 E ≤ 50 20 E ≥ 50 ≤ 70 24 E ≥ 70 ≤ 100 27	Longitudinal (11 E ≤ 50 27 E ≥ 50 ≤ 70 34 E ≥ 70 ≤ 100 41 Transverse (11 E ≤ 50 20 E ≥ 50 ≤ 70 24 E ≥ 70 ≤ 100 27

TABELA T.B2.101.1 (Cont) - MECHANICAL PROPERTIES FOR NORMAL STRENGTH STEEL

Notes:
1. Grade A sections up to a thickness of 12.5 mm may be accepted in rimmed steel subject to the special approval of the RBNA.
2. Max. 0.23% for sections.
3. When Grade B steel is impact tested the minimum manganese content may be reduced to 0.60%.
4. When any grade of steel is supplied in the thermo-mechanically rolled condition variations in the specified chemical composition may be allowed or required by the RBNA.
5. For Grade D steel over 25 mm thick.
6. For Grade D steel over 25 mm thick and Grade E steel the total aluminium content may be determined instead of acid soluble content. In such cases the total aluminium content is to be not less than 0.020%. A maximum aluminium content may also be specified by the RBNA. Other suitable grain refining elements may be used subject to the special approval of the RBNA.
7. The RBNA 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.
9. For all thicknesses of Grade A sections the upper limit for the specified tensile strength range may be exceeded at the discretion of the RBNA.
10. 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

11. See item B3.104
12. Charpy V-notch impact tests are generally not required for Grade B steel with thickness of 25 mm or less.
13. Impact tests for Grade A over 50 mm thick are not required when the material is produced using fine grain practice and furnished normalised. TM rolling may be accepted without impact testing at the discretion of the RBNA.
14. Subject to the special approval of the RBNA, Grades A and B steel plates may be supplied in the as rolled condition - see B8.504.b).
15. Subject to the special approval of the RBNA, 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 B8.507.b) and 507.c) respectively.

TABLE T.B2.101.2 – CHEMICAL COMPOSITION AND DEOXIDATION PRACTICE FOR HIGH STRENGTH STEELS

Grade [1]	AH 32 DH 32 EH 32 AH 36 DH 36 EH 36 AH 40 DH40 EH 40		FH32 FH36 FH40	
Deoxidation practice	Killed and fine grain treated			
Chemical composition [5] [7]				
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: 0,12 max	0.02 – 0.05 [4]	Total: 0,12 max
V	0.05 – 0.10 [4])		0.05 – 0.10 [4]	
Ti max	0,02		0,02	
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. RBNA adds the letter "H" behind the grade mark e.g. AH 32, to indicate high strength steel.
2. Up to a thickness of 12.5 mm the minimum manganese content may be reduced to 0.70%.
3. The total aluminum 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 aluminum, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of a fine graining element is not applicable.
5. When any grade of higher strength steel is supplied in the thermo-mechanically rolled condition variations in the specified chemical composition may be allowed or required by the RBNA.
6. When required, the carbon equivalent value is to be calculated from the ladle analysis using the following formula:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \%$$

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.

For TM (TMCP) steels the following special requirements apply:
a) The carbon equivalent value is to be calculated from the ladle analysis using the following formula and to comply with the requirements of T.B2.101.3

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \%$$

b) The following formula (cold cracking susceptibility) may be used for evaluating weldability

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

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

TABLE T.B2.101.3 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
AH32, DH32, EH32, FH32	0,36	0,38
AH36, DH36, EH36, FH36	0,38	0,40
AH40, DH40, EH40, FH40	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.

TABLE T.B2.101.4 CONDITIONS OF SUPPLY FOR HIGHER STRENGTH STEEL (1)

Grades	Grain Refining Elements Used	Thickness	Condition of Supply
AH32 AH36	Nb and/or V	≤ 12.5 mm	Any
		> 12.5 mm ≤ 100 mm	Normalized, controlled rolled or thermo-mechanically rolled (3)
	Al alone or with Ti	≤ 20 mm	Any
		> 20 mm ≤ 35 mm	Any, as rolled subject to special approval of the RBNA (2)
		> 35 mm ≤ 100 mm	Normalized, controlled rolled or thermo-mechanically rolled (3)
AH40	Any	≤ 12.5 mm	Any
		> 12.5 mm ≤ 50 mm	Normalized, controlled rolled or thermo-mechanically rolled (3)
		> 05 mm ≤ 100 mm	Normalized, thermo-mechanically rolled, or quenched and tempered
DH32 DH36	Nb and/or V	≤ 12.5 mm	Any
		> 12.5 mm ≤ 100 mm	Normalised, controlled rolled or thermo-mechanically rolled (3)
	All alone or with Ti	≤ 20 mm	Any
		> 20 mm ≤ 25 mm	Any, as rolled subject to special approval of the RBNA (2)
		> 25 mm ≤ 100 mm	Normalized, controlled rolled or thermo-mechanically rolled (3)
DH40	Any	≤ 50 mm	Normalized, controlled rolled or thermo-mechanically rolled
		> 50 mm ≤ 100 mm	Normalized, thermo-mechanically rolled or quenched and tempered
EH32 EH36	Any	≤ 50 mm	Normalized or thermo-mechanically rolled (3)
		> 50 mm ≤ 100 mm	Normalized, thermo-mechanically rolled
EH40	Any	≤ 50 mm	Normalized, thermo-mechanically rolled or quenched and tempered
		> 50 mm ≤ 100 mm	Normalized, thermo-mechanically rolled or quenched and tempered
FH32 FH36 FH40	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 T.B8.501.2
(2) The frequency of impact tests is to be in accordance with B8.504
(3) Subject to the special approval of the RBNA, sections in Grades AH32, AH36, DH32 and DH36 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 EH32 and EH36 steels maybe supplied in the as rolled or controlled rolled condition. The frequency of impact tests is to be in accordance with B8.504 and B8.505 respectively.
(4) Subject to the special approval of the RBNA, sections in Grades FH32 and FH36 steels may be supplied in the controlled rolled condition. The frequency of impact tests is to be in accordance with B8.507.b).

TABELA T.B2.101.5 – MECHANICAL PROPERTIES FOR HIGHER STRENGTH STEELS

Grade	Yield Strength ReH (N/mm^2) min	Tensile Strength Rm (N/mm^2)	Elongation ($5.65\sqrt{S0}$) A5 (%)	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)
AH32	315	440/570	22 (1)	0	31	22	38	26	46	31
DH32				-20	31	22	38	26	46	31
EH32				-40	31	22	38	26	46	31
FH32				-60	31	22	38	26	46	31
AH36	355	490/630	21 (1)	0	34	24	41	27	50	34
DH36				-20	34	24	41	27	50	34
EH36				-40	34	24	41	27	50	34
FH36				-60	34	24	41	27	50	34
AH40	390	510/660	20 (1)	0	39	26	46	31	55	37
DH40				-20	39	26	46	31	55	37
EH40				-40	39	26	46	31	55	37
FH40				-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 %	AH32, DH32, EH32, FH32	15	16	17	18	19	20	21	22
	AH 36, DH36, EH36, FH36	13	15	16	17	18	19	20	21
	AH40,DH40,EH4-,FH40	12	14	15	16	17	18	19	20

(2) See paragraph B3.106
(3) For Grades AH32 and AH36 steels a relaxation in the number of impact tests for acceptance purposes may be permitted by special agreement with the RBNA provided that satisfactory results are obtained from occasional check tests.

B3. CHARACTERISTICS OF MATERIALS FOR USE IN HULL STRUCTURE

100. Chemical and mechanical characteristics [IACS UR W11.4 (chemical) e W11.6 (mechanical)]

101. 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 table T.B2.101.1. For steel plates and wide flats over 50 mm thick, slight deviations in the chemical composition may be allowed as approved by the RBNA.

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

103. RBNA considers 16 grades of steel, as follows:

a. Normal strength steels:

A B D E

b. High strength steels:

AH32 AH36 AH40
DH32 DH36 DH40
E3H2 EH36 EH40
FH32 FH36 FH40

104. 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).

105. The results obtained from tensile tests are to comply with the appropriate requirements of Tables T.B2.101.1 and T.B2.101.5.

106. Minimum average energy values are specified for Charpy V-notch impact test specimens taken in either the longitudinal or transverse directions. Generally only longitudinal test specimens need to be prepared and tested except for special applications where transverse test specimens may be required by the purchaser or the RBNA. Transverse test results are to be guaranteed by the supplier. The tabulated values are for standard specimens 10 mm x 10 mm. For plate thicknesses less than 10 mm, impact test may be waived at the discretion of the RBNA or subsize specimens, as specified in Part III, Title 61, Section 2, Chapter A, may be used.

107. The average value obtained from one set of three impact tests is to comply with the requirements given in Tables T.B2.101.1 and T.B2.101.5. One individual value only may be below the specified average value provided it is not less than 70% of that value.

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

B4. HIGH STRENGTH QUENCHED AND TEMPERED STEEL FOR WELDED STRUCTURES [IACS WR16]

100. Scope and Approval [IACS WR16.1 e IACS WR16.2]

101. These requirements apply to weldable high strength and tempered steel plates and wide flats up to 70 mm thickness. The application of these requirements for products with thicknesses above 70 mm are to be specially agreed with the RBNA.

102. Product forms other than plates and wide flats, such as section and tubular, may be provided to these requirements when specially agreed to by the RBNA.

103. Steel covered by the scope of these requirements are divided into six yield strength levels of 420, 460, 500, 550, 620 and 690 N/mm^2. For each yield strength level four grades A, D, E and F are specified, based on the impact test temperature.

104. Steels differing in strength level, mechanical properties, chemical composition, etc, may be subject to special approval of the RBNA.

105. Special consideration may be given to the supply of those steels in thicknesses up to 50mm in the TMCP condition subject to approval of the RBNA.

106. The steels must be approved by the RBNA, and for this purpose the steel maker is to submit a specification containing such details as: chemical composition, manufacturing process, mechanical properties, delivery condition, recommendation for welding, cold and hot forming and heat treatment. In addition, the RBNA may require initial approval tests to be performed.

107. Weldability of each grade of steel should be demonstrated by the steelmaker during the initial approval procedure to the satisfaction of the RBNA.

200. Method of Manufacture [IACS WR16.3]

201. The steel is to be manufactured at works approved by the RBNA, by the basic oxygen, electric furnace or open hearth process or by processes specially approved by the RBNA.

202. The steel shall be fully killed, and fine grain treated.

TABLE T.B4.301.1 - CHEMICAL COMPOSITION

Yield Strength Level	Impact Grade	Maximum Content of Elements (%) C	Si	Mn	P	S	N
	A	0,21	0,55	1,70	0,035	0,035	0,020
420 N/mm^2 to 690 N/mm^2	D	0,20	0,55	1,70	0,030	0,030	0,020
	E						
	F	0,18	0,55	1,60	0,025	0,025	0,020

300. Chemical composition [IACS WR16.4]

301. The chemical composition is to be determined by the steelmaker in an adequately equipped competently staffed laboratory from each cast or ladle and is to comply with the requirements of the approved specification and limits given in Table T.B4.301.1.

302. Elements used for alloying and fine grain treatment are to be as detailed in the approved specification,

303. The cold cracking susceptibility Pcm for evaluating weldability should be calculated from the ladle analysis in accordance with the following formula:

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

304. The maximum Pcm to be achieved is to be agreed with the RBNA and included in the approved specification.

400. Heat treatment [IACS WR16.5]

401. The steels shall be in the quenched and tempered condition. See B4.105.

500. Mechanical properties [IACS WR16.6]

501. Tensile test:

a. For each piece as heat treated at least one tensile test specimen is to be taken and tested in accordance with Part II, Title 61, Section 2, Chapter A. For continuous heat treated plates special consideration may be given regarding the number and location of test specimens required.

b. Test specimens are to be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of section and rolled flats with a finished width of 600 m or less, where the tensile specimens may be taken in either the longitudinal or transverse direction as agreed by the RBNA. Normally flat tensile test specimens are to be prepared in such a manner as to maintain the rolling scale at least at one side. Where the thickness exceeds 40mm, full thickness specimens may be prepared but when instead a machined round tensile test specimen is used then the axis must be located at a position lying at a distance of t/4 from the surface or as near as possible to this position.

c. The results of the tests are to comply with the appropriate requirements of Table T.B4.501.1 In the case of other product forms where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those listed in Tables T.B4.501.1 and T.B4.501.2.

502. Impact test: from each piece as heated treated at least one set of three V-notch impact test specimens in accordance with Requirement Part II, Title 61, Section 2, Chapter A is to be taken and tested.

a. For continuous heat treated plates special consideration may be given to the number and location of test specimens required.

b. Unless otherwise accepted by the RBNA, the V-notch impact test specimens for plates and wide flats over 600 mm are to be taken with their axes transverse to the main rolling direction and the results should comply with the appropriate requirements of T.B4.501.1.

c. For other product forms the impact tests are to be in the longitudinal direction, the results of the tests are to comply with the appropriate requirements of T.B4.501.1.

d. Normally sub-surface test specimens will be taken, however, for material with a thickness in excess of 40mm, impact tests should be taken at the quarter thickness (t/4) location.

TABLE T.B4.501.1 MECHANICAL PROPERTIES REQUIREMENTS, 70 MM MAXIMUM THICKNESS

Grade of Steel	Tensile properties			Charpy V-notch impact test (See note 4)		
	Yield stress ReH (N/mm^2) Min See note1) See note 2)	Tensile strength Rm (N/mm^2)	A_{min} Elongation $Lo=5.65\sqrt{S0}$ (%) (See note 3)	Test Temperature °C	Average energy min	
					Long	Transv
A420	420	530-680	18	0	42	28
D420				-20		
E420				-40		
F420				-60		
A460	460	570-720	17	0	46	31
D460				-20		
E460				-40		
F460				-60		
A500	500	610-770	16	0	50	33
D500				-20		
E500				-40		
F500				-60		
A550	550	670-830	16	0	55	37
D550				-20		
E550				-40		
F550				-60		
A620	620	720-890	15	0	62	41
D620				-20		
E620				-40		
F620				-60		
A690	690	770-940	14	0	69	46
D690				-20		
E690				-40		
F690				-60		

Note 1 Where the Yield Stress ReH does not mark in the tensile test the 0.2% proof stress $R_{po.2}$ is applicable.

Note 2 Subject to the discretion of the RBNA, a yield strength to ultimate tensile strength ratio may be required.

Note 3 For full thickness flat test specimens with a width of 25mm and a gauge length of 200mm the elongation is to comply with the minimum values shown in TABLE T.B4.501.2.

Note 4 For A grade steels, a relaxation in the number of impact tests required for acceptance purposes may be permitted by special agreement with the RBNA provided that satisfactory results are obtained from occasional check tests.

TABLE T.B4.502.2 ELONGATION MINIMUM VALUES FOR A WIDTH OF 25MM AND A 200MM GAUGE LENGTH

Strength Level	Thickness mm						
	≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
420	11	13	14	15	16	17	18
460	11	12	13	14	15	16	17
500	10	11	12	13	14	15	16
550	10	11	12	13	14	15	16
620	9	11	12	12	13	14	15
690	9	10	11	11	12	13	14

600. Retest procedures

601. Re-test procedures for tensile tests and Charpy impact tests are to be in accordance with Part III, Title 61, Section 2, Chapter A, Subchapter A-2.

700 Through thickness tensile test

701. If required by the RBNA, through thickness tensile tests are to be performed in accordance with Part III, Title 61, Section 2, Sub-Chapter B.5, "Steel plates and wide flats with improved thickness properties".

800. Tolerances 16.7

801. Unless otherwise agreed or specially required, the thickness tolerances in Part III, Title 61, Section 2, Sub-Chapter B.7, "Allowable under thickness tolerances of steel plates and wide flats" are applicable.

900. Identification of materials, inspection, branding and documentation

901. Identification: the steelmaker is to adopt a system for the identification of ingots, slabs and finished products, which will enable the material to be traced to its original cast.

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

903. Freedom from defects: the steel is to be reasonably free from segregation and nonmetallic inclusions. The finished material is to be free from internal or surface defects prejudicial to the use of the materials for the intended application.

a. Welding repair procedures and the method for reporting repairs are to be approved by the individual Classification Societies.

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

904. Surface inspection and dimensions: Surface inspection and verification of dimensions are the responsibility of the steelmaker, and acceptance by the RBNA's Surveyor of material later found to be defective shall not absolve the steelmaker of this responsibility.

905. Ultrasonic examination: if required by the RBNA the manufacturer is to perform ultrasonic examinations in accordance with an approved standard.

905. Branding: every finished piece is to be clearly marked by the maker in at least one place with the RBNA's brand and the following particulars:

a. Unified identification mark for the grade of steel (e.g. E620);

b. Name or initials to identify the steelworks;

c. Heat number, plate number or equivalent identification mark;

d. The entire markings are to be encircled with paint or otherwise marked so as to be easily recognised.

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

a. Purchaser's order number and if known the ship number for which the material is intended;

b. Identification of the cast and piece;

c. Identification of the steelworks;

d. Identification of the grade of steel.

e. Ladle analysis (elements given in the approved specification).

f. Condition of supply with heat treatment temperatures.

907. Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the tests required by the Rules of the Classification Societies. The name of the RBNA is to appear on the test certificate. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the makers by an authorised official: *"We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of the RBNA".*

B5. STEEL PLATES AND WIDE FLATS WITH SPECIFIED MINIMUM THROUGH THICKNESS PROPERTIES ("Z" QUALITY) [IACS WR14]

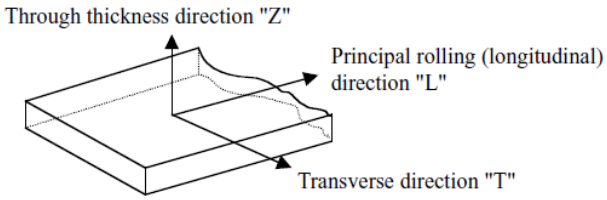
100. Scope [IACS WR14.1]

101. These requirements supplement those given in B2. And B3 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 F.B5.103.1). Products with a thickness less than 15mm may be included at the discretion of the RBNA.

102. 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.

103. Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

FIGURE F.B5.103.1 - SCHEMATIC OF TESTING DIRECTIONS



200. Manufacture [IACS WR14.2]

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

202. The approval should follow the procedure given in B9 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.

300. Chemical composition [IACS WR14.2 bis]

301. In addition to the requirements of the appropriate steel specification B2 or B3, the maximum sulphur content is to be 0.008% determined by the ladle analysis.

400. Test procedure [IACS WR14.3]

401. In addition to the requirements of the appropriate steel specification B2 or B3, preparation of specimens and testing procedures are to be as follows:

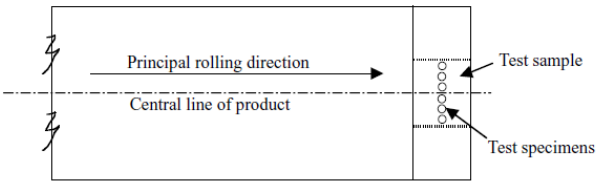
402. Test sampling: or plates and wide flats, one test sample is to be taken close to the longitudinal centreline of one end of each rolled piece representing the batch. See Table T.B5.402.1 and figure F.B5.402.1.

TABLE T.B5.402.1 - 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

403. 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 F.B5.402.1 PLATE AND WIDE FLAT SAMPLING POSITION



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

405. 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 T.B5.405.1.

406. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade Figure F.B5.501.1.

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

TABLE T.B5.405.1 – REDUCTION OF AREA ACCEPTANCE VALUES

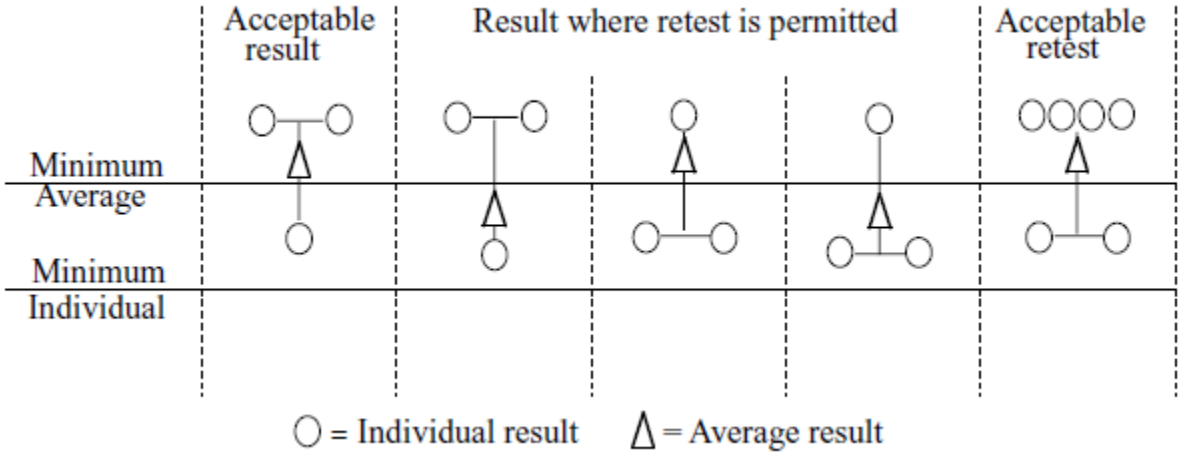
Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

500. Retest procedure [IACS WR14.4]

501. Figure F.B5.501.1 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.

502. 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 F.B5.501.1 - DIAGRAM SHOWING ACCEPTANCE / REJECTION AND RETEST CRITERIA



600. Ultrasonic tests
[IACS WR14.5]

601. Ultrasonic testing is required and is to be performed in accordance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

602. Ultrasonic testing should be carried out on each piece in the final supply condition and with a probe frequency of 4MHz.

700. Marking
[IACS WR14.6]

701. Products complying with these requirements are to be marked in accordance with the appropriate steel requirement B2 (URW11) or B3 (URW16) and in addition with the notation Z25 or Z35 added to the material grade designation, e.g. EH36Z25 or EH36Z35.

800. Certification
[IACS WR14.7]

801. The following information is required to be included on the certificate in addition to the appropriate steel requirement given in B2 or B3:

a. Through thickness reduction in area (%)

b. Steel grade with Z25 or Z35 notation.

B6. ACCEPTANCE CRITERIA
[IACS Rec 12]

100. Scope

101. This Sub-Chapter B6 gives some criteria recommended for the surface finish for hull structural steel plates and wide flats as well as the treatment of imperfections and defects which may occasionally occur on the surfaces of these products.

102. This Sub-Chapter does not cover quality requirements for the edges.

103. At the RBNA's discretion these criteria may also be applied to other steel grades.

104. The criteria contained herein have been based on the consideration that surface imperfections and defects on hull steels may impair the proper coating of tanks and hulls and this may reduce the corrosion resistance. Moreover, they may increase the frictional resistance of the hull and thereby impair the economy of the service. Surface defects may also adversely affect the strength of the structure. Special provisions with respect to the surface finish are therefore deemed necessary.

200. Manufacturer's Responsibility

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

300. Acceptance Criteria

301. All products must have a workmanlike finish and must be free from defects and imperfections which may impair their proper workability and use. This may, however, include some discontinuities of a harmless nature, minor imperfections, e.g. pittings, rolled-in scale, indentations, roll marks, scratches and grooves which cannot be avoided completely despite proper manufacturing and which will not be objected to provided they do not exceed the acceptable limits contained herein.

302. Imperfections: notwithstanding this, the products may have imperfections exceeding the discontinuities inherent to the manufacturing process, as defined under item 301 above. In such cases, limits for their acceptability are to be agreed with the RBNA, taking the end use of the product into consideration.

303. Defects: cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair, irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

400. Repair Procedures

401. Grinding: grinding may be applied provided:

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 m2 and

c. all ground areas do not exceed 2% of the total surface in question.

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

403. Ground areas lying opposite each other on both surfaces must not decrease the product thickness by values exceeding the limits as stated under item B6.401 above.

404. The defects or unacceptable imperfections are to be completely removed by grinding. The ground areas must have smooth transitions to the surrounding surface of the product. Complete elimination of the defects may be verified by a magnetic particle or dye penetrant test procedure at the Surveyor's discretion.

405. Where necessary, the entire surface may be ground to a depth as given by the under thickness tolerances of the product.

500. Welding Repair

501. Local defects which cannot be repaired by grinding as stated under item 401 above may be repaired with the Surveyor's consent by chipping and/or grinding followed by welding subject to the following conditions:

a. Any single welded area shall not exceed 0,125 m2 and the sum of all areas shall not exceed 2% of the surface side in question. The distance between two welded areas shall not be less than their average width.

b. The weld preparation must 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.

c. 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 must be dried in accordance with the manufacturer's requirements and protected against re-humidification before and during welding.

B7. THICKNESS TOLERANCES OF STEEL PLATES AND WIDE FLATS [IACS WR 13]

100. Scope [IACS WR13.1]

101. The requirements of this Sub-Chapter B5 apply to the tolerance on thickness of steel plates and wide flats (hereinafter referred to as: product or products) with thicknesses of 5 mm and over, covering the following steel grades:

a. Normal and higher strength hull structural steels according to sub-chapter B2.

b. High strength quenched and tempered steels for welded structure according to chapter B3.

c. Steels for machinery structures in accordance with the individual Rules of RBNA.

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

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

104. 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.

105. Where Class C of ISO 7452 is applied in lieu of B7.300, the requirements in B7.400 and B7.500 may not be applied.

200. Responsibility
[IACS WR13.2]

201. 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.

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

300. Thickness tolerances
[IACS WR13.3]

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

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

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

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

303. The minus tolerance on thickness of products in accordance with sub-chapter B2 and chapter B3 is 0.3 mm irrespective of nominal thickness.

304. The minus tolerances for products for machinery structures are to be in accordance with Table T.B7.304.1.

TABLE T.B7.304.1 –TOLERANCES FOR MACHINERY STRUCTURES

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

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

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

400. Average thickness
[IACS WR13.4]

401. The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements of B7.500 (UR W13.5).

402. The average thickness of a product or products in accordance with B2 (URW11) or B3 (URW16) is not to be less than the nominal thickness.

500. Thickness measurements
[IACS WR13.5]

501. The thickness is to be measured at locations of a product or products as defined in B7.600.

502. Automated method or manual method is applied to the thickness measurements.

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

600. Thickness Measuring Locations
[IACS WR13 ANNEX]

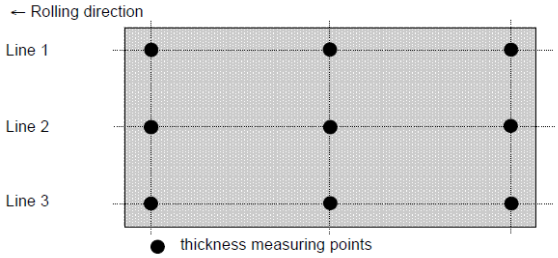
601. Scope of application: this item B7.600 applies to the thickness measuring locations for the thickness tolerance and the average thickness of the product.

602. At least two lines among Line 1, Line 2 or Line 3 as shown in Figure F.B7.602.1, 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.

603. 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.

604. 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 F.B7.602.1 - Locations of Thickness Measuring Points



B8. REQUIREMENTS FOR TESTS

100. Testing and Inspection [IACS WR11.10]

101. 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.

102. Testing Procedures: the prescribed tests and inspections are to be carried out at the place of manufacture before dispatch. T he test specimens and procedures are to be in accordance with Chapter A. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed

103. 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 sub-chapter B.5 is to be carried out

104. Ultrasonic Inspection: if plates and wide flats are ordered with ultrasonic inspection, this is to be made in accordance with an accepted standard at the discretion of the RBNA. .

105. Surface Inspection and Dimensions: surface inspection and verification of dimensions are the responsibility of the steel maker. The acceptance by the RBNA's Surveyor shall not absolve the steel maker from this responsibility.

200. Definitions [IACS WR11.11.1]

201. 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.

202. Batch: a number of similar pieces presented as a group for acceptance tests.

300. Test materials [IACS WR11.11.2]

301. 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:

d.1. *Plates and flats with a width ≥ 600 mm.* The test samples are to be taken from one

d.2. end at a position approximately midway between the axis in the direction of the rolling and the edge of the rolled product (see Fig. F.B8.301.1). Unless otherwise agreed the tensile test specimens are to be prepared with their longitudinal axes transverse to the final direction of rolling.

d.3. *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 Figure F.B8.301.1, 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 Figure F.B8.301.1 Fig. 3). The tensile test specimens may be prepared with their longitudinal axes either parallel or transverse to the final direction of rolling.

d.4. *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:

i. for non-cylindrical sections, at one third of the half diagonal from the outside,

ii. for cylindrical sections, at one third of the radius from the outside (see Figure F.B8.301.1 Fig. 6).

FIGURE F. B8.301.1 – TEST SAMPLES

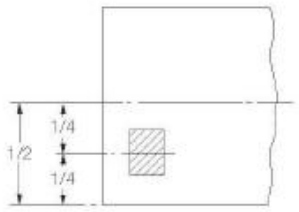


Fig. 1 Plates and flats

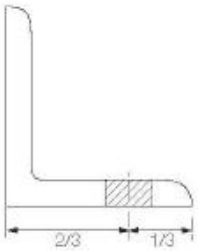


Fig. 2 Angles

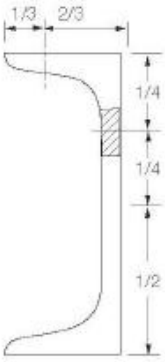


Fig. 3 Channel

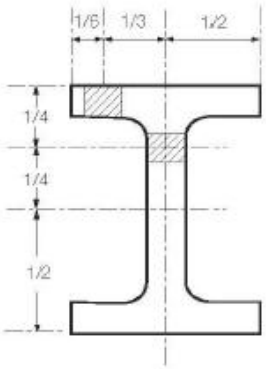


Fig. 4 H-sections

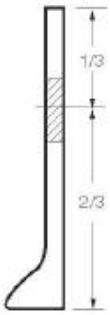


Fig. 5 Bulb flats

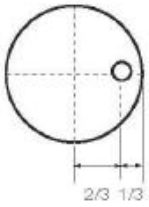


Fig. 6 Bars;

400. Mechanical Test specimens [IACS WR11.12]

401. Tensile Test Specimens: the dimensions of the tensile test specimens are to be in accordance with Part III, Title 61, Section 2, Chapter A3. 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.

402. 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. T.B2.101.1 and T.B2.101.5) or transverse (indicated "Trans" in Table. T.B2.101.1 and T.B2.101.5) 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. T he 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.

500. Number of Test Specimens [IACS WR11.13]

501. **Number of Tensile Tests**. For each batch presented, except where specially agreed by the RBNA, 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.

502. **Number of Impact Tests** (except for Grades E, EH32, EH36, EH40, FH32, FH36 and FH40), see Tables T.B8.501.1 and T.B8.501.2.

503. Except where otherwise specified or specially agreed by the RBNA, 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.

504. For steel plates of Grades AH40 and DH40 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.

505. When, subject to the special approval of the RBNA, 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.

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

507. **Number of Impact Tests** (Grades E, EH32, EH36, EH40, FH32, F36 and FH40).

a. 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.

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

c. When, subject to the special approval of the RBNA, sections other than Grades EH40 and FH40 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.

d. For b) and c) above the piece selected for the preparation of the test specimens is to be the thickest in each batch.

600. Retest Procedures [IACS WR11.14]

601. When the tensile test from the first piece selected in accordance with B2.300 fails to meet the requirements re-test requirements for tensile tests are to be in accordance with Chapter A.

602. 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.

603. Re-test requirements for Charpy impact tests are to be in accordance with Chapter A.

604. 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.

605. 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.

606. 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.

607. 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.

608. 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.

700. Branding [IACS WR11.15]

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

a. Unified identification mark for the grade steel (e.g. A, A36).

b. Steels which have been specially approved by the RBNA and which differ from these requirements (see B3.100) are to have the letter "S" after the above identification mark (e.g. A36S, ES).

c. When required by the RBNA, material supplied in the thermo-mechanically controlled process condition is to have the letters TM added after the identification mark (e.g. E36 TM).

d. Name or initials to identify the steelworks.

e. Cast or other number to identify the piece.

f. If required by the purchaser, his order number or other identification mark.

702. 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 recognizable.

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

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

800. Documentation [IACS WR11.16]

801. The Surveyor is to be supplied with the number of copies as required by the RBNA, of the test certificates or shipping statements for all accepted materials. The RBNA 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:

a. Purchaser's order number and if known the hull number for which the material is intended;

b. Identification of the cast and piece including, where appropriate, the test specimen number;

c. Identification of the steelworks;

d. Identification of the grade of steel;

e. Ladle analysis (for elements specified in Tables T.B8.801.1 and T.B8.801.2);

f. Condition of supply when other than as rolled i.e. normalised, controlled rolled or thermomechanically rolled;

g. State if rimming steel has been supplied for grade A sections, up to 12.5 mm thick.

h. Test Results

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

TABLE T.B8.501.1 - REQUIRED CONDITION OF SUPPLY AND NUMBER OF IMPACT TESTS FOR NORMAL STRENGTH STEELS

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

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

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 T.B8.501.2 - 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
AH32 AH36	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
				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
AH40	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
DH32 DH36	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
				A(50) | N(50), CR(50), TM (50) | N(50), CR25, TM(50)
			Sections	A(50) | N(50) CR(50), TM(50) AR* (25) | Not applicable
EH40	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
DH32 DH40	Killed and fine grain treated	Any	Plates	N(Each piece) TM(Each piece)
			Sections	N(25) TM(25) AR* (15), CR* (15) | Not applicable
DH40	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

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	
FH32 FH36	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
FH40	Killed and fine grain treated	Any	Plates	N(Each piece) TM(Each piece) QT (Each length as heat treated)	N(Each piece) TM(Each piece) QT (Each length as heat treated)
			Sections	N(25) TM(25) QT(25)	Not applicable

Remarks:

(1) Condition of Supply

A - Any
N - Normalized Condition
CR - Controlled Rolled Condition
TM - Thermo-Mechanical Rolling
QT - Quenched and Tempered Condition
AR* - As Rolled Condition subject to the special approval of the RBNA
CR* - Controlled Rolled Condition subject to the special approval of the RBNA

(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 AH32 and AH36 steels a relaxation in the number of impact tests may be permitted.

B9. MANUFACTURING APPROVAL SCHEME OF SEMI FINISHED PRODUCTS FOR HULL STRUCTURAL STEELS [IACS WR11 APPENDIX A1]

100. Scope of application [IACS WR11 APPENDIX A1.1]

101. This document specifies 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 Part III, Title 61, Section 2, item B2.202.

200. Approval application: Documents to be submitted [IACS WR11 APPENDIX A1.2]

201. The manufacturer has to submit to the RBNA, request of approval, proposed approval test program (see Part III, Title 61, Section 2, B2.300) 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:

b.1. organizational chart

b.2. staff employed

b.3. staff employed and organization of the quality control department

b.4. qualification of the personnel involved in activities related to the quality of the products

b.5. certification of compliance of the quality system with IS0 9001 or 9002, if any

b.6. approval certificates already granted by other Classification Societies, if any

c. Manufacturing facilities:

c.1. flow chart of the manufacturing process

c.2. origin and storage of raw materials

c.3. storage of finished products

c.4. equipment for systematic control during fabrication

d. Details of inspections and quality control facilities:

d.1. details of system used for identification of materials at the different stages of manufacturing

d.2. equipment for chemical analyses and relevant calibration procedures

d.3. 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:

e.1. range of chemical composition and aim analyses, including grain refining, micro

e.2. alloying and residual elements, for the various grades of steel; if the range of chemical

e.3. composition depends on thickness and supply condition, the different ranges are to be

e.4. specified, as appropriate

e.5. aim maximum carbon equivalent according to IIW formula

e.6. aim maximum Pcm content for higher strength grades with low carbon content C < 0.13 %

e.7. 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

f.1. steel making process and capacity of furnace/s or converter/s

f.2. raw material used

f.3. deoxidation and alloying practice

f.4. desulphurisation and vacuum degassing installations, if any

f.5. 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.

f.6. ingot or slab size and weight

f.7. ingot or slab treatment: scarfing and discarding procedures

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

202. Documents to be submitted for changing the approval conditions: The manufacturer has to submit to the RBNA the documents required in Part III, Title 61, Section 2, item B9.200 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.

203. 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 (B9.400).

300. Approval tests
[IACS WR11 APPENDIX A1.3]

301. Extent of the approval tests: The extent of the test program is specified in B9.400 below, it may be modified on the basis of the preliminary information submitted by the manufacturer. In particular a reduction of the indicated number of casts, product thicknesses and types to be tested or complete suppression of the approval tests may be accepted by the RBNA 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.

302. 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.

303. Approval test program: Where the number of tests differs from those shown in B9.400 below, the program is to be confirmed by the RBNA before the tests are carried out.

304. 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.

305. 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.

306. 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.

400. Tests on base material: type of tests

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

a. Chemical analysis. The analysis is to be complete and is to include micro alloying elements.

b. Sulphur prints.

402. In addition, for initial approval and for any upgrade of the approval, the RBNA will require full tests indicated in Part III, Title 61, Section 2, B.10 below to be performed at rolling mill on the minimum thickness semi finished product.

403. 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.

500 Test specimens and testing procedure

501. 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.

600. Results

601. 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.

602. All the information required under Part III, Title 61, Section 2, B.10 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.

700. Certification

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

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

a. Type of products (ingots, slabs, blooms, billets)

b. Steelmaking and casting processes

c. Thickness range of the semi-finished products

d. Types of steel (normal or higher strength)

703. 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.

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

705. 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.

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

707. Reconsideration of the approval: during the period of validity the approval may be reconsidered in the following cases:

a. in service failures, traceable to product quality

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

c. discovered failure of the Manufacturer's quality system

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

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

B10. MANUFACTURING APPROVAL SCHEME OF HULL STRUCTURAL STEELS [IACS WR11 APPENDIX A2]

100. Scope of application

101. This document specifies, the scheme for the approval of the manufacturing process of normal and higher strength hull structural steels.

102. 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 Part III, Title 61, Section 2, Chapter B, items B9.200 and B9.300.

200. Approval application

201. Documents to be submitted: the manufacturer has to submit to the RBNA, request of approval, proposed approval test program (see B9.400) 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:

b.1. organizational chart

b.2. staff employed

b.3. staff employed and organization of the quality control department

b.4. qualification of the personnel involved in activities related to the quality of the products

b.5. certification of compliance of the quality system with IS0 9001 or 9002, if any

b.6. approval certificates already granted by other Classification Societies, if any

c. Manufacturing facilities:

c.1. flow chart of the manufacturing process

c.2. origin and storage of raw materials

c.3. storage of finished products

c.4. equipment for systematic control during fabrication

d. Details of inspections and quality control facilities

d.1. details of system used for identification of materials at the different stages of manufacturing

d.2. equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures

d.3. equipment for non destructive examinations

d.4. list of quality control procedures

e. Type of products (plates, sections, coils), grades of steel, range of thickness and aim material properties as follows:

e.1. 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

e.2. aim maximum carbon equivalent according to IIW formula

e.3. aim maximum Pcm content for higher strength grades with low carbon content C < 0.13 %

e.4. 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

f.1. steel making process and capacity of furnace/s or converter/s

f.2. raw material used

f.3. deoxidation and alloying practice

f.4. 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.

f.5. ingot or slab size and weight

f.6. ingot or slab treatment: scarfing and discarding procedures

g. Reheating and rolling

g.1. type of furnace and treatment parameters

g.2. rolling: reduction ratio of slab/bloom/billet to finished product thickness, rolling and finishing temperatures

g.3. descaling treatment during rolling

g.4. capacity of the rolling stands

h. Heat treatment

h.1. type of furnaces, heat treatment parameters and their relevant records

h.2. 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:

i.1. description of the rolling process

i.2. normalizing temperature, re-crystallization temperature and Ar3 temperature and the methods used to determine them

i.3. 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

i.4. calibration of the control equipment

j. Recommendations for working and welding in particular for products delivered in the CR or TM condition

j.1. cold and hot working recommendations if needed in addition to the normal practice used in the shipyards and workshops

j.2. minimum and maximum heat input if different from the ones usually used in the shipyards and workshops (15 - 50 kJ/cm)

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

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

300. Documents to be submitted for changing the approval conditions

301. The manufacturer has to submit to the RBNA the documents required in B10.300 above 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.

400. Approval tests

401. Extent of the approval tests: the extent of the test program is specified in this item B10.400; it may be modified on the basis of the preliminary information submitted by the manufacturer. In particular a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete suppression of the approval tests may be accepted by the RBNA 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.

402. 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 B10.700 below. A reduction or complete suppression of the approval tests may considered by the RBNA taking into account previous approval as follows:

a. 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;

b. 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.

500. Approval test program

501. Where the number of tests differs from those shown in B10.700, the program is to be confirmed by the RBNA before the tests are carried out.

502. 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.

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

600. Position of the test samples

601. 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.

602. The position of the samples to be taken in the length of the rolled product, "piece" defined in Part III, Title 61, Section 2, B8.200 (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 T.B10.602.1.

603. The position of the samples in the width of the product is to be in compliance with Part III, Title 61, Section 2, B8.300.

700 Tests on base material

701. The tests to be carried out are indicated in the following Table T.B10;602.1

TABLE T.B10;602.1 – POSITION OF THE SAMPLES AND DIRECTION OF THE TEST SPECIMENS

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.

702. Test specimens and testing procedure: The test specimens and testing procedures are to be, as a rule, in accordance with Chapter A. In particular the following applies:

a. Tensile test

a.1. for plates made from hot rolled strip one additional tensile specimen is to be taken from the middle of the strip constituting the coil.

a.2. 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.

a.3. Alternatively two round specimens with the axis located at one quarter and at mid thickness can be taken.

b. Impact test

b.1. 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.

b.2. 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.

b.3. 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 Parte III, Title 61, Section 2, B.5. The test results are to be in accordance, where applicable, with the requirements specified for the different steel grades in Part III, Title 11, Section 2, B.5

703. 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 Part III, Title 11, Section 2, B.5, or when deemed necessary by the RBNA.

704. Weldability tests: 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.

705. 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.

c. 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.

d. The bevel preparation should be preferably 1/2V or K.

e. 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.

f. The welding parameters including consumables designation and diameter, pre-heating temperatures, interpass temperatures, heat input, number of passes, etc. are to be reported.

706. 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.

b.1. The fusion boundary is to be identified by etching the specimens with a suitable reagent.

b.2. 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:

c.1. Fusion line

c.2. HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

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

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

707. 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 Part III, Title 11, Section 2, B.5, or when deemed necessary by the RBNA.

800 Results

801. 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.

802. All the information required under Part III, Title 61, Section 2, B.10 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.

900. Certification

901. Approval: upon satisfactory completion of the survey, approval is granted by the RBNA.

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

903. Renewal of approval: the validity of the approval is to be a maximum of five years. Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period.* Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date. Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of results of production of similar grades of products, at the discretion of the RBNA, be re-approved.

904. Reconsideration of the approval: during the period of validity the approval may be reconsidered in the following cases:

a. in service failures, traceable to product quality

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

c. discovered failure of the Manufacturer's quality system

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

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

B11. APPROVAL SCHEME FOR MANUFACTURER OF HULL STRUCTURAL STEELS INTENDED FOR WELDING WITH HIGH HEAT INPUT [IACS WR11 APPENDIX B]

100. Scope

101. This document specifies the weldability confirmation scheme of normal and higher strength hull structural steels stipulated in Part III, Section 61, Section 2, B2 intended for welding with high heat input over 50kJ/cm.

102. 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.

103. 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.

200. Application of certification

201. The manufacturer is to submit to the RBNA, request of certification, proposed weldability test program and technical documents relevant to:

a. Outline of steel plate to be certified:

a.1. Grade

a.2. thickness range

a.3. deoxidation practice

a.4. fine grain practice

a.5. aim range of chemical composition

a.6. aim maximum Ceq and Pcm

a.7. 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.

300. Confirmation tests

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

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 RBNA may be accepted at the discretion of the RBNA.

400. Weldability test program

401. Extent of the test program is specified in section B11.408 but it may be modified according to the contents of certification. In particular, additional test assemblies and/or test items may be required in the case of newly developed type of steel, welding consumable and welding method, or when deemed necessary by the RBNA.

402. Where the content of tests differs from those specified in part II, Title 61, section 2 item B11.408, the program is to be confirmed by the RBNA before the tests are carried out.

403. Test plate: Test plate is to be manufactured by a process approved by the RBNA in accordance with the requirements of Part III, Title 61, Section 2, B9 and B.10.

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

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

406. 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.

407. 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.

408. Examinations and tests for the test assembly: The test assembly is to be examined and tested in accordance with the following a) through h) unless otherwise agreed by the RBNA.

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 Part III, Title 61, Section 2, Chapter A. 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 Part III, Title 61, Section 2, Chapter A 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 T.B2.101.1 or T.B2.101.5 in Part III, Title 61, Section 2, B2. 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 the RBNA.

h. Other test: Additional tests such as wide-width tensile test, HAZ tensile test, cold cracking tests (CTS, Cruciform, Implant, Tekken, and Bead-on plate), CTOD or other tests should be required at the discretion of the RBNA (See Part III, Title 61, Section 2. B11.400).

500. Results

501. The manufacturer is to submit to the RBNA the complete test report including all the results and required information relevant to the confirmation tests specified in Part III, Title 61, Section 2. B.11.

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

600. Certification

601. The RBNA 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.

700. Grade designation

701. 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.

CHAPTER C
STEEL CASTINGS
[IACS UR W 8]

CHAPTER CONTENTS

C1. SCOPE

100. Scope [IACS UR W.8.1]

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

102. 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.

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

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

C2. MANUFACTURE

100. Manufacture [IACS UR W 8. 2]

101. Castings are to be made at a manufacturer approved by the RBNA.

102. The steel is to be manufactured by a process approved by the RBNA.

103. 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.

105. 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.

106. For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by the RBNA.

107. 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.

C3. QUALITY

100. Quality of castings [IACS UR W.8.3]

101. 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.

C4. CHEMICAL COMPOSITION

100. Chemical composition [IACS UR W.8.4]

101. 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.

102. 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.

103. For carbon and carbon-manganese steel castings the chemical composition is to comply with the overall limits given in Table T.C4.103.1 or, where applicable, the requirements of the approved specification.

TABLE T.C4.103.1 CHEMICAL COMPOSITION LIMITS FOR AND MACHINERY HULL 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

104. 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.

C5. HEAT TREATMENT

100. Heat treatment (including straightening) [IACS UR W.8.5]

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

a. Fully annealed

b. Normalized

c. Normalized and tempered

d. Quenched and tempered.

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

103. 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.

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

105. 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.

106. 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.

C6. MECHANICAL PROPERTIES

100. Mechanical properties [IACS UR W.8.7]

101. Table T.C6.101.1 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.

102. Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in T.C6.101.1 but subject to any additional requirements of the relevant construction Rules.

103. The mechanical properties are to comply with the requirements of Table T.C6.101.1 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

104. Re-test requirements for tensile tests are to be in accordance with Chapter A above.

105. The additional tests detailed in the present C6.104 above are to be taken, preferably from the same, but

alternatively from another, test sample representative of the casting or batch of castings.

106. 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 T.C6.101.1 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
(1) A tensile strength range of 150 *N/mm^2* may additionally be specified.			

C7. MECHANICAL TESTS IAC WR8.6

100. Mechanical tests

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

102. 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.

103. 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.

104. For castings where the method of manufacture has been specially approved by the RBNA in accordance with item C2.106, the number and position of test samples is to be agreed with the RBNA having regard to the method of manufacture employed.

105. As an alternative to item C3.102 above, 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.

106. 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.

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

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

C8. INSPECTIONS AND TESTS [ICACS UR W8 E REC 69]

100. Inspection [W.8.8]

101. 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.

102. 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.

103. When required by the relevant construction Rules, or by the approved procedure for welded composite components (see item C1.107 above), 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 RBNA. Sub-Chapter C4 above [IACS Recommendation No. 69] is an acceptable standard.

104. When required by the relevant RBNA Part II Sections 2 and 5 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.

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

106. 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.

107. 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.

108. When required by the relevant construction Rules, or by the approved procedure for welded composite components (see see Part III, Title 61, Section 2, Chapter C, item C1.107.), 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 Part III, Title 61, Section 2, Sub-Chapter C4 below [IACS Recommendation No. 69] which is an acceptable standard.

109. 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.

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

C9. RECTIFICATION OF DEFECTIVE CASTINGS [IACS UR W8.9 and Rec 69 sec 8]

100. General

101. The approval of the RBNA is to be obtained where steel castings from which defects were removed are to be used with or without weld repair.

102. 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.

103. 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.

104. Defects and unacceptable indications must be repaired as indicated below;

105. Defective parts of material may be removed by grinding, or by chipping and grinding, or by arc air-gouging and grinding. Thermal methods of metal removal should only be allowed before the final heat treatment. All grooves shall have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to that of the adjacent surface.

200. Weld repairs [W8.9.2]

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

a. Before welding is started, 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 approval.

b. 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.

c. 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.

d. 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 Part III, Title 61, Section 2, Chapter C.5 item 101.

e. After welding has been completed the castings are to be given either a suitable heat treatment in accordance with the requirements of Part III, Title 61, Section 2, Chapter C.5 item 101 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 .

f. Subject to the prior agreement of RBNA, 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.

g. 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.

C10. IDENTIFICATION

100. Identification of castings

101. 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.

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

a. Steel quality.

b. Identification number, cast number or other marking which will enable the full history of the casting to be traced.

c. Manufacturer's name or trade mark.

d. The RBNA's name, initials or symbol.

e. Abbreviated name of the RBNA's local office.

f. Personal stamp of Surveyors responsible for inspection.

g. Where applicable, test pressure.

103. Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the RBNA.

C11. CERTIFICATION

100. Certification

101. 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:

a. Purchaser's name and order number.

b. Description of castings and steel quality.

c. Identification number.

d. Steel making process, cast number and chemical analysis of ladle samples.

e. Results of mechanical tests.

f. Results of non-destructive tests, where applicable.

g. Details of heat treatment, including temperatures and holding times.

h. Where applicable, test pressure.

C12. NON-DESTRUCTIVE EXAMINATION OF MARINE STEEL CASTINGS (HULL) [IACS REC69]

100. Scope

101. This Subchapter C12 is intended to give general guidance on the extent, methods and recommended quality levels applicable to the non-destructive examinations (NDE), of marine steel castings, except in those cases where alternative criteria have been otherwise approved or specified.

102. Although no detailed guidelines are given for machinery components, the requirements in these guidelines may apply correspondingly considering their materials, kinds, shapes and stress conditions being subjected.

200. Personnel Requirements

201. Personnel carrying out NDE are generally to be qualified and certified to Level II of a recognised certification scheme such as EN 473, ISO9712 or SNT-TC-1A.

202. Personnel responsible for the NDE activity including approval of procedures should be qualified and certified to Level III.

203. Personnel qualifications are to be verified by certification.

300. Casting Condition

301. **Heat Treatment:** non-destructive examinations applied for acceptance purposes should be made after the final heat treatment of the casting. Where intermediate inspections have been performed the manufacturer shall furnish the documentation of the results upon request of the Surveyor.

302. **Surface Condition : c**astings are to be examined in the final delivery condition free from any material such as scale, dirt, grease or paint that might affect the efficacy of the inspection. A thin coating of contrast paint is permissible when using magnetic particle techniques.

303. Unless otherwise specified in the order, magnetic particle test shall be carried out within 0.3mm of the final machined surface condition for AC techniques or within 0.8mm for DC techniques.

304. Ultrasonic testing is to be carried out after the castings have been ground, machined or shot blasted to a suitable condition. The surfaces of castings to be examined should be such that adequate coupling can be

established between the probe and the casting and that excessive wear of the probe is avoided.

400. Extent of Examinations, Castings to be examined and Zones to be examined

401. Castings to be examined by NDE methods are identified in Figure F.C12.200 1 to 200.6 to this document. The list of castings is not definitive. Criteria for the examination of other castings not listed in Figure F.C9.200 1 t0 200.6 will be subject to agreement.

402. Zones to be examined in nominated castings are identified in Chapter C12 item 200 of the present. Examinations are to be made in accordance with an inspection plan approved by the RBNA. The plan should specify the extent of the examination, the examination procedure, the quality level or, if necessary, level for different locations of the castings.

403. In addition to the areas identified in Annex 1, surface inspections shall be carried out in the following locations:

a. at all accessible fillets and changes of section,

b. in way of fabrication weld preparati

c. on, for a band width of 30mm,

d. in way of chaplets,

e. in way of weld repairs,

f. at positions where surplus metal has been removed by flame cutting, scarifying or arc-air gouging.

404. Ultrasonic testing shall be carried out in the zones indicated in Annex 1 and also at the following locations:

a. in way of all accessible fillets and at pronounced changes of section, - in way of fabrication weld preparations for a distance of 50mm from the edge,

b. in way of weld repairs where the original defect was detected by ultrasonic testing.

c. in way of riser positions,

d. in way of machined areas particularly those subject to further machining such as bolt hole positions.

405. In the case of castings such as rudder horns, which may have a large surface area still untested after the above inspections have been applied, an additional ultrasonic inspection of the untested areas should be made along continuous perpendicular grid lines on nominal 225 mm centres, scanning from one surface only.

500. Examination Procedures

501. **Visual inspection**:

a. Steel castings nominated for NDE shall be subjected to a 100% visual examination of all accessible surfaces by the Surveyor. Lighting conditions at the inspected surfaces shall be in accordance with a nationally or internationally recognised standard. Unless otherwise agreed, the visual and surface crack detection inspections are to be carried out in the presence of the Surveyor.

502. **Surface crack detection**:

a. The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to comply with recognised national or international standards. Magnetic particle inspection will be carried out in preference to liquid penetrant testing except in the following cases;

a.1. austenitic stainless steels,

a.2. interpretation of open visual or magnetic particle indications,

a.3. at the instruction of the Surveyor.

b. For magnetic particle testing attention is to be paid to the contact between the casting and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage in its surface. Prods shall not be permitted on finished machined items. Note that the use of solid copper at the prod tips must be avoided due to the risk of copper penetration.

c. When indications have been detected as a result of the surface inspection, acceptance or rejection is to be decided in accordance with Section 6.

505. **Volumetric inspection**

a. In accordance with the present Subchapter C12 is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique. The testing procedures, apparatus and conditions of ultrasonic testing are to comply with the recognised national or international standards. Radiographic testing may be carried out on the basis of prior agreement with the RBNA.

b. Only those areas shown in the agreed inspection plan need to be tested. The plan should include those locations nominated in C12.404 together with the scanning zones identified for the relevant casting in Annex 1.

c. Ultrasonic scans are to be made using a 0o probe of 1 - 4MHz (usually 2MHz) frequency. Whenever possible scanning is to be performed from both

surfaces of the casting and from surfaces perpendicular to each other.

d. The backwall echo obtained on parallel sections should be used to monitor variations in probe coupling and material attenuation. Any reduction in the amplitude of the back wall echo without evidence of intervening defects should be corrected. Attenuation in excess of 30dB/m could be indicative of an unsatisfactory annealing heat treatment.

e. Machined surfaces, especially those in the vicinity of riser locations and in the bores of stern boss castings, should also be subject to a near surface (25mm) scan using a twin crystal 0o probe. Additional scans on machined surfaces are of particular importance in cases where bolt holes are to be drilled or where surplus material such as 'padding' has been removed by machining thus moving the scanning surface closer to possible areas of shrinkage. Also, it is advisable to examine the machined bores of castings using circumferential scans with 70^o probes in order that axial radial planar flaws such as hot tears can be detected. Fillet radii should be examined using 45^o, 60^o, or 70^o probes scanning from the surfaces/direction likely to give the best reflection.

f. In the examinations of those zones nominated for ultrasonic examination the reference sensitivity is to be established against a 6mm diameter disk reflector. Sensitivity can be calibrated either against 6mm diameter flat bottomed hole(s) in a reference block (or series of blocks) corresponding to the thickness of the casting provided that a transfer correction is made, or, as a preferred alternative, by using the DGS (distance-gain-size) method. The DGS diagrams issued by a probe manufacturer identify the difference in dB between the amplitude of a back wall echo and that expected from a 6mm diameter disk reflector. By adding this difference to the sensitivity level initially set by adjusting a back wall echo to a reference height eg 80%, the amended reference level will be representative of a 6mm diameter disk reflector. Similar calculations can be used for evaluation purposes to establish the difference in dB between a back wall reflector and disk reflectors of other diameters such as 12 or 15 mm.

600. Acceptance Criteria

601. Visual Testing

a. All castings shall be free of cracks, crack-like indications, hot tears, cold shuts or other injurious indications. Thickness of the remains of sprues or risers is to be within the casting dimensional tolerance.

b. Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor.

602. Surface Crack Detection:

a. The following definitions relevant to indications apply:

a.1. Linear indication = an indication in which the length is at least three times the width.

a.2. Non-linear indication = an indication of circular or elliptical shape with a length less than three times the width.

a.3. Aligned indication = three or more indications in a line, separated by 2mm or less edge-to-edge.

a.4. Open indication = an indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.

a.5. Non-open indication = an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.

a.6. Relevant indication = an indication that is caused by a condition or type of discontinuity that requires evaluation. Only the indications which have any dimension greater than 1.5mm shall be considered relevant.

b. For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 22500mm2 for level MT2/PT2. The band length and/or area shall be taken in the most unfavourable location relative to the indications being evaluated.

c. The following quality levels recommended for magnetic particle testing (MT) and/or liquid penetrant testing (PT) are;

c.1. Level MT1/PT1 - fabrication weld preparation and weld repairs; and

c.2. Level MT2/PT2 - other locations nominated for surface crack detection in C9.200.

d. The allowable numbers and sizes of indications in the reference band length and/or area are given in Table T.C3.706.1. The required quality level should be shown on the manufacturer's inspection plan. Cracks and hot tears are not acceptable.

TABLE T.C12.706.1 ALLOWABLE NUMBER AND SIZE OF INDICATIONS IN A REFERENCE BAND LENGTH/AREA

Quality level	Max. number of indications	Type of indication	Max number for each type	Max. dimension of single indication, mm^2
MT1 / PT1	4 in 150 mm length	Non-linear Linear Aligned	4 (1) 4 (1) 4 (1)	5 3 3
MT2 / PT2	20 in 22500 mm^2 area	Non-linear Linear Aligned	10 6 6	7 5 6
Note 1 – 10 mm minimum between relevant indications Note 2 – In weld repairs, the maximum dimension is 2 mm				

603. **Volumetric Testing**

a. Acceptance criteria for ultrasonic testing are identified in Table T.C4.801.1 as UT1 and UT2. As stated in C12.402 the quality levels applicable to the zones to be examined are to be identified on an inspection plan. The following quality levels are nominated for the castings identified in C9.200.

a.1. **Level UT1 is applicable to**:

i. fabrication weld preparations for a distance of 50mm,

ii. 50mm depth from the final machined surface including boltholes,

iii. fillet radii to a depth of 50mm and within distance of 50mm from the radius end,

iv. castings subject to cyclic bending stresses e.g. rudder horn, rudder castings and rudder stocks

v. the outer one third of thickness in the zones nominated for volumetric examination by C9.200,

vi. discontinuities within the examined zones interpreted to be cracks or hot tears.

a.2. **Level UT2 is applicable to:**

i. other locations nominated for ultrasonic testing in Annex 1 or on the inspection plan.

ii. positions outside locations nominated for level UT1 examination where feeders and gates have been removed.

iii. castings subject to cyclic bending stresses - at the central one third of thickness in the zones of nominated for volumetric inspection by C9.200.

b. Ultrasonic acceptance criteria for other casting areas not nominated in C9.200 will be subject to special consideration based on the anticipated stress levels and the type, size and position of the discontinuity.

TABLE T.C12.802.1 ULTRASONIC ACCEPTANCE CRITERIA FOR STEEL CASTINGS

Quality level	Available disc shape according to DGS [1] mm	Maximum number of indications to be registered [2]	Allowable length of linear indications [3]
UT1	4 in 150 mm length	Non-linear Linear Aligned	4 [1] 4 [1] 4 [1]
UT2	20 in 22500 mm^2 area	Non-linear Linear Aligned	10 6 6
Note 1 – DGS: distance-gain size Note 2: Grouped in an area measuring 300 x 300 mm Note 3: Measured on the scanning surface			

700. Reporting

701. General: all reports of non-destructive examinations should include the following items;

a. Date of testing.

b. Names and qualification level of inspection personnel.

c. Type of casting.

d. Product number for identification.

e. Grade of steel.

f. Heat treatment.

g. Stage of testing.

h. Locations for testing.

i. Surface condition.

j. Test standards used.

k. Results.

l. Statement of acceptance / non-acceptance.

m. Locations of reportable indications.

n. Details of weld repairs including sketches.

702. In addition to the items listed in C4.901, reports of surface crack detection inspections are to include at least the following items:

a. for liquid penetrant testing; the consumables used,

b. for magnetic particle testing: method of magnetising, test media and magnetic field strength.

703. In addition to the items listed in 7.1, reports of ultrasonic inspection should include at least the following items:

a. flaw detector, probes, calibration blocks and couplant used.

800. Rectification of defects

801. Defects and unacceptable indications must be repaired as indicated below. Defective parts of material may be removed by grinding, or by chipping and grinding, or by arc air-gouging and grinding. Thermal methods of metal removal should only be allowed before the final heat treatment. All grooves shall have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to that of the adjacent surface.

802. Weld repairs should be suitably classified. Major repairs are those;

a. where the depth is greater than 25% of the wall thickness or 25mm whichever is less,

b. where the total weld area on a casting exceeds 2% of the casting surface noting that where a distance between two welds is less than their average width, they are to be considered as one weld.

c. 203. Major repairs require the approval of the RBNA before the repair is carried out. The repair should be carried out before final furnace heat treatment.

803. Minor repairs are those where the total weld area (length x width) exceeds 500mm2. Minor repairs do not usually require the approval of the RBNA but should be recorded on a weld repair sketch as a part of the manufacturing procedure documents. These repairs should be carried out before final furnace heat treatment.

804. Cosmetic repairs are all other welds. Cosmetic repairs do not require the approval of the RBNA but should be recorded on a weld repair sketch. These repairs

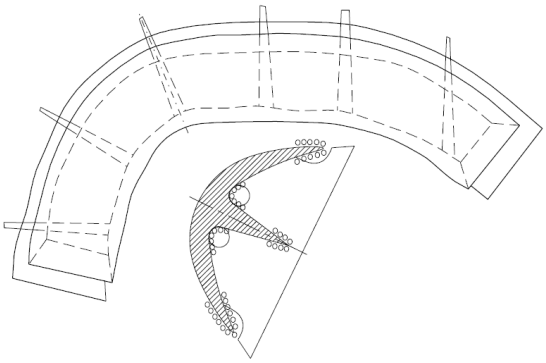
may be carried out after final furnace heat treatment but are subject to a local stress relief heat treatment.

805. As advised in IACS RULES UR W8 castings in carbon or carbon manganese steel may require pre-heating prior to welding and also a post weld stress relieving heat treatment depending upon their chemical composition and the dimensions and position of the weld repairs. Post weld heat treatment should be carried out at a temperature of not less than 550°C.

806. Castings subject to the removal of defects may be supplied without welding under the specific conditions;

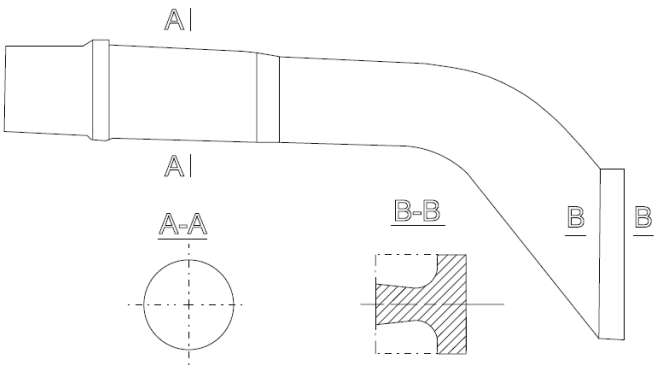
a. on un-machined surfaces where the depth of defect removal is not over 15mm or 10% of wall thickness, whichever is less, and the length of the removed part is not over 100 mm.

FIGURE F.C9.200.1 STERN FRAME



Notes: Location of non-destructive examination
1) All surfaces: Visual examination
2) Location indicated with (OOO): Magnetic particle and Ultrasonic testing
3) The detailed extents of examinations and quality levels are given C12.400 and C12.700below

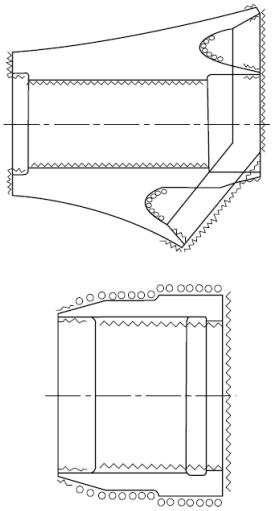
FIGURE F.C9.200.2 RUDDER STOCK



Notes: Location of non-destructive examination
1) All surfaces: Visual examination.
Magnatic particle and Ultrasonic testing.

2) The detailed extent of examinations and quality levels are given in sections C12.400 and C12.700

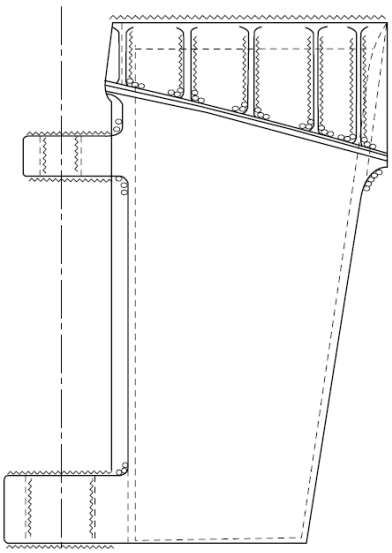
FIGURE F.C9.200.3 – STERN BOSS



Notes: Location of non-destructive examination

1) All surfaces: Visual examination
2) Location indicated with (OOO): Magnetic particle and Ultrasonic testing
3) Location indicated with (^^^^): Ultrasonic testing
4) The detailed extents of examinations and quality levels are given in Sections 4 and 6.

FIGURE F.C9.200.4 RUDDER HANGINGS

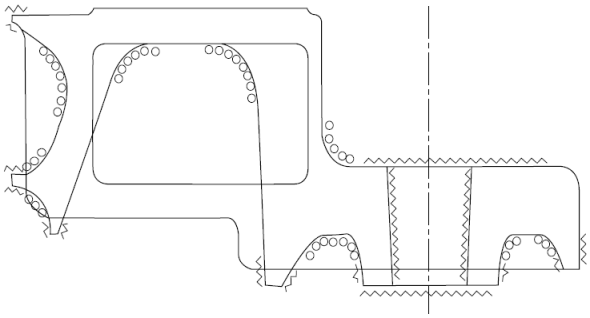


Notes: Location of non-destructive examination

1) All surfaces: Visual examination
2) Location indicated with (OOO): Magnetic particle and Ultrasonic testing
3) Location indicated with (^^^^): Ultrasonic testing

4) The detailed extent of examinations and quality levels are given in sections C12.400 and C12.700

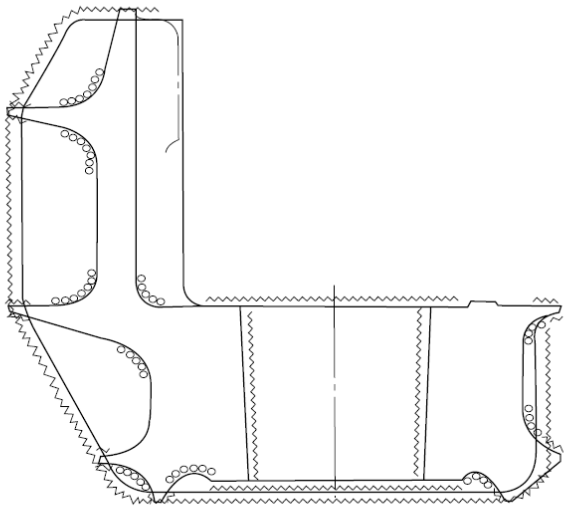
FIGURE F.C9.200.5 – RUDDER (UPPER PART)



Notes: Location of non-destructive examination

1) All surfaces: Visual examination
2) Location indicated with (OOO): Magnetic particle and Ultrasonic testing
3) Location indicated with (^^^^): Ultrasonic testing
4) The detailed extents of examinations and quality levels are given in Sections 4 and 6.

FIGURE F.C9.200.6 – RUDDER (LOWER PART)



Notes: Location of non-destructive examination

1) All surfaces: Visual examination
2) Location indicated with (OOO): Magnetic particle and Ultrasonic testing
3) Location indicated with (^^^^): Ultrasonic testing

4) The detailed extent of examinations and quality levels are given in sections C12.400 and C12.700

CHAPTER D
STEEL FORGINGS

CHAPTER CONTENTS

D1. SCOPE
[IACS W7]

100. Scope
[W7.1]

101. The requirements of the present Chapter D 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.

102. The requirements of the present Chapter D 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.

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

D2. MANUFACTURE

100. Manufacture
[W7.2]

101. Forgings are to be made at a manufacturer approved by the RBNA.

102. The steel used in the manufacture of forgings is to be made by a process approved by the RBNA.

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

104. 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.

105. Unless otherwise approved the total reduction ratio is to be at least:

a. for forgings made from ingots or from forged blooms or billets, 3:1 where L>D and 1.5:1 where L≤□D

b. for forgings made from rolled products, 4:1 where L>D and 2:1 where L≤□D

c. 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

d. for rolled bars, 6:1.

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

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

108. 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.

108. 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.

D3. QUALITY OF FORGINGS

100. Qualtityof forgings [W7.3]

101. All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

D.4 CHEMICAL COMPOSITION

100. Chemical composition [W7.4]

101. 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.

102. 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.

103. The chemical composition is to comply with the overall limits given in Table T.D4.103.1 or, where applicable, the requirements of the approved specification.

104. 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.

105. 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 T.D4.103.1 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 T.D4.103.1 CHEMICAL COMPOSITION LIMITS 1) FOR MACHINERY STEEL FORGINGS

Steel type	C	Si	Mn	P	S	Cr	Mo	Ni	Cu[3)]	Total residuais
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 range or as a minimum.

[2)] The carbon content of C and C-Mn steel forgings intended for welded construction is to be 0.23 maximum. The carbon content may be increased above this level provided that the carbon equivalent (Ceq) is not more than 0.41%.

[3)] Elements are considered as residual elements unless shown as a minimum.

[4)] Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by the Classification Society.

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

D5. HEAT TREATMENT (INCLUDING SURFACE HARDENING AND STRAIGHTENING)

100. Heat treatment [W7.5]

101. 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. Except as provided in item D5.106 and D5.107 forgings are to be supplied in one of the following conditions:

a. Carbon and carbon-manganese steels

a.1. Fully annealed

a.2. Normalized

a.3. Normalized and tempered

a.4. Quenched and tempered

b. Alloy steels

c. Quenched and tempered

102. 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.

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

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

105. If for any reasons a forging is subsequently heated for further hot working the forging is to be reheat treated. Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for the approval of the RBNA. 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.

106. 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.

107. 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.

108. 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.

109. 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.

D6. MECHANICAL TESTS [IACS W7.6]

100. Mechanical Tests

101. 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 D6.208 and D6.210. Where batch testing is permitted according to D6.210, 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.

a. In the cases of very small forgings of less than 120 kg weight each, where the procedures contained in the present instructions turn out to be impractical, when a special forging may be made for the purpose of obtaining test specimens provided the following conditions are fulfilled:

a.1. the forgings should be representative of the forgings under approval, to the satisfaction of the surveyor;

a.2. the sample forgings should be subjected to the same amount of working and reduction, and heat treated, in the same way as the forging under approval.

b. Where batch testing is permitted according to 2.11, 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.

102. 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.

103. 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.

104. 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.

104. 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.

105. Except as provided in D6.210 the number and direction of tests is to be as follows:

a. 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 Figure F.D6.105.4). 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. F.D6.105.4). If however, the journal diameter is 200mm or less the tests are to be taken in a longitudinal direction (test position A in Fig. F.6.105.4). Where the finished length of the toothed portion exceeds 1.25m, one set of tests is to be taken from each end.

b. 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. F.D6.105.4).

c. Gear wheels One set of tests is to be taken from each forging in a tangential direction (test position A or B in F.D6.105.5).

d. 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 F.D6.105.6). 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 F.D6.105.4). The mechanical properties for longitudinal test are to be applied.

e. Pinion sleeves, shaft sleeves and rudder bearings.

f. One set of tests is to be taken from each forging in a tangential direction (test position A or B in F.D6.105.7). Where the finished length exceeds 1.25m one set of tests is to be taken from each end.

g. Crankwebs.

h. One set of tests is to be taken from each forging in a tangential direction.

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 F.D6.105.8)

106. 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 F.D6.105.8). 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 F.D6.105.8).

FIGURE F.D6.105.1 – PLAIN SHAFT

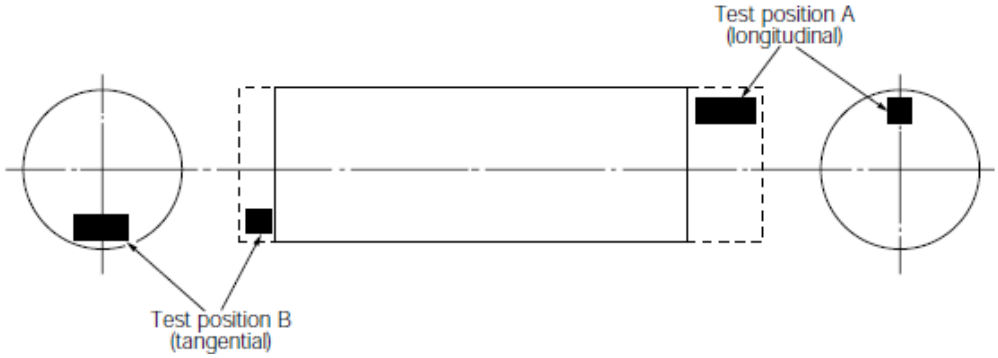


FIGURE F.D6.105.2 – FLANGED SHAFT

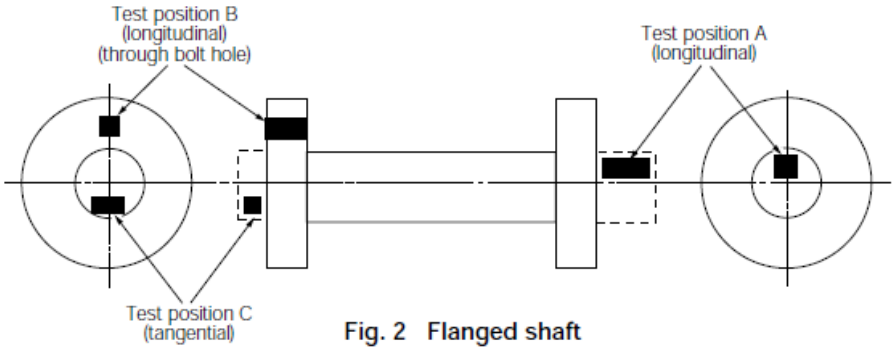
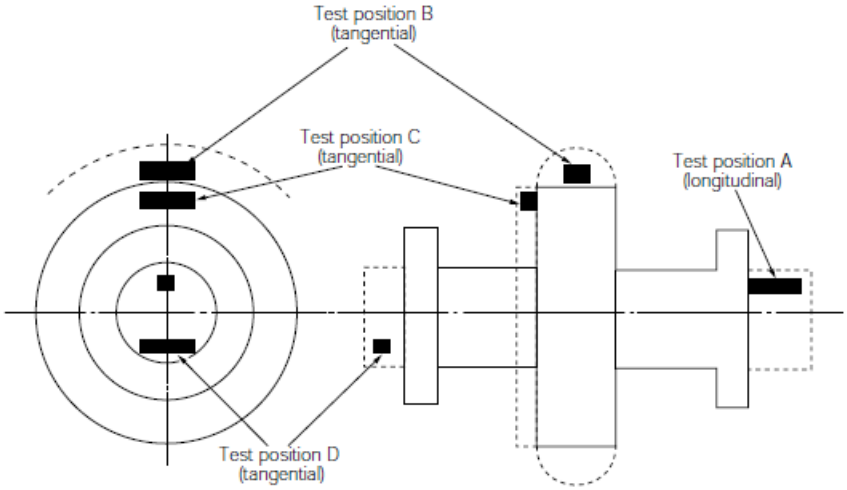


Fig. 2 Flanged shaft

FIGURE F.D6.105.3 – FLANGED SHAFT WITH COLLAR



207. For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with D2.106, the number and position of test specimens is to be agreed with the RBNA having regard to the method of manufacture employed.

208. 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.

209. 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.

FIGURE F.D6.105.4 – PINION

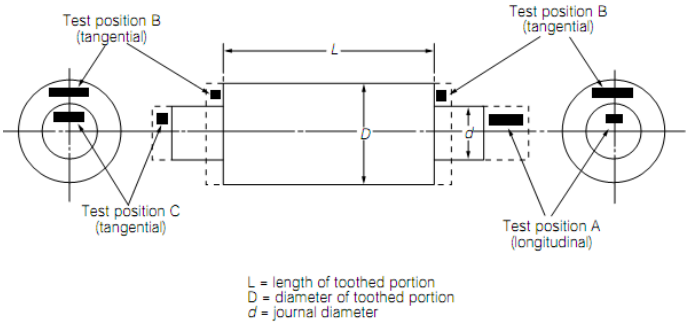


FIGURE F.D6.105.5 – GEAR WHEEL

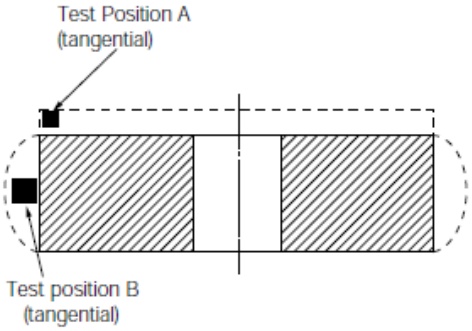


FIGURE F.D6.105.6 – GEAR REIM (MADE BY EXPANDING)

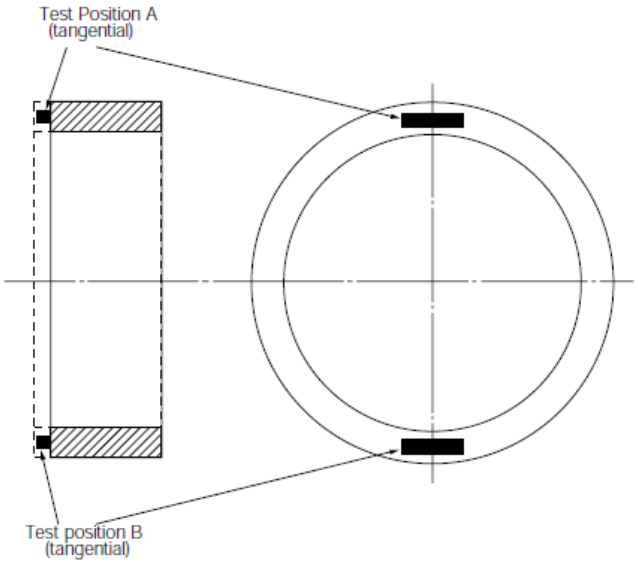


FIGURE F.D6.105.7 – PINION SLEEVE

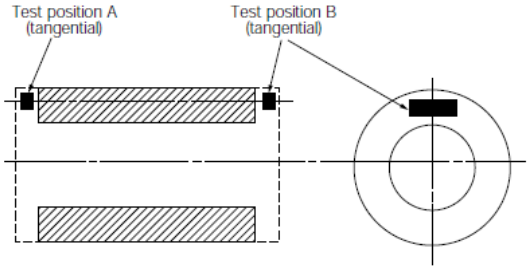
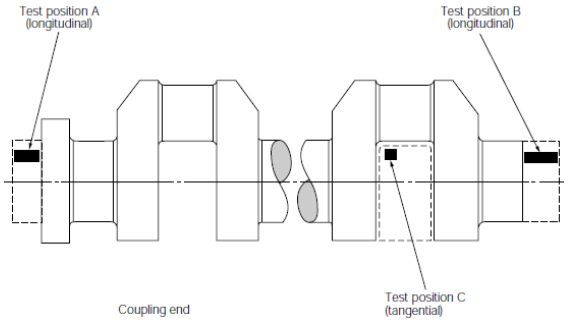


FIGURE F.D6.105.8 – SOLID FORGED CHANKSHAFT



210. 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 D6.105, except that irrespective of the dimensions or mass of the forging, tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction. This test material is to be machined to a diameter of D/4 or 60mm, whichever is less, where D is the finished diameter of the toothed portion. For preliminary tests at the forge one set of test material is to be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the second set of test material is to be blank carburized and heat treated along with the forgings which they represent. At the discretion of the forgemaster or gear manufacture test samples of larger cross section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment. Alternative procedures for testing of forgings which are to be carburized may be specially agreed with the RBNA.

211. 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.

D7. MECHANICAL PROPERTIES [IACS W7.7]

100. Mechanical Properties

101. Table T.D7.101.1 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.

102. Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table T.D7.101.1 but subject to any additional requirements of the relevant construction Rules.

103. The mechanical properties are to comply with the requirements of T.D7.101.1 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

104. Hardness tests may also be required on forgings which have been induction hardened, nitride 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 D5.105).

105. Re-test requirements for tensile tests are to be in accordance with Part III, Title 61, Sub-Chapter A3.

106. Re-test requirements for Charpy impact tests are to be in accordance with Part III, Title 61, Sub-Chapter A3.

107. The additional tests detailed in D6.105 and D5.106 above 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.

108. 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 T.D7.101.1- MECHANICAL PROPERTIES FOR MACHINERY 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. %		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 ^oC 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.

110. For main propulsion shaft the tension is not to exceed 800 N/mm^{2}in. Nevertheless, in Table T.D7.101.1. showing a boundary between 800-950 N/mm^2 is acceptable.

111. For applications in other machinery items other than propulsion shafts the tensile resistance is not to exceed 1100 N/mm^2, nonetheless values between 1100-1300 N/mm^2 may be accepted.

112. For shafts destined for ships having additional class notation ICE Class and when the fitting between the propeller and the shaft is by means of a key, a set of three Charpy V-impact tests (longitudinal) is to be carried out at the propeller end of the shaft at a temperature of -10°C the value for the average energy being 27 J.

D.8. INSPECTION [IACS W7.8]

100. Inspection

101. 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.

102. When required by the relevant construction Rules, or by the approved procedure for welded composite components (see D2.108) appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer.

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

104. When required by the conditions of approval for surface hardened forgings (D5.105 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.

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

D9. RECTIFICATION OF DEFECTIVE FORGINGS [IACS W7.9]

100. Rectification of defective forgings

101. 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.

102. Repair welding of forgings except crankshaft forgings may be permitted subject to prior approval of the RBNA. 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.

103. 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.

D10. IDENTIFICATION OF FORGINGS [IACS W7.10]

100. Identification of forgings

101. 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.

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

a. Steel quality.

b. Identification number, cast number or other marking which will enable the full history of the forging to be traced.

c. Manufacturer's name or trade mark.

d. The RBNA's name, initials or symbol.

e. Abbreviated name of the RBNA's local office.

f. Personal stamp of Surveyor responsible for inspection.

103. Where small forgings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the RBNA.

D11. CERTIFICATION [IACS W7.11]

100. Certification

101. 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:

a. Purchaser's name and order number.

b. Description of forgings and steel quality.

c. Identification number.

d. Steelmaking process, cast number and chemical analysis of ladle sample.

e. Results of mechanical tests.

f. Results of non-destructive tests, where applicable.

g. Details of heat treatment, including temperature and holding times.

D12. GUIDELINES FOR NON-DESTRUCTIVE EXAMINATION OF MACHINERY STEEL FORGINGS [IACS Rec 68]

100. Scope

101. These guidelines complement the requirements of the Chapter D ("Hull and machinery steel forgings") and Chapter D13 ("Parts of internal combustion engines for which non-destructive tests are required"), and contain general guidance for the non-destructive examination methods, the extent of examination and the minimum recommended quality levels to be complied with unless otherwise approved or specified.

102 This document contains guidelines on "Surface Inspections" (D12.200) by visual examination, magnetic particle testing and liquid penetrant testing and "Volumetric Inspection" (D12.300) by ultrasonic testing.

103 For steel forgings (e.g. components for couplings, gears, boilers and pressure vessels) other than those specified in these guidelines, the requirements in these guidelines may apply correspondingly considering their materials, kinds, shapes and stress conditions being subjected.

104 Forgings should be examined in the final delivery condition. For specific requirements see paragraphs D12.209 and D12.307.

105 Where intermediate inspections have been performed the manufacturer shall furnish a documentation of the results upon the request of the Surveyor.

106 Where a forging is supplied in semi finished condition, the manufacturer shall take into consideration the quality level of final finished machined components.

200. Surface Inspections

201. General: Surface inspections in these guidelines are to be carried out by visual examination and magnetic particle testing or liquid penetrant testing.

202. The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to comply with the recognized national or inter-national standards.

203. Personnel engaged in visual examination is to have sufficient knowledge and experience. Personnel engaged in magnetic particle testing or liquid penetrant testing is to be qualified in accordance with the Society's Rules. The qualification is to be verified by certificates.

204. **Products:** The steel forgings specified in Chapter D shall be subjected to a 100% visual examination by the Surveyor. For mass produced forgings the extent of examination is to be established at the discretion of the individual Society.

205. Surface inspections by magnetic particle and/or liquid penetrant methods generally apply to the following steel forgings:

a. crankshafts with minimum crankpin diameter not less than 100 mm;

b. propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 100 mm;

c. connecting rods, piston rods and crosshead with minimum diameter not less than 75 mm or equivalent cross section,

d. bolts with minimum diameter not less than 50 mm, which are subjected to dynamic stresses such as cylinder cover bolts, tie rods, crankpin bolts, main bearing bolts, propeller blade fastening bolts.

206. **Zones for Surface Inspections**. Magnetic particle or where permitted liquid penetrant testing, shall be carried out in the zones I and II as indicated in Figures D12.208.1 to D12.208.4.

207. **Surface Condition.** The surfaces of forgings to be examined are to be free from scale, dirt, grease or paint.

208. **Surface Inspection.** Where indicated by Figures F.D12.208.1 to F.D12.208.4 magnetic particle inspection will be carried out with the following exceptions, when liquid penetrant testing will be permitted:

a. austenitic stainless steels;

b. interpretation of open visual or magnetic particle indications,

c. at the instruction of the Surveyor.

209. Unless otherwise specified in the order, the magnetic particle test shall be performed on a forging in the final machined surface condition and final thermally treated condition or within 0.3 mm of the final machined surface condition for AC techniques (0.8mm for DC techniques).

210. Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor. The surface inspection is to be carried out before the shrink fitting, where applicable.

211. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetization benches in order to avoid local overheating or burning damage in its surface. Prods shall not be permitted on finished machined items.

212. When indications were detected as a result of the surface inspection, acceptance or rejection is to be decided in accordance with clause D12.213-D12.

213 **Acceptance Criteria Visual Inspection of Defects.** All forgings shall be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, liquid penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

214. The bores of hollow propeller shafts are to be visually examined for imperfections uncovered by the machining operation. Machining marks are to be ground to a smooth profile.

215. **Acceptance criteria magnetic particle testing and liquid penetrant testing.**

216. The following definitions relevant to indications apply:

a. Linear indication - an indication in which the length is at least three times the width;

b. Nonlinear indication - an indication of circular or elliptical shape with a length less than three times the width;

c. Aligned indication - three or more indications in a line, separated by 2mm or less edge-to-edge;

d. Open indication - an indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant;

e. Non-open indication - an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant,

f. Relevant indication - an indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5mm shall be considered relevant.

217. For the purpose of evaluating indications, the surface is to be divided into reference areas of 225cm$^{2.}$. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

218. The allowable number and size of indications in the reference area is given in table T.D12.218.1 for crankshaft forgings and in table T.D12.218.2. for other forgings, respectively. Cracks are not acceptable. Irrespective of the results of non-destructive examination, the Surveyor may reject the forging if the total number of indications is excessive table T.D12.218.1 . Crankshaft forgings: Allowable number and size of indications in a reference area of 225cm^2.

TABLE T.D12.218.1 CRANKSHAFT FORGINGS ; ALLOWABLE NUMBER AND SIZE OF INDICATIONS IN A REFERENCE AREA OF 225CM^2

Inspection Zone	Max. number of indications	Type of indication	Max. number for each type	Max. dimension (mm)
I (critical fillet area)	0	Linear Nonlinear Aligned	0 0 0	- - -
II (important filet area)	3	Linear Nonlinear Aligned	0 3 0	- 3.0 -
III (journal surfaces)	3	Linear Nonlinear Aligned	0 3 0	- 5.0 -

TABLE T.D12.218.2. STEEL FORGINGS EXCLUDING CRANKSHAFT FORGINGS; ALLOWABLE NUMBER AND SIZE OF INDICATIONS IN A REFERENCE AREA OF 225CM2

Inspection Zone	Max. number of indications	Type of indication	Max. number for each type	Max. dimension (mm)
I	3	Linear Nonlinear Aligned	0[1)] 3 0[1)]	- 3.0 -
II	10	Linear Nonlinear Aligned	3[1)] 7 3[1)]	3.0 5.0 3.0

Note:
[1)] Linear or aligned indications are not permited on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts, cylinder cover bolts.

219. **Rectification of Defects.** Defects and unacceptable indications must be rectified as indicated below and detailed in D12.220 thru D12.226

a. Defective parts of material may be removed by grinding, or by chipping and grinding. All grooves shall have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to the adjacent surface.

b. To depress is to flatten or relieve the edges of a non-open indication with a fine pointed abrasive stone with the restriction that the depth beneath the original surface shall be 0.08mm minimum to 0.25mm maximum and that the depressions be blended into the bearing surface. A depressed area is not considered a groove and is made only to prevent galling of bearings.

c. Non-open indications evaluated as segregation need not be rectified.

d. Complete removal of the defect is to be proved by magnetic particle testing or penetrant testing, as appropriate.

e. Repair welding is not permitted for crankshafts. Repair welding of other forgings is subjected to prior approval of RBNA.

220. Zone I in crankshaft forgings. Neither indications nor repair are permitted in this zone.

221. Zone II in crankshaft forgings. Indications must be removed by grinding to a depth no greater than 1.5mm.

222. Indications detected in the journal bearing surfaces must be removed by grinding to a depth no greater than 3.0mm. The total ground area shall be less than 1% of the total bearing surface area concerned.

223. Non-open indications, except those evaluated as segregation, shall be depressed but need not be removed.

224. Zone I in other forgings. Indications must be removed by grinding to a depth no greater than 1.5mm. However, grinding is not permitted in way of finished machined threads.

225. Zone II in other forgings. Indications must be removed by grinding to a depth no greater than 2% of the diameter or 4.0mm, whichever is smaller.

226. Zones other than I and II in all forgings. Defects detected by visual inspection must be removed by grinding to a depth no greater than 5% of the diameter or 10mm, whichever is smaller. The total ground area shall be less than 2% of the forging surface area.

227. **Record.** Test results of surface inspections are to be recorded at least with the following items:

a. Date of testing;

b. Names and qualification level of inspection personnel;

c. Kind of testing method;

c.1. for liquid penetrant testing : test media combination

c.2. for magnetic particle testing : method of magnetizing, test media and magnetic field strength

a. Kind of product;

b. Product number for identification;

c. Grade of steel;

d. Heat treatment;

e. Stage of testing;

f. Position (zone) of testing;

g. Surface condition;

h. Test standards used;

i. Testing condition;

j. Results;

k. Statement of acceptance/non acceptance,

l. Details of weld repair including sketch;

300. Volumetric Inspection

301. Volumetric inspection in these guidelines is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique.

302. The testing procedures, apparatus and conditions of ultrasonic testing are to comply with the recognized national or international standards. Generally the DGS(distance-gain size) procedure is to be applied using straight beam probes and/or angle beam probes with 2 to 4 MHz and inspection should be carried out using a twin crystal 0o probe for near surface scans (25mm) plus an 0o probe for the remaining volume. Fillet radii should be examined using 45^o, 60^o or 70^o probes.

303. Personnel engaged in ultrasonic testing is to be qualified in accordance with the Society's Rules. The qualification is to be verified by certificates.

304. **Products.** Volumetric inspections by ultrasonic testing generally apply to the following steel forgings:

a. crankshaft with minimum crankpin diameter not less than 150mm;

b. propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 mm,

c. connecting rods, piston rods and crosshead with minimum diameter not less than 200mm or equivalent cross section.

305**. Zones for Volumetric Inspection.** Ultrasonic testing shall be carried out in the zones I to III as indicated in Figures F.D12.305.1 to F.D12.305.4. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

306. **Surface Condition.** The surfaces of forgings to be examined are to be such that adequate coupling can be established between the probe and the forging and that excessive wear of the probe can be avoided. The surfaces are to be free from scale, dirt, grease or paint.

307. The ultrasonic testing is to be carried out after the steel forgings have been machined to a condition suitable for this type of testing and after the final heat treatment, but prior to the drilling of the oil bores and prior to surface hardening. Black forgings shall be inspected after removal of the oxide scale by either flame descaling or shot blasting methods.

308. **Acceptance Criteria.** Acceptance criteria of volumetric inspection by ultrasonic testing are shown in Table T.D12.308.1 and Table T.D12.308.2.

309. **Record.** Test results of volumetric inspection are to be recorded at least with the following items:

a. Date of testing;

b. Names and qualification level of inspection personnel;

c. Kind of testing method;

d. Kind of product;

e. Product number for identification;

f. Grade of steel;

g. Heat treatment;

h. Stage of testing;

i. Position (zone) of testing;

j. Surface condition;

k. Test standards used;

l. Testing condition;

m. Results,

n. Statement of acceptance/non acceptance;

TABLE T.D12.308.1. - ACCEPTANCE CRITERIA FOR CRANKSHAFTS

Type of forging	Zone	Allowable disc shape according to DGS [1)]	Allowable length of indication	Allowable distance between two indications[2)]
Crank shaft	I	d ≤ 0.5 mm	-	-
	II	d ≤ 2.0 mm	≤ 10 mm	≥20 mm
	III	d ≤ 4.0 mm	≤ 15 mm	≥20 mm

Notes:
1) DGS: distance-gain size
2) In case of accumulations of two or more isolated indications which are subjected to registration the minimum distance between two neighbouring indication must be at least the length of the bigger indication.

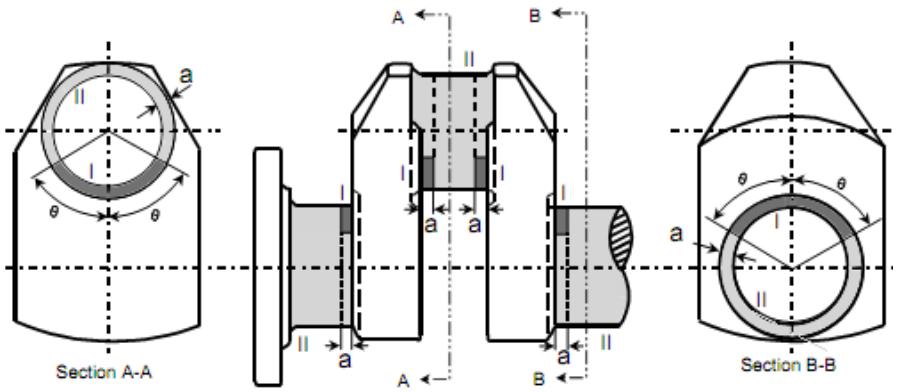
This applies as well to the distance in axial dirction as to the distance in depth. Isoalted indications with less distance are to be determined as one single indication.

TABLE T.D12.308.2. - ACCEPTANCE CRITERIA FOR SHAFTS AND MACHINERY COMPONENTS

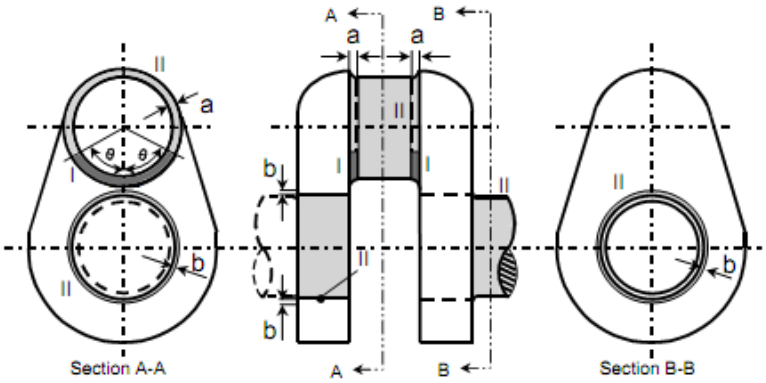
Type of forging	Zone	Allowable disc shape according to DGS [1)2)]	Allowable length of indication	Allowable distance between two indications[3)]
Propeller shaft intermediate shaft	II	outer d ≤ 2 mm inner d≤ 4 mm	≤ 10 mm ≤ 15 mm	≥20 mm ≥20 mm
Thrust shaft Rudder stock	III	outer d ≤ 3 mm inner d≤ 6 mm	≤ 10 mm ≤ 15 mm	≥20 mm ≥20 mm
Connecting rod Piston rod Crosshead	II	d ≤ 2 mm	-≤ 10 mm	-≥20 mm
	III	d ≤ 4 mm	≤ 10 mm	≥20 mm

Notes:
1) DGS: distance-gain size
2) Outer part means the part beyond one third of the shaft radius from the center, the inner part means the remaining core area.
3) In case of accumulations of two or more isolated indications which are subjected to registration the minimum distance between two neighbouring indication must be at least the length of the bigger indication.

FIG F.D12.208.1. ZONES FOR MAGNTETIC PARTICLE/LIQUID PENTRANT TESTING ON CRANKSHAFTS



(a) Solid crankshaft



(b) Semi built-up crankshaft

Notes)

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil holes are to be treated as Zone I . (See the figure in the right.)
2. In the above figures, "θ", " a" and "b " mean:
   θ = 60°
   a = 1.5 r
   b = 0.05 d (: circumferential surfaces of shrinkage fit)
   where,
   r : fillet radius
   d : journal diameter
3. Identification of the Zones (Similar in Figs. 1 thru 4) :
   : Zone I
   : Zone II

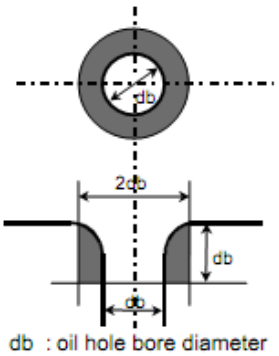
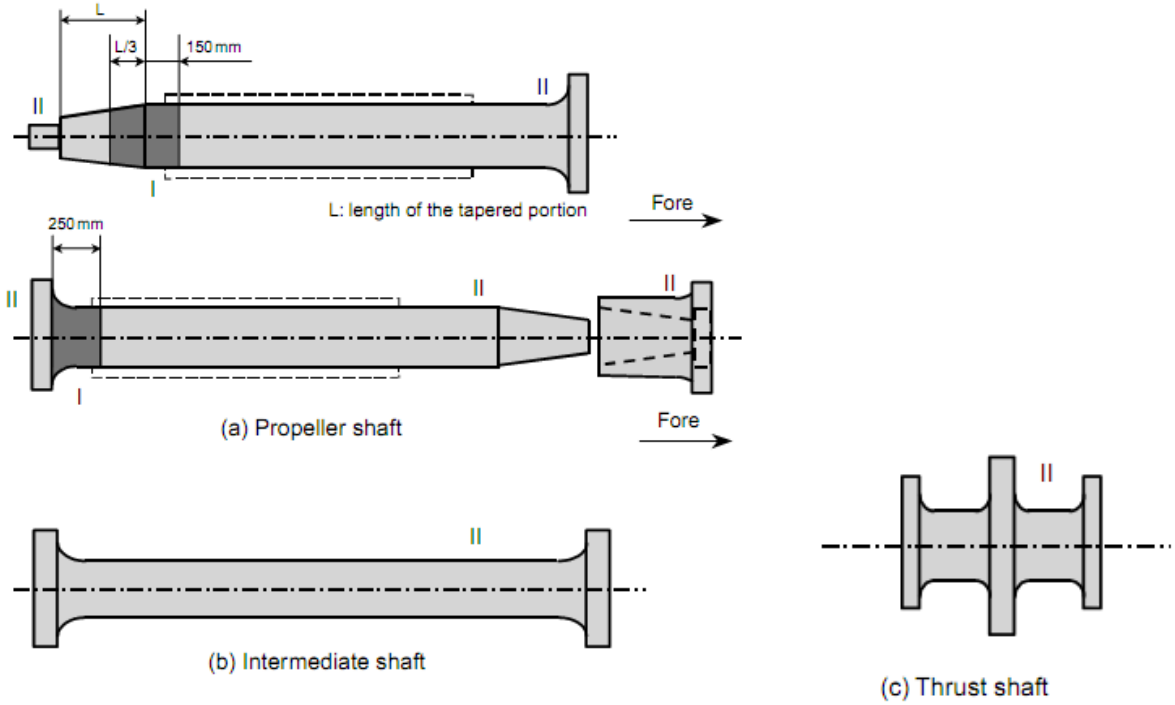
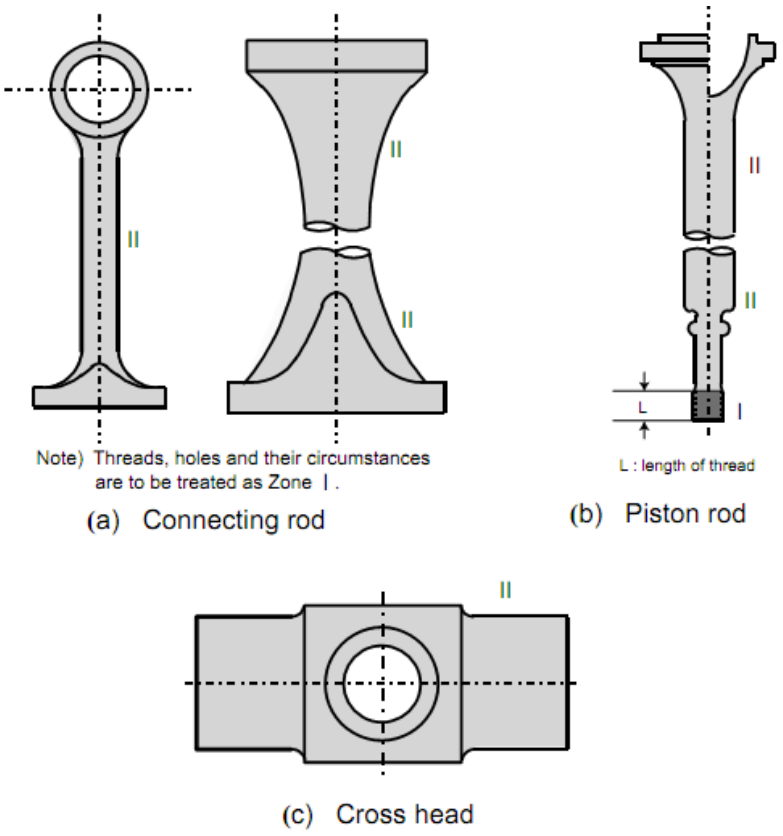


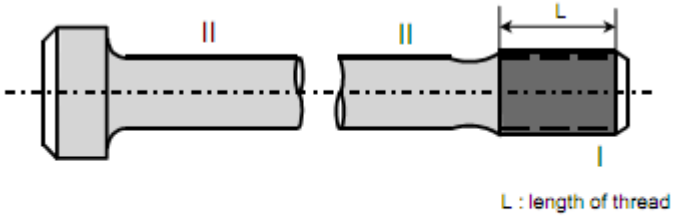
FIGURE F.D12.208.2 ZONES FOR MAGNTETIC PARTICLE/LIQUID PENTRANT TESTING ON SHAFTS



Note: For propeller shaft intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be threated as Zone I

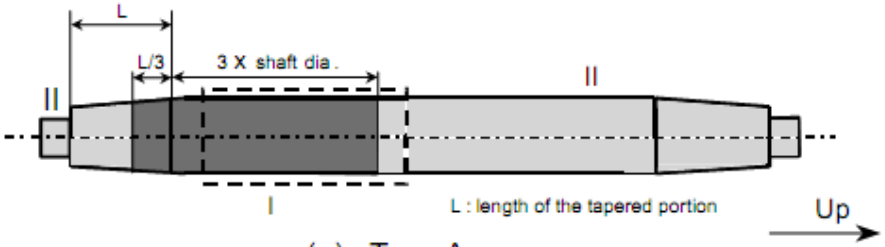
FIGURE F.D12.208.3 ZONES FOR MAGNETIC PARTICLE/ LIQUID TESTING ON MACHINERY COMPONENTS



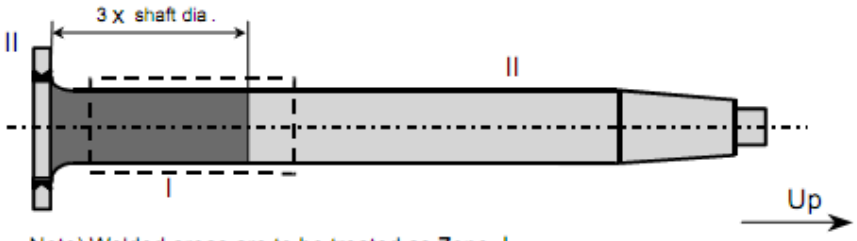


(d) Bolt

FIGURE F.D12.208.4 ZONES FOR MAGNETIC PARTICLE/LIQUID PENETRANT TESTING ON RUDDER STOCK

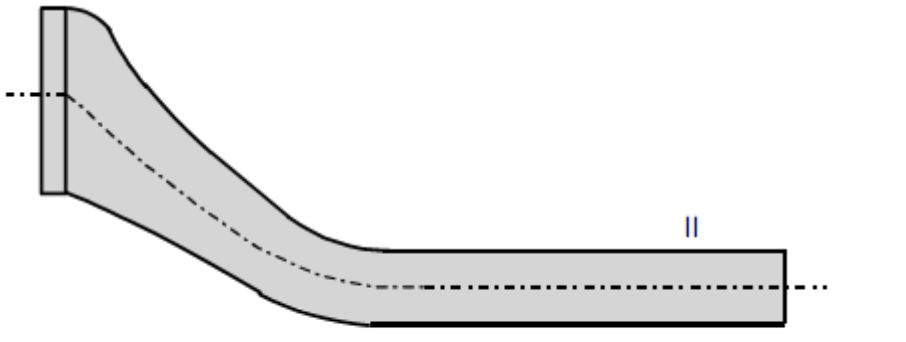


(a) Type A



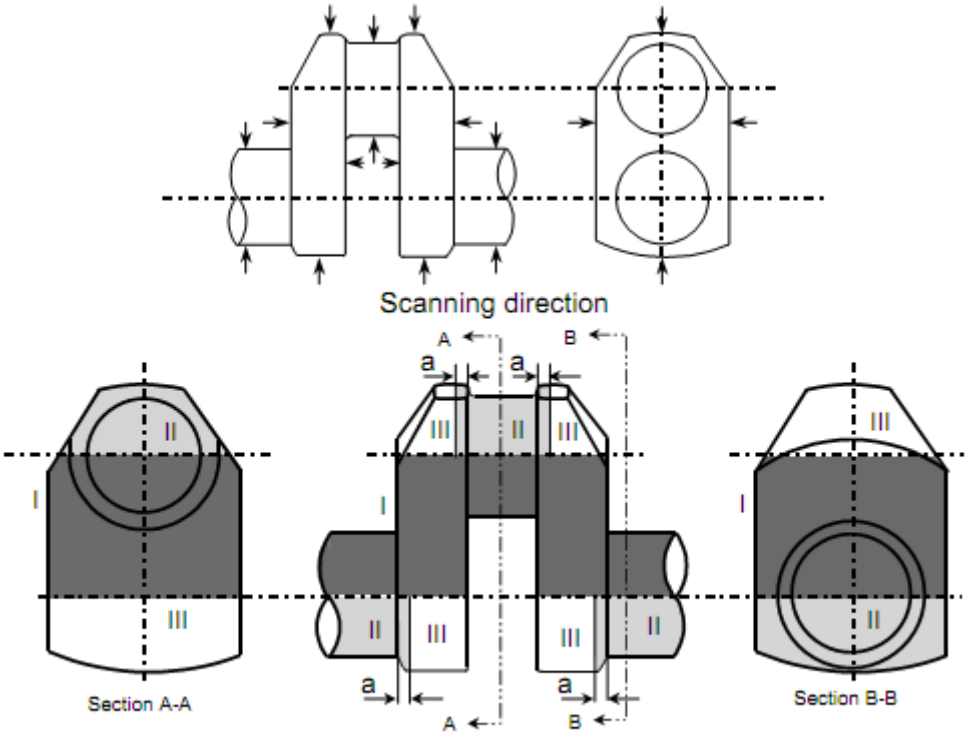
Note) Welded areas are to be treated as Zone I .

(b) Type B

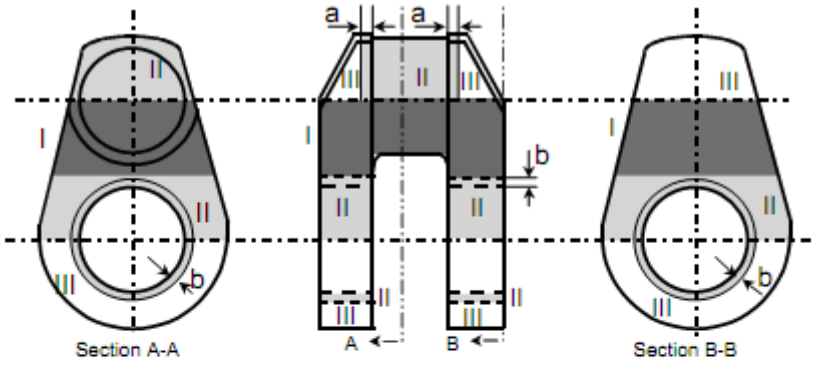


(c) Type C

FIGURE F.D12.305.1. ZONES FOR ULTRASONIC TESTING ON CRANKSHAFTS



(a) Solid crankshaft

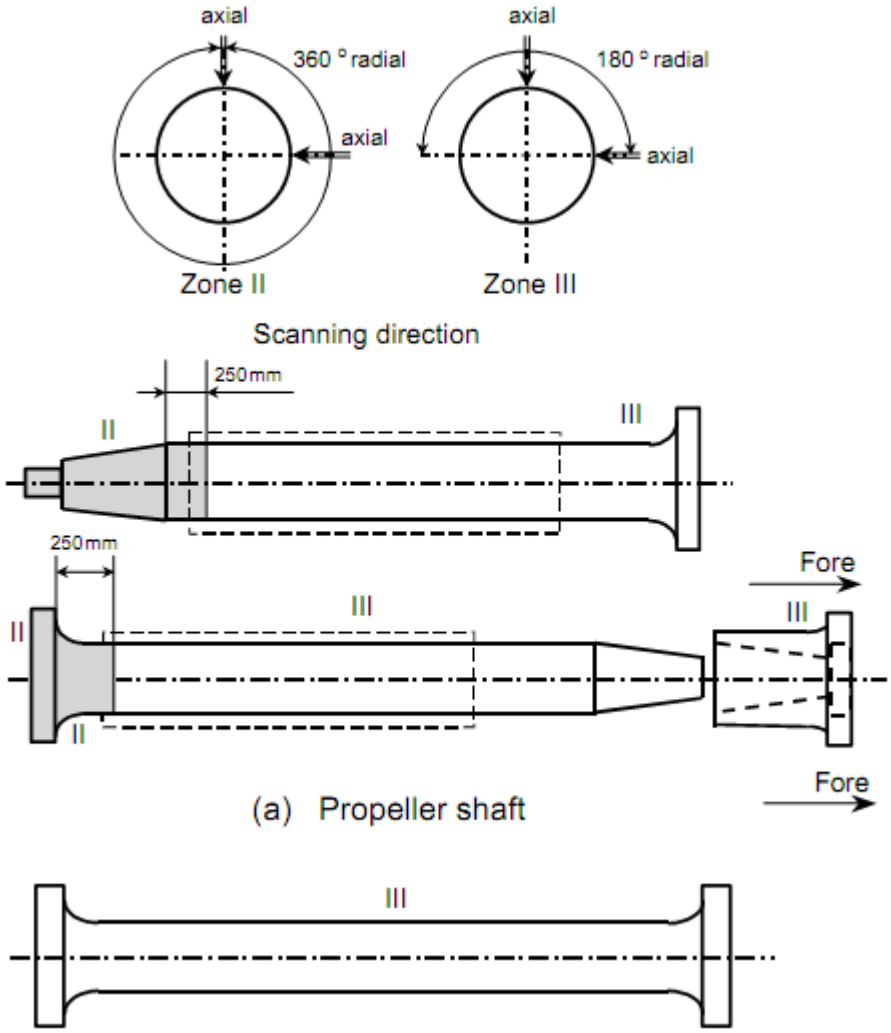


(b) Semi built-up crankshaft

Notes)

1. In the above figures, "a" and "b" mean:
   a = 0.1d or 25mm, whichever greater
   b = 0.05 d or 25mm, whichever greater (: circumstances of shrinkage fit)
   where,
   d : pin or journal diameter
2. Core areas of crank pins and/or journals within a radius of 0.25d between the webs may generally be coordinated to Zone II .
3. Identification of the Zones (Similar in Figs. 5 thru 8.) :
   : Zone I
   : Zone II
   : Zone III

FIGURE F.D12.305.2 ZONES FOR ULTRASONIC TESTING ON SHAFTS

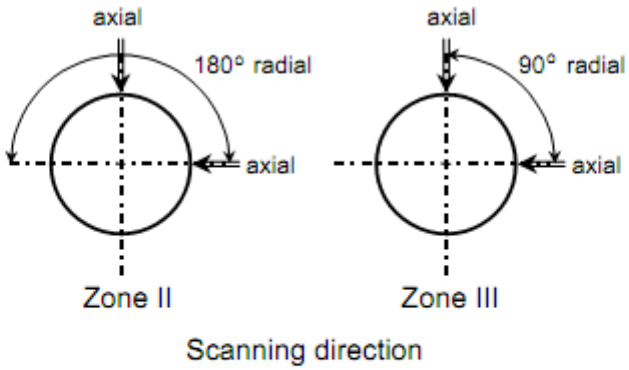


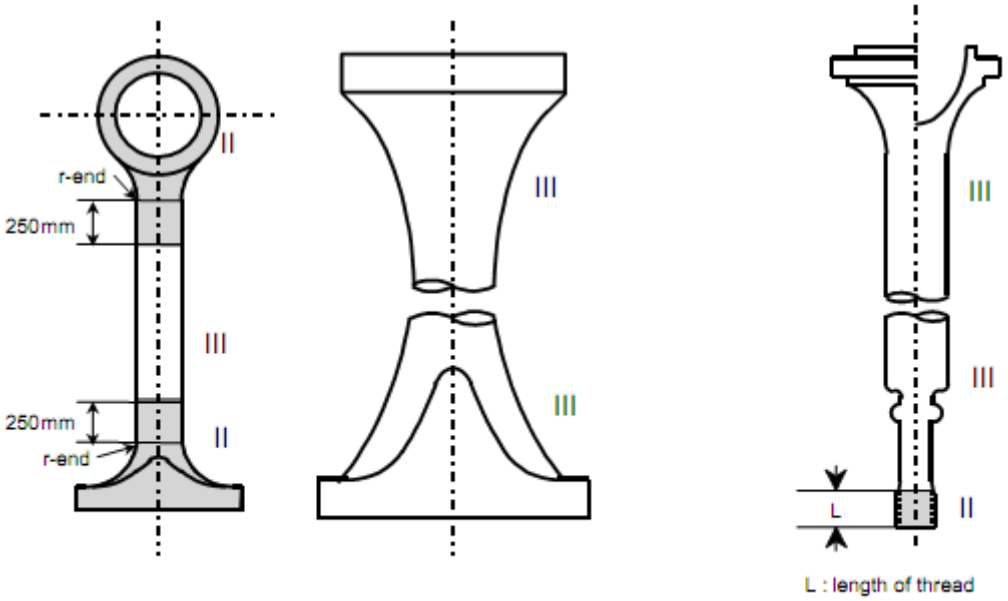
Notes:

1) For hollow shafts, 360 ° radial scanning applies to Zone III

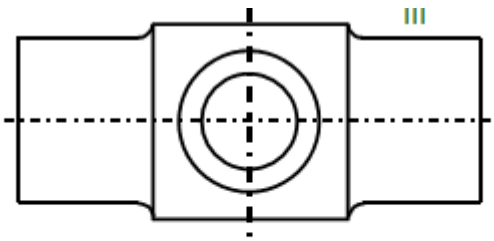
2) Circumferences of the bolt holes in the flanges are to be treated as Zone II

FIGURE F.D12.305.3 ZONES FOR ULTRASONIC TESTING ON MACHINERY COMPONENTS



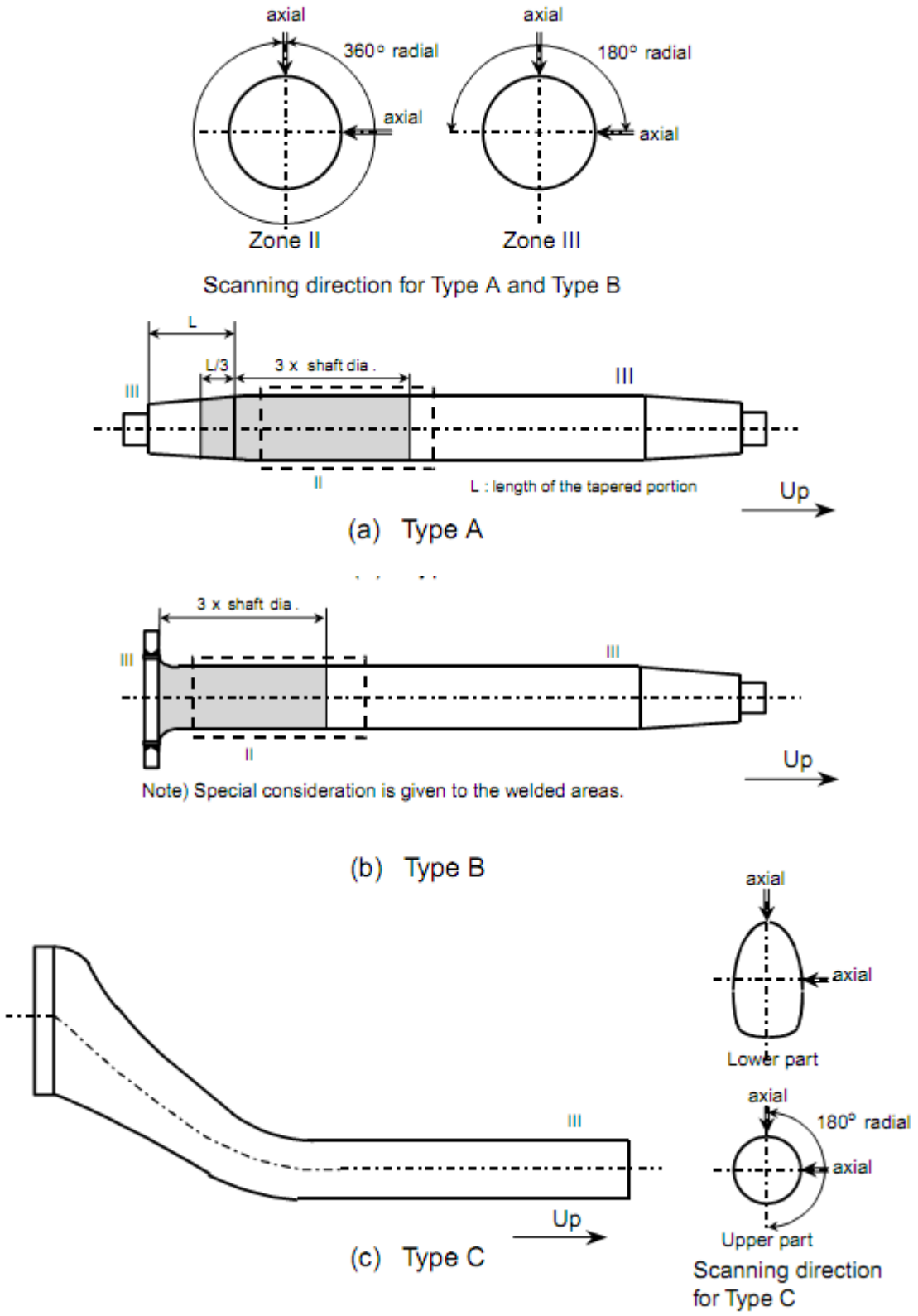


(a) Connecting rod (b) Piston rod



(c) Cross head

FIGURE F.D12.305.4 ZONES FOR ULTRASONIC TESTING ON RUDDER STOCKS



D13. FORGINGS FOR REDUCTION/REVERSE GEAR.

100. Prescriptions

101. These requirements apply to the gears where the maximum transmitted power is more than 140 kW for main propulsion plant and 100 kW for auxiliary machinery.

102. When it is proposed the use of forged alloy steel, chemical composition, mechanical properties and heat treatment must be submitted for approval.

103. The gears and teeth where the tensile strength is greater than 760 N/mm2 , as well as pinion sleeve and pinion, are to be made of adequate alloy steel.

104. The gears and teeth where the tensile strength is between 400 N/mm2 and 760 N/mm2, can be made of carbon steel or carbon-manganese.

105. During selection of materials for pinion and crown wheel it must be considered their compatibility throughout operation. The gear steels undergo the process of hardening, are to be subjected to provision for a difference between the hardness of the pinion and the crown. Thus, the minimum tension specified for the edge of the wheel must not be more than 85% of the pinion's tension.

106. The chemical composition of samples taken from the crucible for carbon steels and carbon-manganese steels must comply with the limits given in the table T.D14.106.1 below.

TABLE T.D14.106.1 LIMITS FOR CARBON STEELS AND CARBON-MANGANESE STEELS

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30- 1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chrome	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max

107. All forgings are to be manufactured leaving sufficient material for corrections in case of defects and deformations occurring.

108. The specified minimum tension must be within the following limits:

a. Pinions and pinion sleeves: 550 - 1050 N/mm2

b. Wheel crown and flanges: 400 - 850 N/mm2

109. A range for the tensile stress is to be specified, it must not exceed 120 N/mm2 when the minimum tension is 600 N/mm2 or less.

110. For more resistant steels this range must not exceed 150 N/mm2.

111. Unless specified to the contrary, the tensile stress strength specified for the core is to be:

a. 800 N/mm2 for the gear treated with surface hardening by nitriding or induction, and

b. 750 N/mm2 for gears with carburizing surface treatment.

112. For gears that have been subjected to nitriding, the total thickness of the hardened zone is not to be less than 0.5 mm and hardness must not be less than 500 HV to a thickness of 0.25 mm.

113. For requirements concerning the different types of heat treatment it must be followed the standards of ISO-6336-5.

200. Quality grades and heat treatment

201. The materials for gears are classified into three material quality grades ML, MQ and ME, according to the ISO 6226-5 standards, according to the permissible maximum stress (see Part II, Title 11, Section 5,Subchapter H3) where:

a. ML stands for modest demands on the material quality and on the material heat treatment process during gear manufacture.

b. MQ stands for requirements that can be met by experienced manufacturers at moderate cost.

c. ME represents requirements that must be realized when a high degree of operating reliability is required.

202. The requirements of item 6 of the standard reference are to be followed.

300. Non-destructive testing.

301. Ultrasonic inspections are to be performed in all gear blocks when the machined surfaces diameter, where the teeth shall be cut, is greater than 200 mm.

302. It is to be performed either magnetic particle inspection or liquid penetrant testing for all tooth surfaces which had been subjected to hardening processes.

303. This inspection is also to be done on gear teeth, which were subjected to hardening after the final machining.

CHAPTER E
APPROVAL OF CONSUMABLES FOR WELDING NORMAL AND HIGH STRENGTH STEELS [IACS UR W 17]

CHAPTER CONTENTS

E1. GENERAL [IACS UR W.17.1]

100. Scope [IACS UR W17.1.1]

101. These requirements give the conditions of approval and inspection of welding consumables used for hull structural steel welding as follows:

a. normal strength steels Grades A, B, D and E ,

b. higher strength steels Grades A32, D32, E32, A36, D36 and E36,

c. higher strength steels with minimum yield strength 390 N/mm2: Grades A 40, D 40 and E40,

d. higher strength steels for low temperature application: Grades F 32, F 36 and F 40.

102. Welding consumables for high strength quenched and tempered steels for welded structures according to Part III, Title 61, Section 2, chapter B.3 are subject to special consideration by the individual RBNA.

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

200. Categories of products [IACS UR W71.1.2]

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

a. covered electrodes for manual welding and gravity welding,

b. wire/flux combinations for two run or multi-run submerged arc welding,

c. solid wire/gas combinations for arc welding,

d. flux cored wires with or without gas for arc welding,

e. consumables for use in electroslag and electrogas vertical welding

300. Grading [IACS UR W17.1.2]

301. Basic groups and grades: filler metals are divided into three groups:

a. normal strength filler metals for welding normal strength hull structural steels,

b. higher strength filler metals for welding normal and higher strength hull structural steels with minimum yield strength up to 355 N/mm2,

c. higher strength filler metals for welding normal and higher strength hull structural steels with minimum yield strength up to 390 N/mm2.

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

303. Each filler metal group is further divided into several grades:

a. Grades 1, 2 and 3 for ordinary-strength filler metals,

b. Grades 1Y, 2Y, 3Yand 4Y for higher strength filler metals for steels up to 355 N/mm2 yield strength,

c. Grades 2Y 40, 3 Y 40 and 4 Y 40 for higher strength filler metals for steels up to 390 N/mm2 yield strength.

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

305. The following suffixes are added after the Grade mark as applicable:

S : Semi-automatic

T : Two-run technique

M : Multi-run technique

TM : Both two-run and multi-run technique

V : Vertical

306. 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.

307. 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 T.E1.307.1:

TABLE T.E1.307.1 – CORRELATION OF WELDING CONSUMABLES TO STRUCTURAL STEEL

Grades of welding	**Hull structural steel grades**											
Consumables (see notes)	**A**	**B**	**D**	**E**	**AH32/36**	**DH32/36**	**EH32/36**	**FH32/6**	**AH40**	**DH40**	**EH40**	**FH40**
1, 1S. 1T, 1M, 1TM, IV	X											
1YS, 1YT, 1YM, 1YTM, 1YV	X				X (2)							
2, 2S, 2T, 2M, 2TM, 2V	X	X	X									
2Y, 2YS, 2YT, 2YM, 2YTM, 2YV	X	X	X		X	X						
2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V	(1)	(1)	(1)		X	X			X	X		
3, 3S, 3T, 3M, 3TM, 3V	X	X	X									
3Y, 3YS, 3YT, 3YM, 3YTM, 3YV	X	X	X		X	X	X					
3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V	(1)	(1)	(1)		X	X	X		X	X	X	
4Y, 4YS, 4YT, 4YM, 4YTM, 4YV	X	X	X		X	X	X	X				
4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V	(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 the RBNA when the carbon equivalent is below or equal to 0.41%.When other than controlled low hydrogen type electrodes are used appropriate procedure tests for hydrogen cracking may be conducted at the discretion of the RBNA.
(d) The welding consumables approved for steel Grades A 40, D 40, E 40 and/or F 40 may also be used for welding of the corresponding grades of normal strength steels subject to the special agreement with the RBNA (e) When joining higher strength steels using Grade 1Y welding consumables, the material thicknesses should not exceed 25 mm.

1.2.3 Hydrogen marks: welding consumables of Grades 2 and 3 and Grades 2Y, 3Y and 4Y and of Grades 2Y 40, 3Y 40 and 4Y 40, for which the hydrogen content has been controlled in accordance with paragraph 4.5.3 are identified by the mark H15, H10 or H5.

400. Manufacture
[IACS UR W17.1.3]

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

E2. APPROVAL PROCEDURE
[IACS UR W17.2]

100. Plant inspection
[IACS UR W17.2.1]

101. 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 E2.400 above.

200. Test assemblies
[IACS UR W17.2.2]

201. 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.

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

203. 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.

300. Firms with several factories - sister firms
[IACS UR W17.2.3]

301. 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.

302. This requirement is applicable to all manufacturers of filler products under license (sister firms).

303. However, should there be any doubt, complete test-series may be required.

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

400. Annual inspection and tests
[IACS UR W17.2.4]

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

500. Alterations to approved consumables
[IACS UR W17.2.5]

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

600. Upgrading and updating
[IACS UR W17.2.6]

601. Upgrading and updating 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.

700. Additional tests
[IACS UR W17.2.7]

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

E3. MECHANICAL TESTING PROCEDURE
[IACS UR W17.3]

100. Test specimens
[IACS UR W17.3.1]

101. 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 part III, Title 61, Section 2, Chapter A.

102. Specimens location and preparation:

a. **Deposited metal tensile**:

a.1. the longitudinal axis must coincide with the centre of the weld and:

a.2. the mid thickness of the weld in the deposited metal test assemblies;

a.3. the mid thickness of the 2nd run in the two-run welded test assemblies.

a.4. 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.

b. **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.

c. **Butt weld bend: t**he 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.

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

d.1. at mid thickness of the weld in the deposit metal and butt weld test assemblies
d.2. with multi-run technique;

d.3. on the 2nd run side, 2 mm maximum below the surface in the two-run welded
d.4. test assemblies;

d.5. 2 mm maximum below one surface in the electroslag or electrogas welded test assemblies.

d.6. 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.

200. Testing procedures [W17.3.2]

201. Tensile tests are to be carried out on an approved tensile testing machine.

202. 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.

203. Bend 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.

204. However, superficial cracks of less than 3 mm long on the outer surface should not be taken into consideration.

205. 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.

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

207. 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.

208. The test temperature for Grades 2, 2Y, 2Y 40, 3, 3Y, 3Y 40, 4Y and 4Y 40 test pieces is to be controlled to within ±2°C of the prescribed temperature.

300. Re-test procedures [IACS UR W17.3.3]

301. **Tensile and bend**

a. 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.

b. 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.

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

E4. COVERED ELECTRODES FOR MANUAL ARC WELDING [IACS UR W17.4]

100. General [IACS UR W17.4.1]

101. **Grades**: depending on the results of the Charpy V-notch impact tests, electrodes are divided into the following grades:

a. for normal strength steel: Grades 1, 2 and 3

b. for higher strength steel with minimum yield strength up to 355 N/mm2: Grades 2Y and 3Y and 4Y (Grade 1Y not applicable for manual welding).

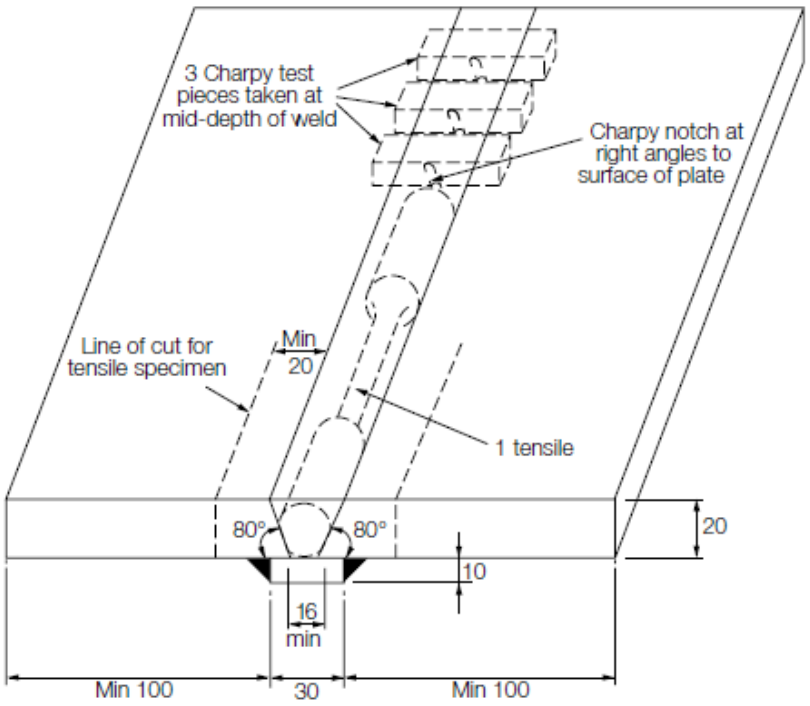
c. for higher strength steels with minimum yield strength up to 390 N/mm2: Grades 2Y 40, 3Y40, and 4Y 40.

102. **Hydrogen marks: i**f 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.

200. Deposited metal tests [IACS UR W17.4.2]

201. Preparation of deposited metal test assemblies Two deposited metal test assemblies are to be prepared in the downhand position as shown in figure F.E4.201.1, 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 F.E4.201.1 DEPOSITED METAL TEST ASSEMBLY



202. 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.

203. **Chemical analysis:** At the discretion of each individual RBNA, 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.

204. **Execution of tests:** One tensile and three impact test specimens are to be taken from each test assembly as shown in Figure F.E4.201.1. 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 sub-chapter E3 of these requirements.

205. **Results of tests and requirements:** The results of all tests are to comply with the requirements of Table T.E4.205.1 as appropriate.

TABLE T.E4.205.1 REQUIREMENTS FOR DEPOSITED METAL TESTS (COVERED MANUAL ELECTRODES)

Grade	Yield stress N/mm^2 minimum	Tensile Strength N/mm2	Elongation on 50 mm gauge length ($L_o = 5$ d) % minimum	Charpy V-notch impact tests	
				Test Temperature oC	Average Energy J minimum
1 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
2Y 40 3Y 40 4Y 40	400	510 - 690	22	0 -20 -40	47 47 47

300. Butt weld tests [IACS UR W17.4.3]

301. Preparation of butt weld test assemblies Butt weld assemblies as shown in figure T.E4.301.1 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward and overhead) for which the electrode is recommended by the manufacturer, except that electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal / vertical position subject to the agreement of the RBNA.

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

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

a. Grade 1 electrodes : A

b. Grade 2 electrodes : A, B, D

c. Grade 3 electrodes : A, B, D, E

d. Grade 2Y electrodes : AH32, AH36, DH32, DH36

e. Grade 3Y electrodes : AH 32, AH 36, DH32, DH36, EH32, EH36.

f. Grade 4Y electrodes : AH32, AH36, DH 32, DH 36, EH 32, EH 36, FH 32, FH 36

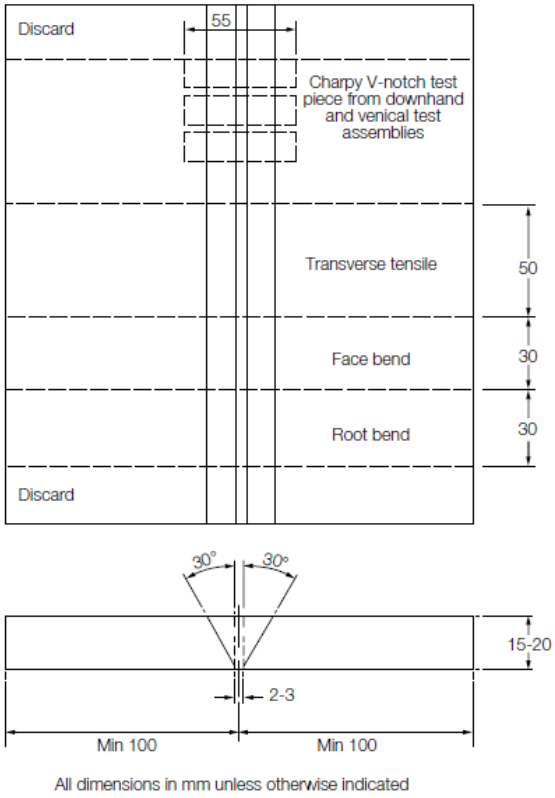
g. Grade 2Y 40 electrodes : AH 40, DH 40

h. Grade 3Y 40 electrodes : AH 40, DH 40, EH 40

i. Grade 4Y 40 electrodes : AH 40, DH 40, EH 40, FH 40

304. 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 T.E4.301.1 BUTT WELD TEST ASSEMBLY



304. **Sequence of welding:** The following welding procedure is to be adopted in making test assemblies:

a. **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.

b. **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.

c. **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.

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

e. **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.

305. 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.

306. 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.

307. **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.

400. Execution of tests
[IACS UR W17.4.3.4]

401. The test specimens as shown in Figure T.E4.301.1 are to be prepared from each test assembly. Tests are to be performed according to sub- chapter E3 of these requirements.

402. **Result of tests and requirements:** the results of all tensile and impact tests are to comply with the requirements of table T.E4.402.1 as appropriate.

403. 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 T.E4.402.1 REQUIREMENTS FOR BUTT WELD TEST (COVERED MANUAL ELECTRODES)

Grade	Tensile strength (transverse test) N/mm2	Charpy V-notch impact tests		
			Average energy - J minimum	
		Test Temperature °C	Downhand, horizontal-vertical, overhead	Vertical (upward and downward)
1	400	20	47	34
2		0	47	34
3		-20	47	34
2Y	490	0	47	34
3Y		-20	47	34
4Y		-40	47	34
2Y 40	510	0	47	39
3Y 40		-20	47	39
4Y 40		-40	47	39

500. Hot cracking test
[IACS UR W17.4.4]

501. Hot cracking test may be required at the discretion of each individual RBNA.

600. Hydrogen test
[IACS UR W17.4.5]

601. **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.

602. **Execution of hydrogen test:** The mercury method as specified in the Standard ISO 3690-1977, or any method such as the gas chromatographic method which correlates with that method, must be used. The use of the glycerine method may be admitted at the RBNA discretion. This method is described hereafter.

a. Four test specimens are to be prepared, measuring 12 mm by 25 mm in cross section by about 125 mm inlength. 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.

b. The welding is to be carried out with an arc as short as possible and with a current of about 150 amp.

c. The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer.

d. 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.

e. After 30 seconds in the water, the specimen is to be cleaned and dried, and then placed in an apparatus suitable

f. 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.

g. 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 cm3 and corrected for temperature and pressure to 0°C and 760 mm Hg.

603. The individual and average diffusible hydrogen contents of the four specimens are to be reported, and the average value in cm3 per 100 grams is not to exceed the following:

Mark	Mercury Method (ISO 3690 - 1977)
H 15	15 [1]
H 10	10 [2]
H 5	5

1) 10 cm^3 per 100 grams where the glycerine method is used
2) 5 cm^3 per 100 grams where the glycerine method is used

Note: For H5 mark only the mercury method is to be used.

700. Covered electrodes for manual fillet welding [IACS UR W17 4.6]

701. Where an electrode is submitted only to approval for fillet welding and to which the butt weld test provided in sub-chapter E4.300 of the present is not considered applicable, the first approval tests are to consist of the fillet weld tests given in E4.301 above, and deposited metal tests similar to those indicated in sub-chapter E4.200 above. Where an electrode is submitted to approval for both butt and fillet welding, the first approval tests may, at the discretion of the RBNA, include one fillet weld test as detailed hereunder and welded in the horizontal-vertical position.

702. **Fillet weld test assemblies:** When the electrode is proposed only for fillet welding, fillet weld assemblies as shown in figure F.E4.702.1, 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.

703. The grade of steel used for the test assemblies is to be as detailed in E4.301 of the present.

704. 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.

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

706. **Tests on fillet weld assemblies**

a. **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.

b. **Hardness:** At the discretion of each RBNA, the hardness of the weld, of the heat affected zone (HAZ) and of parent metal may be determined, and reported for information (see figure F.E4.706.1).

c. **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 F.E4.702.1 FILLET WELD TEST ASSEMBLY

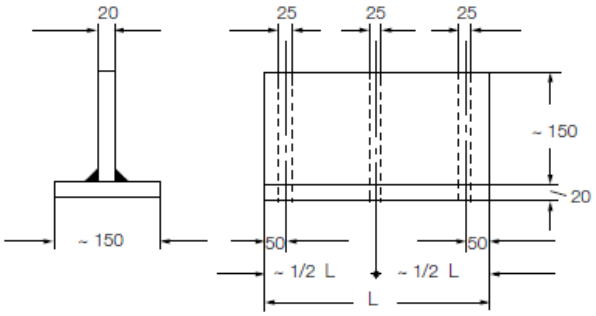
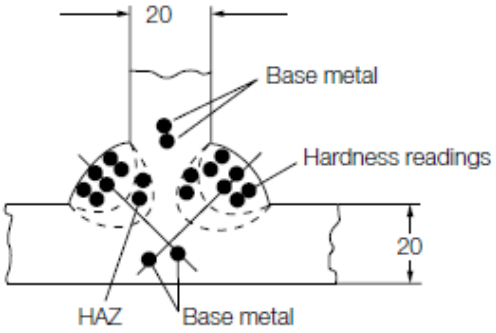


FIGURE F.E4.706.1 HARDNESS READINGS



800. Covered electrodes for gravity or contact welding [IACS UR W17.4.6]

801. 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.

802. 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.

803. 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.

804. 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.

900. Annual tests and upgrading [IACS UR W17.4.8]

901. A**nnual tests and periodical inspection of manufacturer's plant**: All establishments where approved electrodes are manufactured shall be subject to annual inspection.

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

a. **Covered electrode for normal manual arc welding:** Two deposited metal test assemblies are to be prepared in accordance with E4.200 of the present. The mechanical properties (one tensile test, 3 Charpy-V impact tests on each assembly) are to be in accordance with Table T.E4.205.1. This also applies to electrodes which are approved only for fillet welding. At the discretion of the RBNA a butt weld test to be welded in down-hand or in vertical position, can be required in lieu of the deposited metal test 4 mm electrodes. Three Charpy V-notch impact test specimens are to be taken from the butt weld assembly. For Mark H 10 and Mark H 5 covered electrodes, an hydrogen test following E4.600 above can also be required for each annual test at the discretion of the RBNA.

b. **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 item E4.600 of the present.

903. **Upgrading and uprating of electrodes**: **[IACS UR W17.4.8.2]**

a. 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.

b. Upgrading refers to notch toughness and consequently, only Charpy V impact tests are required from the respective butt-weld assemblies as required by E4.300 above (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).

c. 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. For this purpose all butt-weld tests are to be made again, as required in E4.300 above and using higher strength steel, as parent metal.

E5. WIRE FLUX COMBINATIONS FOR SUBMERGED ARC WELDING [IACS UR W17.5]

100. General [IACS UR W17.5.1]

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

a. For use with the multi-run technique

b. For use with the two run technique

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

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

a. For normal strength steel: Grades 1, 2 or 3

b. For higher strength steels with minimum yield strength up to 355 N/mm2: Grades 1Y, 2Y, 3Y or 4Y.

c. for higher strength steels with minimum yield strength up to 390 N/mm2: Grades 2Y 40, 3Y 40 or 4Y 40.

104. 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.

105. **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.

106. **Mechanical tests on assemblies**: Mechanical tests on assemblies with submerged arc welding for wire/flux approval are given in Table TE5.106.1.

200. Approval tests for multi run technique [IACS UR W17.5.2]

201. **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.

202. For deposited metal test assembly any grade of ship structural steel may be used.

203. For butt weld test assembly one of the grades of steel as listed below for the individual grades of wireflux combinations shall be used:

a. Grade 1 wire-flux combinations : A

b. Grade 2 wire-flux combinations : A, B, D

c. Grade 3 wire-flux combinations : A, B, D, E

d. Grade 1 Y wire-flux combinations : A 32, A 36

e. Grade 2 Y wire-flux combinations : A32, A 36, D 32, D 36

f. Grade 3 Y wire-flux combinations : A32, A 36, D 32, D 36, E 32, E 36

g. Grade 4 Y wire-flux combinations : A32, A 36, D 32, D 36, E 32, E 36, F 32, F 36

h. Grade 2 Y 40 wire-flux combinations : A40, D 40

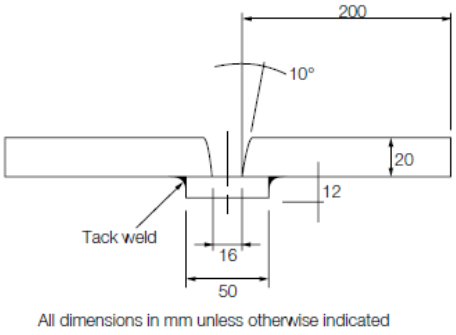
i. Grade 3 Y 40 wire-flux combinations : A40, D 40 E 40

j. Grade 4 Y 40 wire-flux combinations : A40, D 40, E 40, F 40

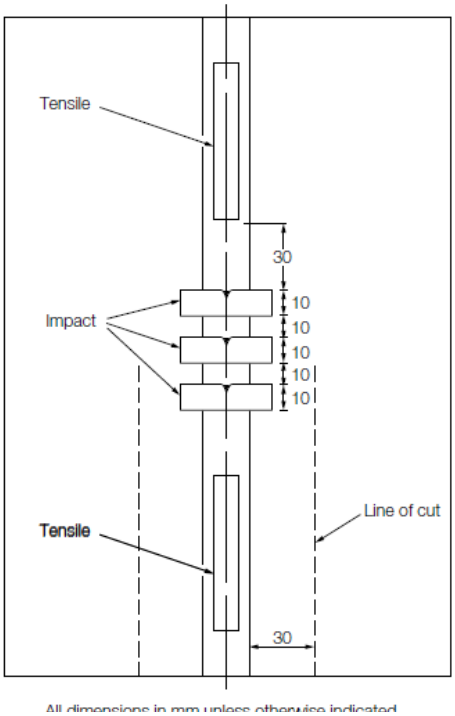
203. Deposited metal test assembly

a. **Preparation:** One deposited metal test assembly is to be prepared as shown in Figure F.E5.203.1

FIGURE F.E5.203.1



All dimensions in mm unless otherwise indicated



All dimensions in mm unless otherwise indicated

TABLE T.E5.106.1 - GENERAL TABLE GIVING THE MECHANICAL TESTS ON ASSEMBLIES WITH SUBMERGED ARC WELDING FOR WIRE/FLUX APPROVAL

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

204. 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.

205. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm.

206. 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.

206. Chemical analysis: at the discretion of each individual RBNA, 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.

207. Execution of tests: in accordance with table T.E5.106.1, the test specimens as shown in Figure F.E5.203.1 are to be prepared from each test assembly. Tests are to be performed according to Sub Chapter E3. requirements.

208. Results and requirements: the results of all tests are to comply with the requirements of Table T.E5.208.1, as appropriate.

TABLE T.E5.208.1 REQUIREMENTS FOR DEPOSITED METAL TESTS (WIRE-FLUX COMBINATIONS)

Grade	Yield stress N/mm^2 minimum	Tensile Strength N/mm2	Elongation on 50 mm gauge length ($L_o = 5$ d) % minimum	Charpy V-notch impact tests	
				Test Temperature °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
2Y 40	400	510 - 690	22	0	39
3Y 40				-20	39
4Y 40				-40	39

300. Butt Weld Test Assembly [IACS UR W17.5.2.3]

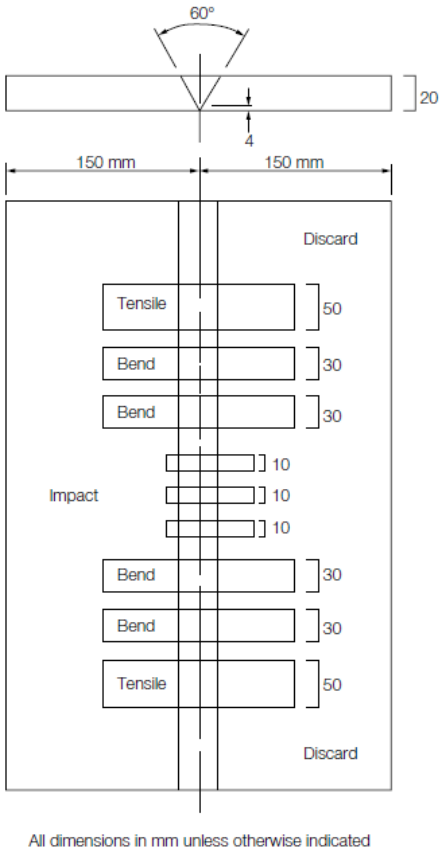
301. Preparation: one butt weld test assembly is to be prepared as shown in Figure F.E5.301.1 in the downhand position by welding together two plates (20 to 25 mm thick), each not less than 150 mm in width and sufficient length to allow the cutting out of test specimens of the prescribed number and size.

302. 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.

303. 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.

304. 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.

FIGURE F.E5.301.1 MULTI-RUN BUTT WELD TEST ASSEMBLY (SUBMERGED ARC WELDING)



305. 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.

306. Execution of tests: the test specimen to be prepared from the welded assembly are given in Table T.E5.106.1a and shown in Fig. F.E5.301.1. The tests are to be performed according to the requirements of Chapter E3.

307. Results of tests and requirements: the results of all tensile and impact tests are to comply with the requirements of Table T.E5.307.1 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 T.E5.307.1 REQUIREMENTS FOR BUTT WELD TESTS (WIRE-FLUX COMBINATIONS)

Grade	Tensile strength (transverse test) N/mm²	Charpy V-notch impact tests	
		Test temperature °C	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

400. Approval tests for two run techniques [IACS UR W17.5.3]

401. 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:

a. For grades 1 and 1Y: 12 to 15 mm and 20 to 25 mm

b. For Grades 2, 2Y, 3, 3Y and 4Y: 20 to 25 mm and 30 to 35 mm

c. For Grades 2Y 40, 3Y 40 and 4Y 40: 20 to 25 mm and 30 to 35 mm

402. limitation of the approval to the medium range (up to the maximum welded plate thickness) may be agreed to by the RBNA. 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.

403. 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 E5.404 hereafter. Where approval is requested for welding of both normal strength and higher strength steel two assemblies are to be prepared using higher strength steel. Two assemblies prepared using normal strength steel may also be required at the discretion of each RBNA.

404. Butt weld test assemblies:

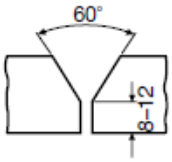
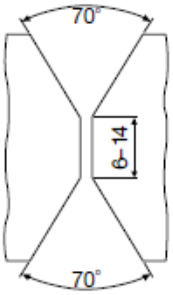
a. Preparation of assemblies: the maximum diameter of wire, grades of steel plate and edge preparation to be used are to be in accordance with Fig. T.E5.404.1. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The root gap should not exceed 1 mm.

b. 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.

c. 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.

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

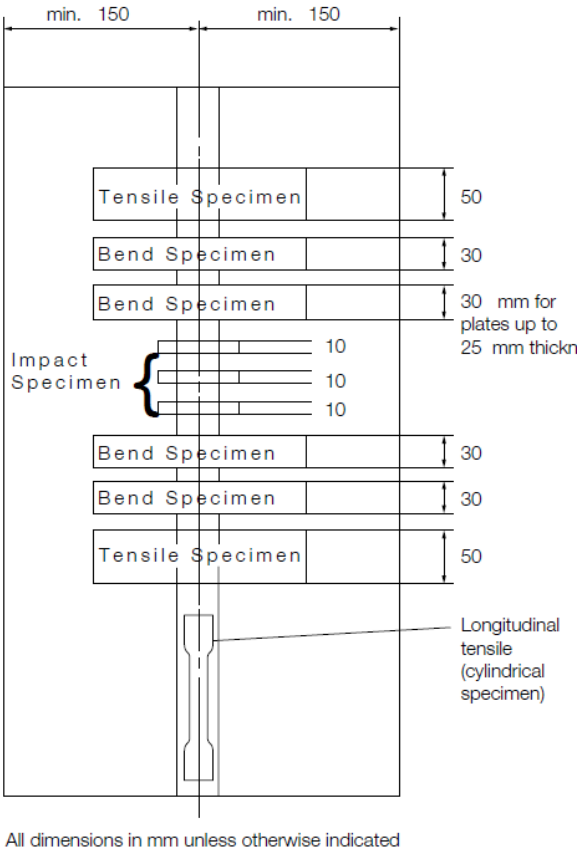
FIGURE T.E5.404.1 BUTT WELD TEST ASSEMBLIES (TWO-RUN TECHNIQUE)

Plate thickness [mm]	Recommended preparation [mm]	Maximum diameter of wire [mm]	Grade of wire-flux combination	Grade of normal strength steel	Grade of higher strength steel
about 12 – 15		5	1 1 Y	A –	– A 32, A 36
about 20 – 25		6	1 1 Y 2 2 Y 2 Y 40 3 3 Y 3 Y 40 4 Y 4 Y 40	A – A, B or D – – A, B, D or E – – – –	– A 32, A 36 – A 32, A 36, D 32, D 36 A 40, D 40 – A 32, A 36, D 32, D 36, E 32, E 36 A 40, D 40, E 40 A 32, A 36, D 32, D 36, E 32, E 36, F 32, F 36 A 40, D 40, E 40, F 40
about 30 – 35		7	2 2 Y 2 Y 40 3 3 Y 3 Y 40 4 Y 4 Y 40	A, B or D – – A, B, D or E – – – –	– A 32, A 36, D 32, D 36 A 40, D 40 – A 32, A 36, D 32, D 36, E 32, E 36 A 40, D 40, E 40 A 32, A 36, D 32, D 36, E 32, E 36, F 32, F 36 A 40, D 40, E 40, F 40

405. 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.

406. Execution of tests: the test specimens indicated in Table T.E5.106.1 and shown in Figure T.E5.406.1 are to be prepared from each test assembly. Tests are to be performed according to sub-chapter E3 above requirements. T he Charpy V-notch impact test specimens are to be machined from each welded assembly from the positions and with the orientations shown in Fig. T.E5.406.2.

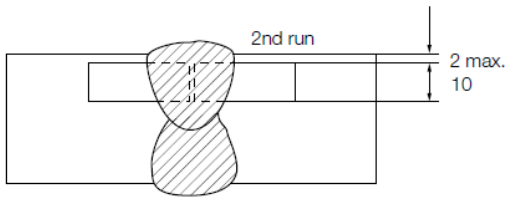
FIGURE T.E5.406.1



All dimensions in mm unless otherwise indicated

Figure 5.4

FIGURE T.E5.406.2



All dimensions in mm unless otherwise indicated

407. Results of tests and requirements: The results of all tensile and impact tests are to comply with the requirements of table T.E5.208.1 and T.E5.307.1 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.

408. 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.

500. Annual tests – upgrading [IACS UR W17.5.4]

501. 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: 1transverse 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.

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

503. 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 E5.501 b above).

504. Upgrading and rating: upgrading of wire-flux combinations in connection with the impact properties will be considered as detailed in E4.903.b), 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 E5.406.

505. Uprating of wire-flux combinations in connection with the tensile properties will be considered as detailed in E4.706.

600. Wires and wire-gas combinations for metal arc welding [IACS UR W17.6]

601. 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.

d. 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.

602. Grades and suffixes:

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

a.1. For normal strength steel Grades 1, 2 and 3;

a.2. For higher strength steels with minimum yield strength up to 355 N/mm2: Grades 1Y, 2Y, 3Y and 4Y;

a.3. For higher strength steems with minimum yield strength up to 390 N/mm2: Grades 2Y 40, 3Y 40, and 4Y 40.

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

c. 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.

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

603. Composition of shielding gas:

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

b. 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 T.E5.603.1, subject to the agreement of the RBNA.

TABLE T.E5.603.1 COMPOSITIONAL LIMITS OF DESIGNATED GROUPS OF GAS TYPES AND MIXTURES.

Group		Gas composition (Vol. %)			
		CO_2	O_2	H_2	Ar
M1	1	> 0 to 5	-	> 0 to 5	Rest 1) 2)
	2	> 0 to 5	-	-	Rest 1) 2)
	3	-	> 0 to 3	-	Rest 1) 2)
	4	> 0 to 5	> 0 to 3	-	Rest 1) 2)
M2	1	> 5 to 25	-	-	Rest 1) 2)
	2	-	> 3 to 10	-	Rest 1) 2)
	3	> 5 to 25	> 0 to 8	-	Rest 1) 2)
M3	1	>25 to 50	-	-	Rest 1) 2)
	2	-	> 10 to 15	-	Rest 1) 2)
	3	> 5 to 50	> 8 to 15	-	Rest 1) 2)
C	1	100	-	-	-
	2	Rest	> 0 to 30	-	-

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

604. Low hydrogen approval

a. Flux-cored or flux-coated wires which have satisfied the requirements for Grades 2, 2Y, 2Y40,3, 3Y, 3Y40, 4Y or 4Y40 may, at manufacturer's option, be submitted to the hydrogen test as detailed in E4.600. 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.

b. A suffix H15, H10 or H5 will be added to the grade mark, in the same conditions as for manual arc welding electrodes (see E4.603 above) to indicate compliance with the requirements of the test.

700. Approval for semi-automatic multi-run welding [IACS UR W17.6.2]

701. General: approval tests for semi-automatic multi-run welding are to be carried out generally in accordance with sub chapter E4, except as required by this item E5.700, using the semi-automatic multi-run technique for the preparation of all test assemblies.

702. Preparation of deposited metal assemblies

a. Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. F.E5.702.1, 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.

b. 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.

703. 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.

704. Mechanical tests: on each assembly, tests are to be made in accordance with E4.204, and the results are to comply with the requirements of E4.205, appropriate to the required grade.

705. Preparation of butt weld assemblies

a. Butt weld assemblies as shown in Figure F.E5.406.1 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.

b. 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.

c. 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 E5.705.b above. Where only one diameter is manufactured, only one downhand butt weld assembly is to be prepared.

d. 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.

706. 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.

707. On each assembly, tests are to be made in accordance with E4.401, and the results are to comply with the requirements of E4.402.

708. Fillet weld tests: fillet weld test assemblies are required to be made in accordance with E4.701 and E4.702, and tested in accordance with E4.706.

800. Approval for automatic multi-run welding and automatic two run welding [IACS UR W17.6.3/6.4]

801. 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 E5.200, using the automatic multi-run technique for the preparation of all test assemblies.

802. Preparation of deposited metal assembly One deposited metal assembly is to be prepared as shown in Figure T.E5.406.1. Welding is to be as detailed in E5.203, except that the thickness of each layer is to be not less than 3 mm.

803. 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.

804. Mechanical tests: tests on this assembly are to be made in accordance with E5.207, and the results are to comply with the requirements of E5.208.

805. 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 E5.301.

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

807. Mechanical tests: tests are to be made on each assembly in accordance with E5.207 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.

808. Discretionary approval: at the discretion of each individual RBNA, 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 semiautomatic 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.

900. Approval for automatic two-run welding

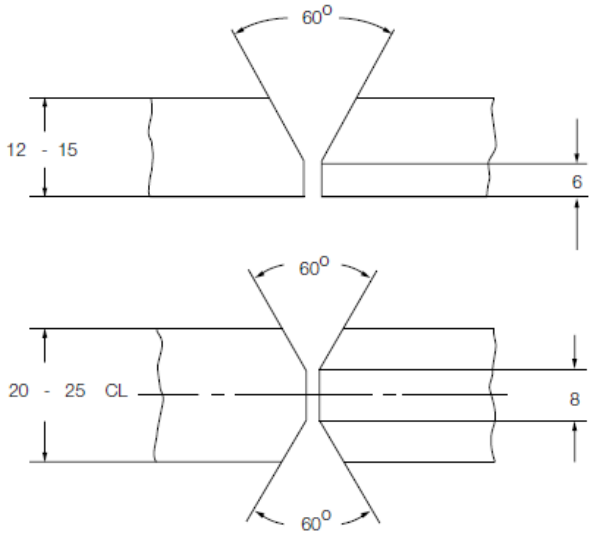
901. General: approval tests for automatic two-run welding are to be carried out generally in accordance with the requirements of E5.400, except as required by E5.800, using the automatic two-run welding technique for the preparation of all test assemblies.

902. Preparation of butt weld assemblies:

a. 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.

b. The plate preparation of the test assemblies is to be as shown in Figure F.E5.702.1. 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.

FIGURE F.E5.702.11 RECOMMENDED EDGE PREPARATION FOR TWO-RUN BUTT WELD TEST ASSEMBLIES



All dimensions in mm unless otherwise indicated

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

903. 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.

904. Mechanical tests: tests are to be made on each assembly in accordance with E5.400 t0 E5.600 and the results are to comply with the requirements of E5.200 and Table T.E5.307.1

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

906. Annual tests and up-grading: annual tests: 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 E5.700 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 E5.800 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 E5.800 using plates of 20-25 mm in thickness. The wire diameter used is to be reported.

907. 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 each individual RBNA, hydrogen test can be carried out following 4.5.

908. Up-grading and up-rating:

a. Up-grading of flux cored wires and wire-gas combinations in connection with the impact properties will be considered as detailed in E4.900.

b. Up-rating of flux cored wires and wire-gas combinations with the tensile properties will be considered as detailed in E4.900.

E6 CONSUMABLES FOR USE IN ELETROSLAG AND ELECTROGAS VERTICAL WELDING [IACS UR 17.7]

100. Consumables for use in eletroslag and electrogas vertical welding

101. General: the requirements for the two-run technique as detailed in sub chapter E5 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.

102. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 approval of the consumables may be restricted for use only with specific types of higher strength steel. This is in respect of the content of grain refining elements, and if general approval is required, a niobium treated steel is to be used for the approval tests.

103. For these special welding consumables, the prescription E6.101 may not be entirely applicable for technical reasons. Where approval is requested for welding of both normal strength and higher strength steel two assemblies are to be prepared using higher strength steel. Two assemblies prepared using normal strength steel may also be required at the discretion of each RBNA.

200. Butt weld tests 7.2.1

201. 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 table T.E5.404.1 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.

202. 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.

203. Test series: each assembly shall be cut to give test specimens according to Figure F.E6.203. The length of the assembly should be sufficient to allow the selection of all the test specimens:

a. 2 longitudinal tensile test specimens with their axis at the centre of the weld.

b. 2 transverse tensile test specimens.

c. 2 side bend test specimens.

d. 2 sets of 3 Charpy-V notch impact test specimens in accordance with Figure F.E6.203.1:

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

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

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

204. Results to be obtained: the results of the tensile, bend and impact tests are to comply with the requirements of item E5.600 (two-run welding) for the class of filler product in question.

300. Annual tests and up-grading

[W17.7.3]

301. 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 E2.400.

302. One test assembly must be prepared from plates 20/25 mm thick, and tested as indicated in E.6. The following specimens are to be selected:

a. 1 longitudinal tensile specimen from the axis of the weld,

b. 1 transverse tensile specimen,

c. 2 side bend specimens,

d. 3 Charpy-V specimens notched at the centre of the weld (position 1 Figure F.E6.203.1),

e. 3 Charpy-V specimens cut out transverse to the weld with their notches at 2 mm from the fusion

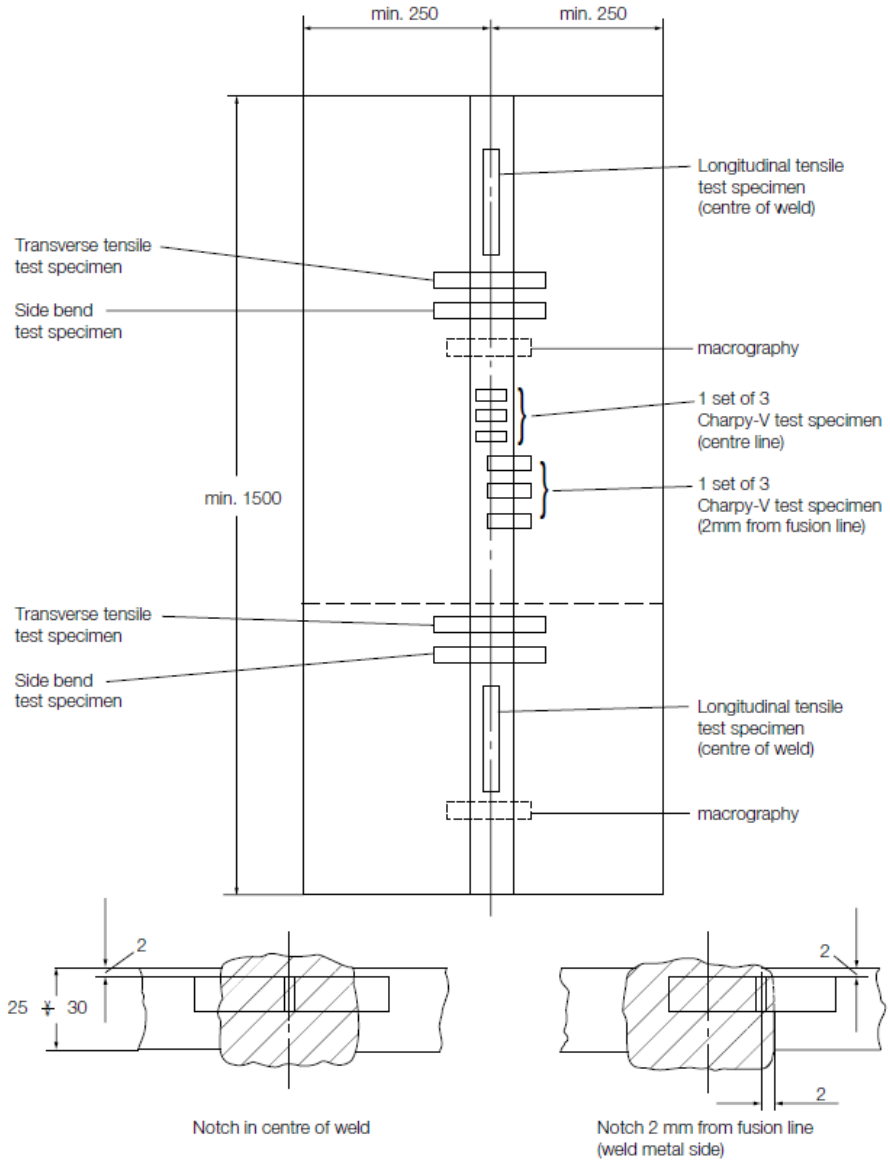
f. line, in the weld,

g. macro section.

303. The results to be obtained should meet the requirements given in E5.400 (two-run welding) for the class of the consumables in question.

304. 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 E6 will be required, irrespective of the other tests requested if the concerned consumable is also approved (and possibly upgraded or uprated) according to E5.100 to E5,500 or E5.600.

FIGURE F.E6.203.1 ELECTROSLAG AND ELECTROGAS BUTT WELD TEST ASSEMBLY



CHAPTER F
WELDING PROCEDURE QUALIFICATION TESTS OF STEELS FOR HULL CONSTRUCTION AND MARINE STRUCTURES
[IACS UR W28]

CHAPTER CONTENTS

F1. APLICATION

100. Scope

101. This document gives requirements for qualification tests of welding procedures intended for the use of weldable steels as specified in Part II, Title 61, Section 2, D2 and Part III, Title 61, Section 2 Chapter C (IACS UR W7, UR W8), Part II, Title 61, Section 2, Chapter B, B.2 (UR W11) and Part III, Title 61, Section 2, Chapter B, B3 (UR W16) for hull construction and marine structures.

102. This document specifically excludes the welding procedure specified in CHAPTER I - MATERIALS AND WELDING FOR GAS TANKERS.

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

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

200. GENERAL

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

202. 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.

203. 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.

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

F2. WELDING PROCEDURE SPECIFICATION

100. Preliminary welding procedure specification and welding procedure specification

101. 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).

Notes:

a. This rule is to be uniformly implemented by IACS Societies on ships contracted for construction from 1 January 2007 as well as the manufacturing of which is commenced on or after 1 January 2007.

b. The "contracted or construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder.

102. The shipyard or manufacturer is to submit to the RBNA 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.

103. The WPS is to be used as a basis for the production welds, and upon satisfactory completion of the tests based on the pWPS, the RBNA may approve it as a WPS. In case that a WPS is approved by the RBNA the approval range is to be in compliance with Sub Chapter E5.

F3. QUALIFICATION OF WELDING PROCEDURES

100. General

101. 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.

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

103. 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.

200. Butt weld

201. Assembly of test pieces: the test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to **F3.201.1** with the minimum dimensions:

- manual or semi-automatic welding:

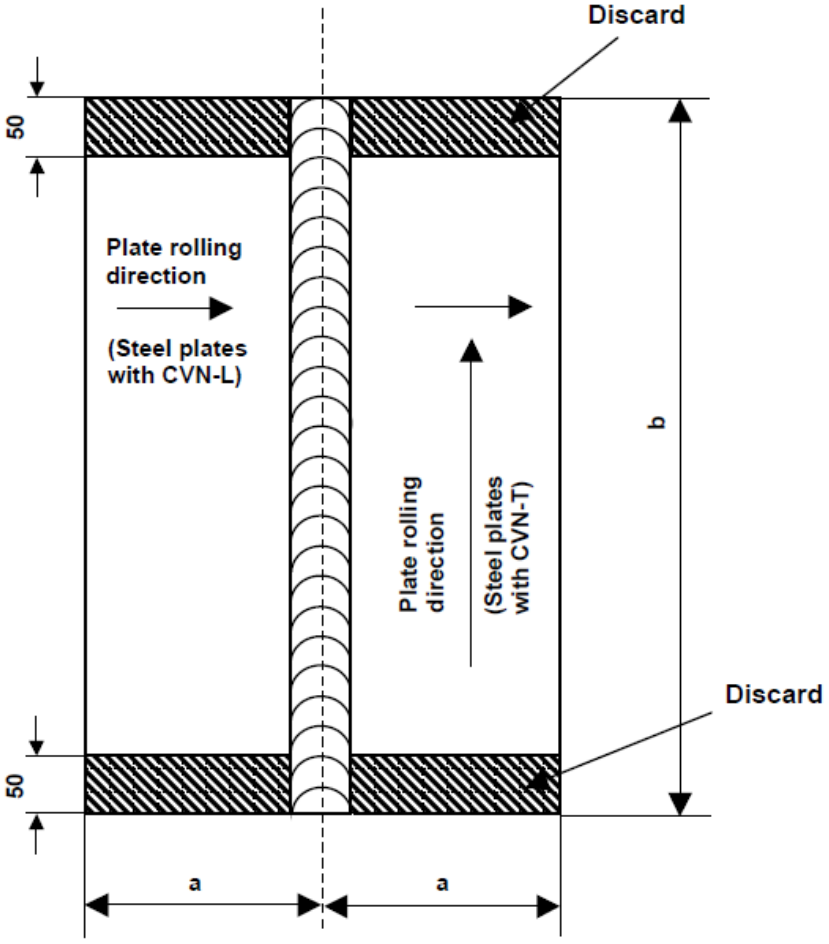
width = 2a , a = 3 x t, min 150 mm
length b = 6 x t, min 350 mm

- automatic welding:

width = 2a , a = 4 x t, min 200 mm

length b = 1000 mm

FIGURE F3.201.1 TEST ASSEMBLY FOR BUTT WELD



202. For hull structural steel plates impact tested in the longitudinal direction (CVN-L) B6, the butt weld of the test piece is perpendicular to the rolling direction of the two plates.

203. For high strength quenched and tempered steel plates impact tested in the transverse direction (CVN-T) in B4 the butt weld of the test piece is parallel to the rolling direction of the two plates.

204. Examinations and tests: test assemblies are to be examined non-destructively and destructively in accordance with the following and **F3.204.1**:

a. Visual testing 100 %

b. Surface crack detection 100 %
(dye penetrant testing or magnetic particle testing)

c. Radiographic or Ultrasonic testing 100 %

d. Transverse tensile test two specimens as per sub-item b) this item.

e. Longitudinal tensile test required as per sub-item c) this item.

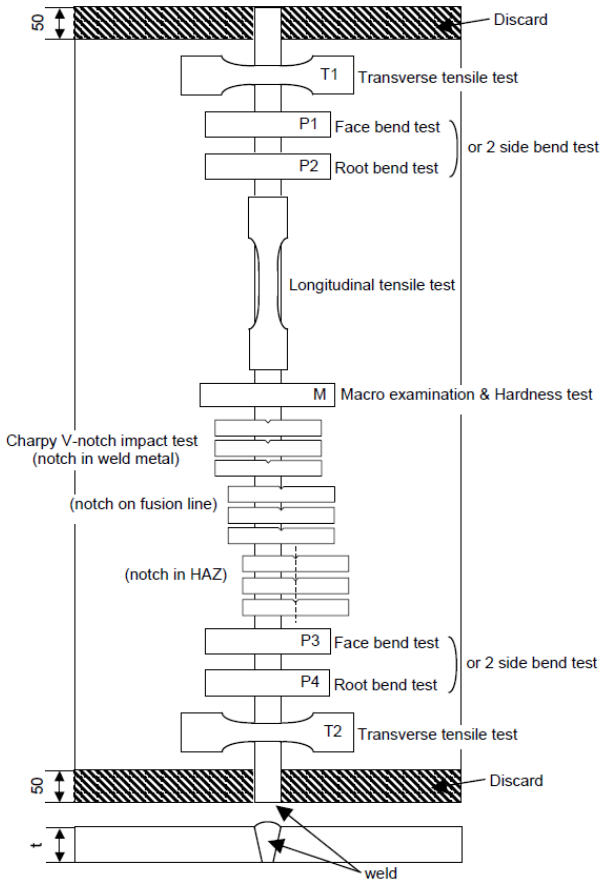
f. Transverse bend test four specimens as per sub-itemd) this item.

g. Charpy V-notch impact test required as per sub-item e) this item.

h. Macro examination one specimen as per sub-item f) this item.

i. Hardness test required as per sub-item g) this item.

FIGURE F3.204.1 TEST SAMPLING



205. Non-destructive testing:

a. 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 chapter B4 with specified minimum yield strength of 420 N/mm2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with the RBNA.

b. 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.

206. Transverse tensile test:

a. The testing is to be carried out in accordance with Chapter A. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal.

b. 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 weld the steel grade having lower strength.

207. Longitudinal tensile test:

a. Longitudinal tensile test of deposited weld metal taken lengthways from the weld is required for cases where the welding consumable is not approved by the RBNA.

b. The testing is to be carried out in accordance with UR Chapter A. 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.

c. 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.

208. Bend test:

a. Transverse bend tests for butt joints are to be in accordance with Chapter A.

b. The mandrel diameter to thickness ratio (i.e. D/t) is to be that specified for the welding consumable approvals + 1.

c. 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.

d. 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.

e. For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

209. Impact test

a. Normal and higher strength hull structural steels according to Chapter B6.

a.1. The positions of specimens are to be in accordance with these requirements. Dimensions and testing are to be in accordance with the requirements of chapter A8 and A9.

a.2. 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.

a.3. V-notch specimens are located in the butt-welded joint as indicated in figure F.F3.204.2 and figure F.F3.204.3 and the V-notch is to be cut perpendicular to the surface of the weld.

a.4. Test temperature and absorbed energy are to be in accordance with table T F3.204.1.

TABLE T F3.204.1 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 the Society.

(2) These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.

(3) For Grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be minimum 27 J.

a.5. When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

a.6. 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.

a.7. The testing of sub - size specimen is to be in accordance with chapter A8.200

b. High strength quenched and tempered steels according to chapter B4

a.1. Impact test is to be performed as described in the above a).

a.2. V-notch specimens are located in the butt welded joint as indicated in figure F.F3.202.2 and figure F.F3.202.3 and the V-notch is to be cut perpendicular to the surface of the weld.

a.3. Test temperature and absorbed energy are to be in accordance with the requirements of base metal as specified in chapter B4

c. Weldable C and C-Mn hull steel castings and forgings according chapter D and C

c.1. 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.

210. Macro examination

a. The test specimens are to be prepared and etched on one side to clearly reveal he weld metal, the fusion line and the heat affected zone.

b. Macro examination is to include about 10 mm unaffected base metal.

c. 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.

211. Hardness test

a. Hardness test is required for steels with specified minimum yield strength of ReH ≥ 355 N/mm2. 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 figure F.F3.202.4 and figure F.F3.202.5.

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 figure F.F3.202.4, F.F3.202.5, F.F3.303.1, F.F3.303.2 and F.F3.303.3**.**

c. The results from the hardness test are not to exceed the following:

c.1. Steel with a specified minimum yield strength ReH ≤ 420 N/mm2 ; 350 HV10

c.2. Steel with a specified minimum yield strength 420 N/mm2 < ReH ≤ 690 N/mm2 ; 420 HV10

300. Fillet welds

301. Assembly of test pieces

a. The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to F3.301.1 with the minimum dimensions:

a.1. manual and semi-automatic welding:

width a = 3 x t, min. 150 mm

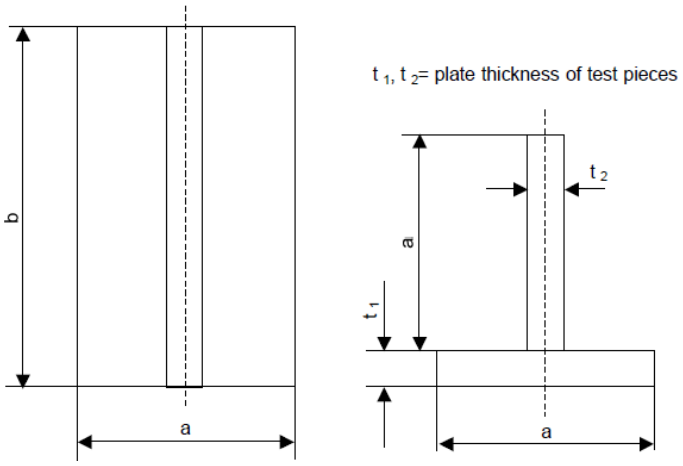
length b = 6 x t, min. 350 mm

a.2. automatic welding:

width a = 3 x t, min. 150 mm

length b = 1000 mm

FIGURE F.F3.301.1 TEST ASSEMBLY FOR FILLET WELD



302. Welding of test pieces

a. 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.

303. Examinations and tests

b. Test assemblies are to be examined non-destructively and destructively in accordance with the following:

b.1. Visual testing 100 %

b.2. Surface crack detection 100 % (dye penetrant testing or magnetic particle testing)

b.3. Macro examination two specimen as per sub-item b) this item. Hardness test required as per sub-item c) this item.

b.4. Fracture test required as per sub-item d) this item.

c. Non-destructive testing

c.1. Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified non-destructive testing is to be performed after heat treatment. For steels according to UR W16 with specified minimum yield strength of 420 N/mm2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless

heat treatment has been carried out. NDT procedures are to be agreed with the RBNA.

c.2. Imperfections detected by visual or non-destructive testing are to be assessed in accordance itch ISO 5817, class B except for excess convexity and excess throat thickness for which the level C applies.

d. Macro examination

d.1. 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.

d.2. Macro examination is to include about 10 mm unaffected base metal.

d.3. 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.

e. Hardness test

e.1. Hardness test is required for steels with a specified minimum yield strength of ReH ≥ 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 figure F.F3.303.1, F.F3.303.2 and F.F3.303.3**.**

e.2. 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 figure F.F3.202.4, F.F3.202.5, F.F3.303.1, F.F3.303.2 and F.F3.303.3. The results from the hardness test are not to exceed the following:

i. Steel with a specified minimum yield strength ReH ≤ 420 N/mm2 ; 350 HV10]

ii. Steel with a specified minimum yield strength 420 N/mm2 < ReH ≤ 690 N/mm2 ; 420 HV10

f. Fracture test

f.1. 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.

400. Re-testing

401. 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.

402. 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.

403. If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with A3. 500

404. 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.

405. The re-testing of Charpy impact specimens are to be carried out in accordance with A8.400 .

406. 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.

500. Test record

501. Welding conditions for test assemblies and test results are to be recorded in welding procedure test record. Forms of welding procedure test records can be taken from the RBNA's rules or from relevant standards.

502. 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.

503. A statement that the test piece was made according to the particular welding procedure is to be signed by the

Surveyor witnessing the test and is to include the RBNA´s identification.

F4. RANGE OF APPROVAL

100. General

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

102. Changes outside of the ranges specified are to require a new welding procedure test.

103. 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.

104. Other variables: The range of approval relating to other variables may be taken according to the RBNA requirements.

200. Base metal

201 Normal and higher strength hull structural steels according to chapter B.

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 RBNA may require additional tests.

202. High strength quenched and tempered steels according to Chapter B4

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.

203. Weldable C and C-Mn hull steel forgings according to chapter D

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.

204. Weldable C and C-Mn hull steel castings according to chapter C

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.

300. Thickness

301. The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in Table F4.301.1.

TABLE F4.301.1 APPROVAL RANGE OF THICKNESS FOR BUTT AND T-JOINT WELDS AND FILLET WELDS

Thickness of test piece t [(1)] (mm)	Range of approval	
	Butt and T-joint welds with single run or single run from both sides	Butt and T-joint welds with multi-run and fillet welds[(2)]
3 < t ≤ 12	0.7 x t to 1.1 x t	3 to 2 x t
12 < t ≤ 100	0.7 x t to 1.1 x t[(3)]	0.5 x t to 2 x t (Max. 150)

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.

302. In addition to the requirements of **Table F4.301.1** the range of approval of throat thickness "a" for fillet welds is to be as follows:

a.1. Single run ; "0.75 x a" to "1.5 x a"

a.2. Multi-run ; as for butt welds with multi-run (i.e. a=t)

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

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

305. 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 F3.202.g) and F3.303.c)

400. Welding position

401. Approval for a test made in any position is restricted to that position (see figure F.F4.401.1 and figure F.F4.401.2). 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.

500. Welding process

501. 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.

502. 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.

600. Welding consumable

601. 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 chapter E and Chapter H with the welding consumable tested.

700. Heat input

701. 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.

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

800. Preheating and interpass temperature

801. The minimum preheating temperature is not to be less than that used in the qualification test.

802. The maximum interpass temperature is not to be higher than that used in the qualification test.

900. Post-weld heat treatment end - Type of joint

901. The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

902. Range of approval depending on type of welded joints for test assembly is to be specified in T F4.902.1.

903. A qualification test performed on a butt weld wil also qualify for fillet welding within the thickness ranges specified for fillet welds specified in F4.300 above.

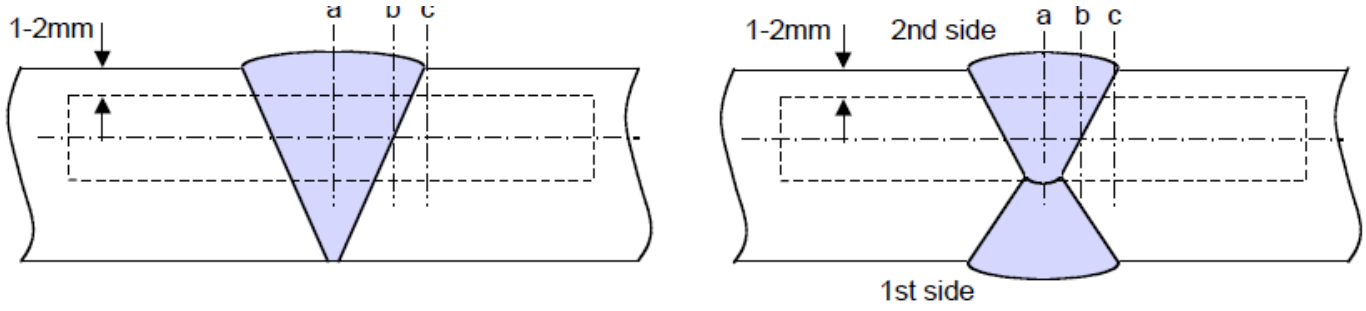
TABLE T F4.902.1 RANGE OF APPROVAL FOR TYPE OF WELDED JOINT

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing	A	A, C, D
		Without backing	B	A, B, C, D
	Both side	With gouging	C	C
		Without gouging	D	C, D

FIGURE F3.204.2 LOCATIONS OF V-NOTCH FOR BUTT WELD OF NORMAL HEAT INPUT (HEAT INPUT ≤ 50 KJ/CM)

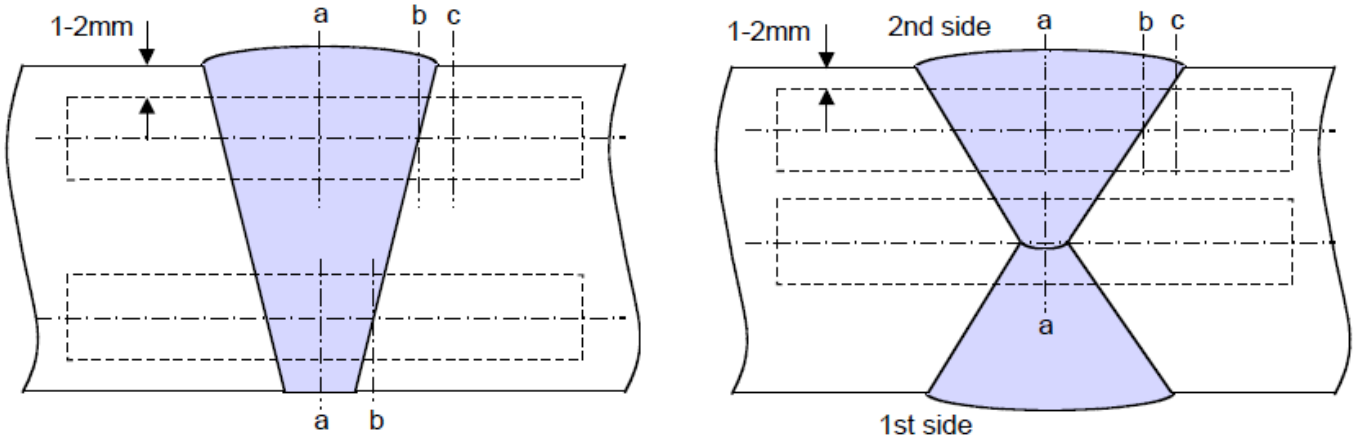
Location of Charpy V-notch impact test

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

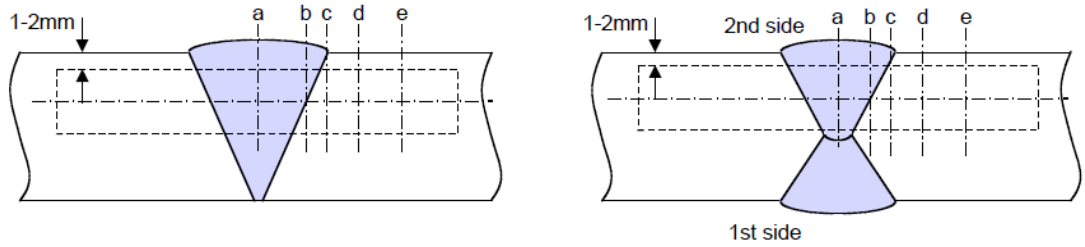


Notch locations:

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

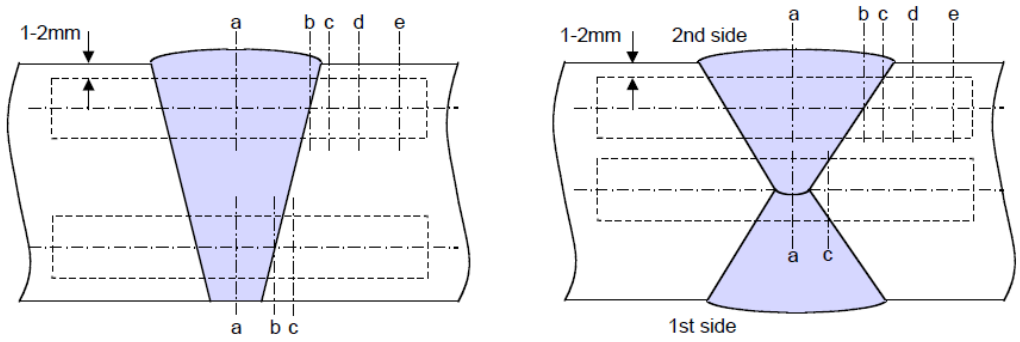
FIGURE F.F3.204.3 - LOCATIONS OF V-NOTCH FOR BUTT WELD OF NORMAL HEAT INPUT (HEAT INPUT > 50 KJ/CM)

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

FIGURE F.F3.202.4 – EXAMPLES OF HARDNESS TEST WITH ROWS OF INDENTATIONS (R) IN BUTT WELDS

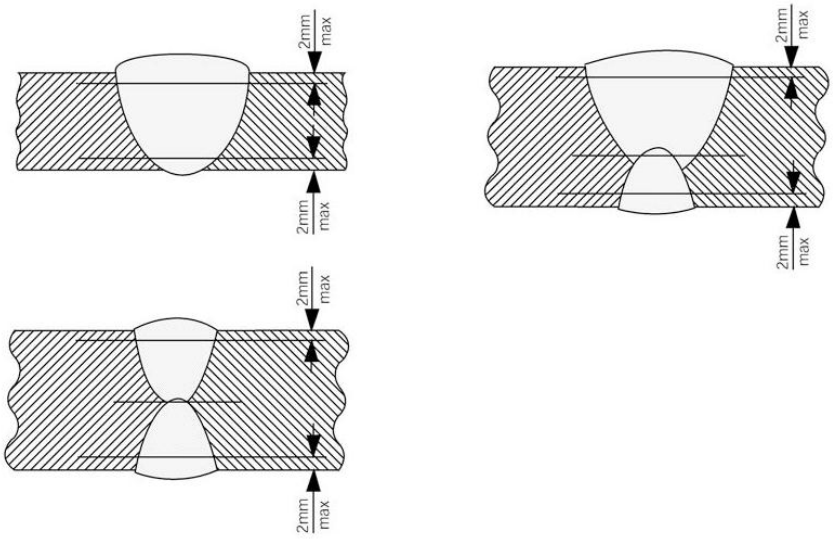


TABLE T.F3.202.1 – RECOMMENDED DISTANCES l BETWEEN INDENTATIONS FOR HARDNESS TEST IN THE HEAT AFFECTED ZONE.

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.

FIGURE F.F3.202.5 – 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)

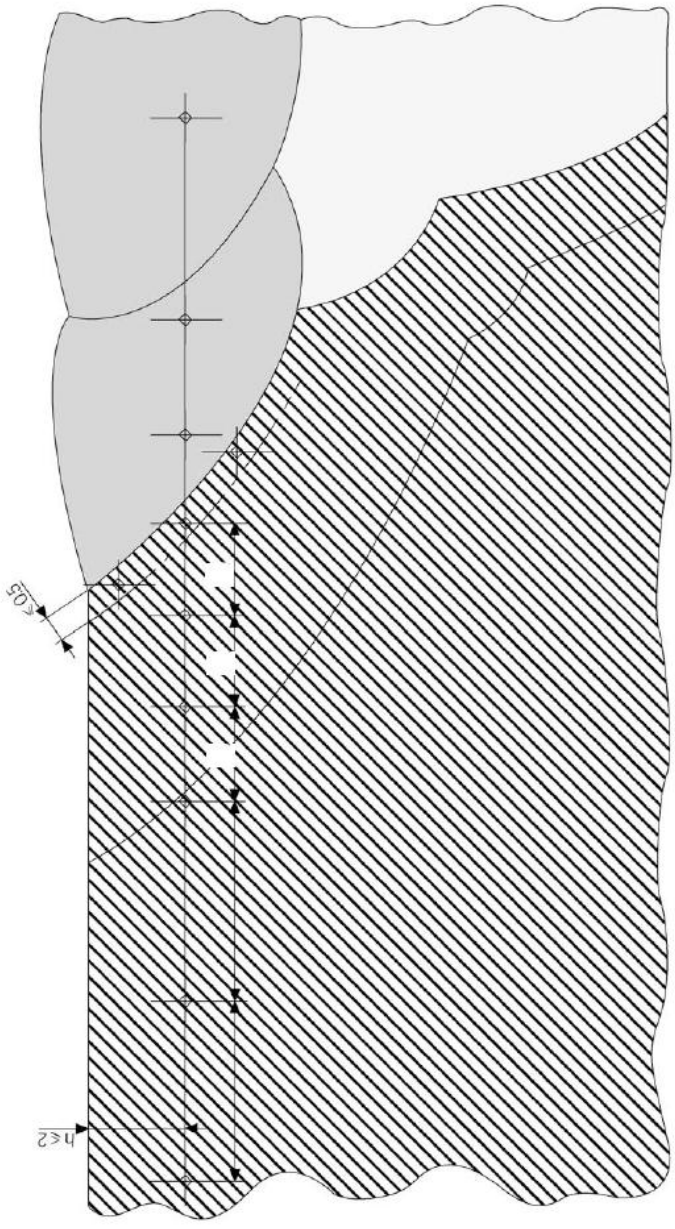


FIGURE F.F3.303.1 – EXAMPLES OF HARDNESS TEST WITH ROW INDENTATION (R) IN FILLET WELDS AND T-joint WELDS

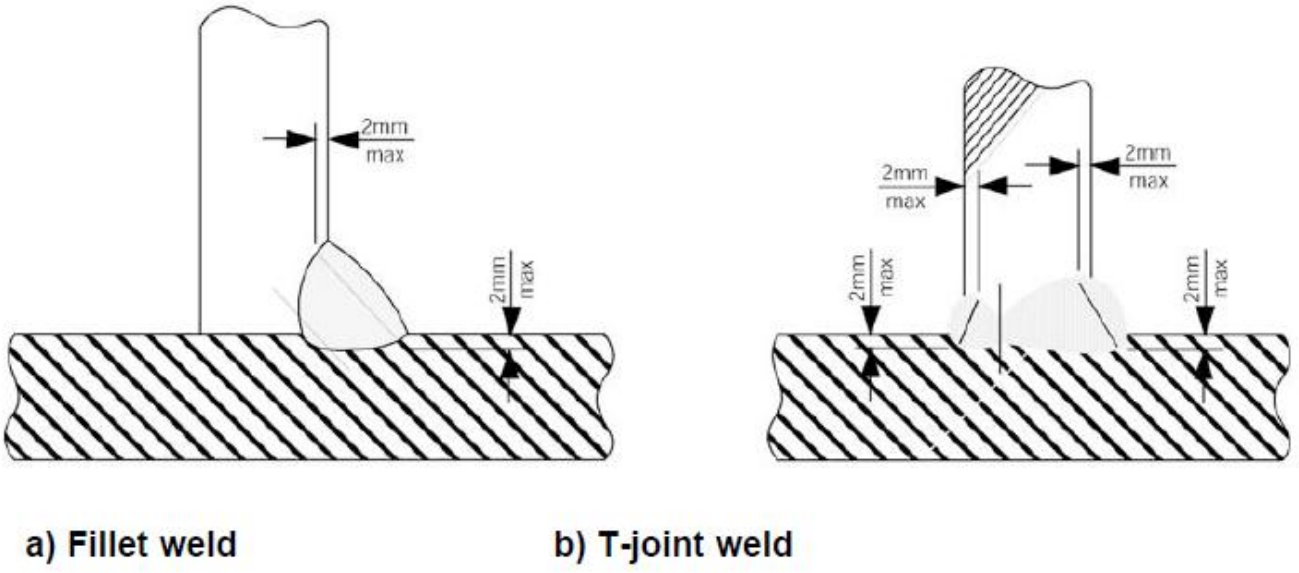


FIGURE F.F3.303.2 – EXAMPLE SHOWING THE POSITION OF THE INDENTATIONS FOR HARDNESS TEST IN THE WELD METAL, THE HEAD AFFECTED ZONE AND THE BASE METAL OF FILLET WELD (DIMENSIONS IN mm)

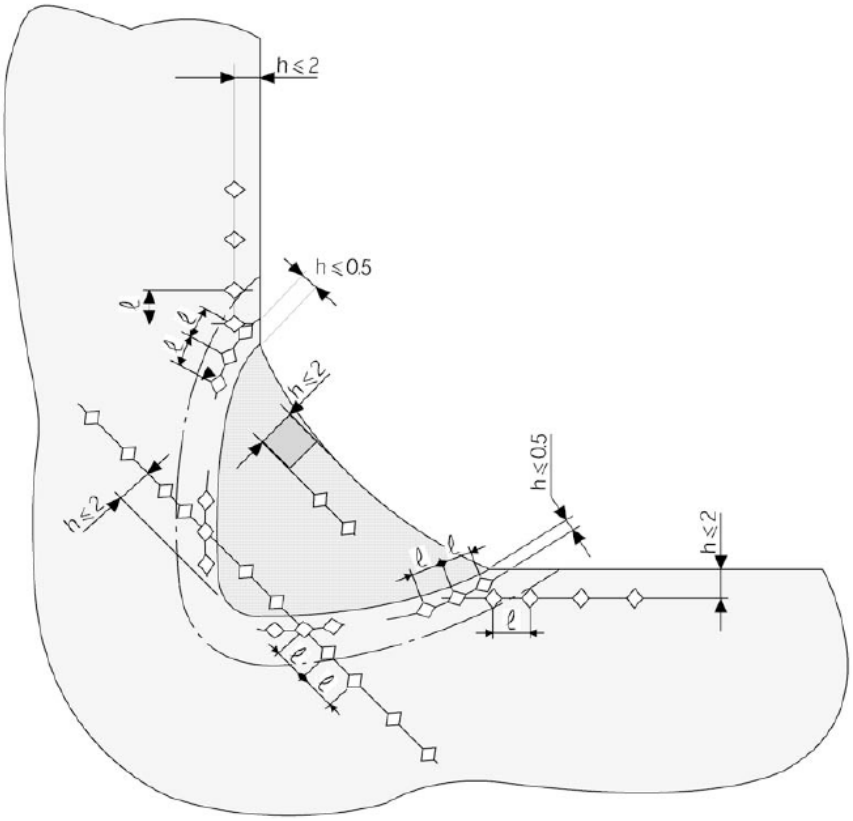


FIGURE F.F3.303.3 – EXAMPLE SHOWING THE POSITION OF THE INDENTATIONS FOR HARDNESS TEST ON THE WELD METAL, THE HEAD AFFECTED ZONE AND THE BASE METAL OF T-joint WELD (DIMENSIONS IN mm)

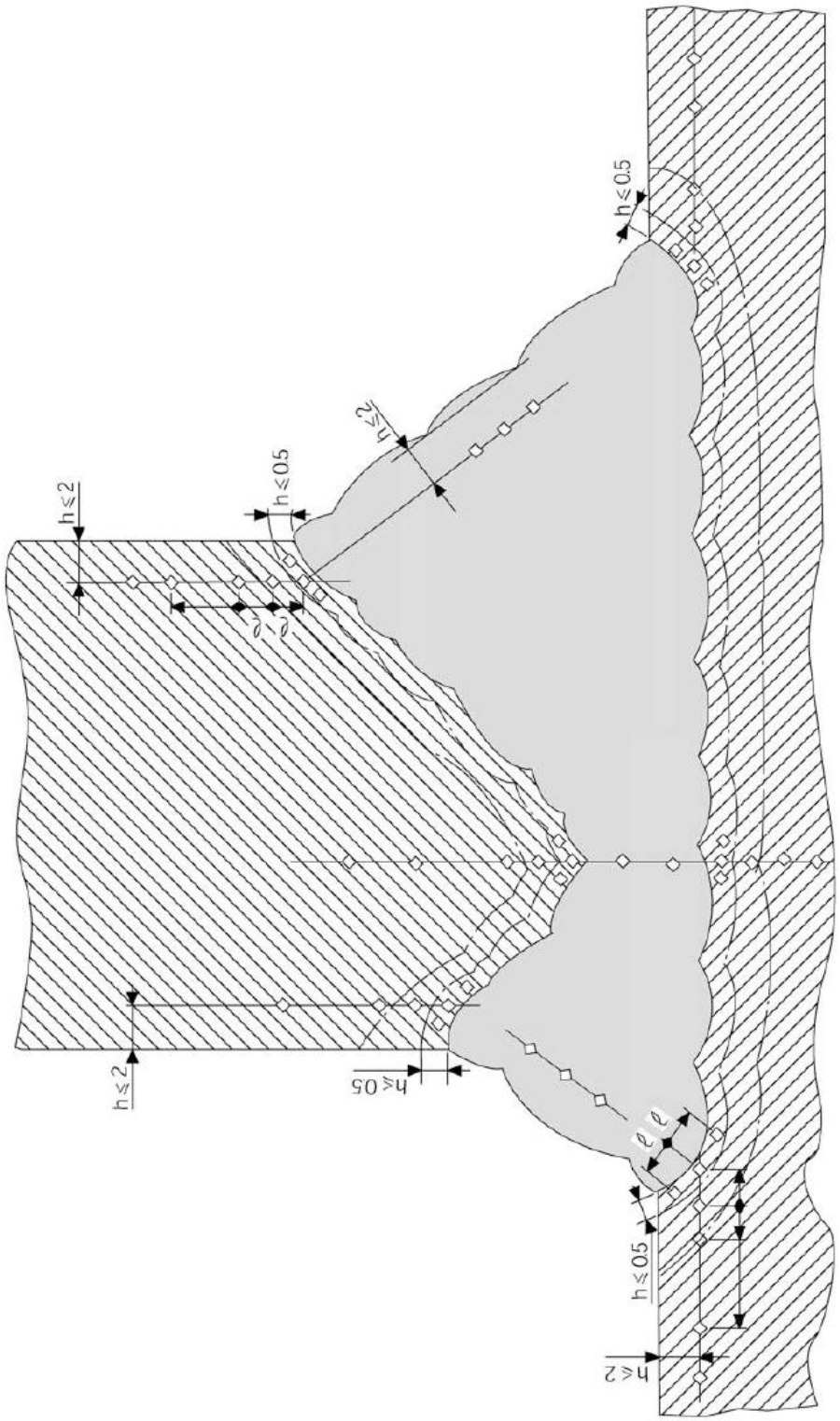


FIGURE F.F4.401.1 – WELDING POSITIONS ACCORDING TO ISO STANDARD

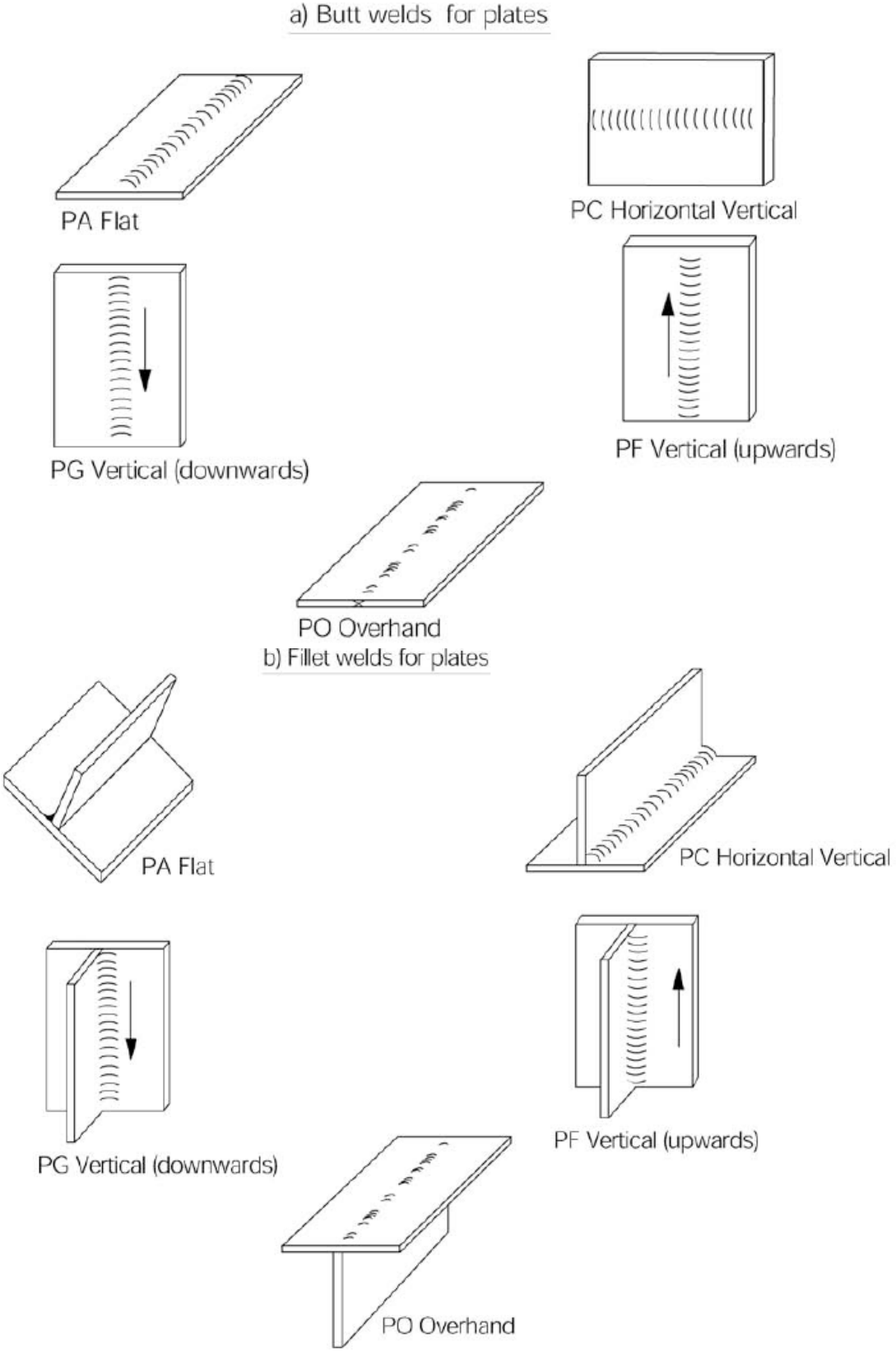
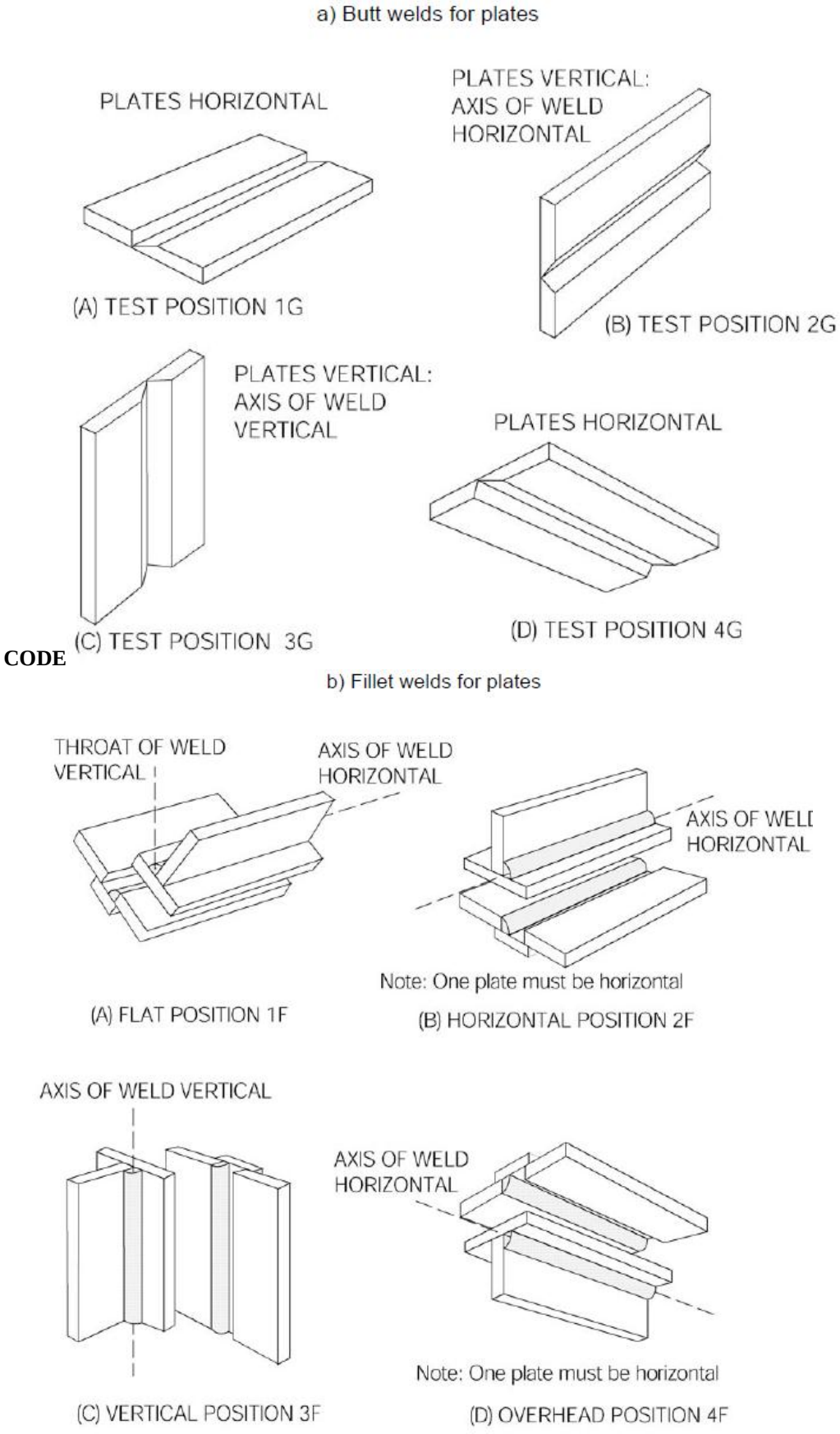


FIGURE F.F4.401.2 – WELDING POSITIONS ACCORDING TO AWS-CODE



F5. WELDER QUALIFICATION

100. Procedures for welder qualification

101. The trials for the welder's qualification will be carried out at the shipyards and factories responsible for the welding operations, where adequate installations and operational conditions are required to carry out the trials.

102. The shipyards and manufacturers are to organize and keep updated a Welding Manual containing all the informations about the welders' training history, operational welding parameters, limitations of the qualified welders, dates and results of the qualification trials.

200. Welders conditions

201. Where during the qualification trials the surveyor finds that any welder or operator is not demonstrating the ability required for the production of satisfactory welding seams, the qualification trials for that welder are to be suspended.

202. Welders who have been granted qualifications by Classification Societies or any other recognized and accredited bodies equivalent to those adoped by RBNA are to have their qualifications recognized by RBNA.

203. Welders employed in the preparation of samples for the qualification of welding procedures are to be qualified based on the satisfactory results of those samples.

204. Welder who have been qualified for but welding in the positions depicted on figure F.F5.204.1 will be automatically qyualified to carry out fillet weldings in the involved positions for any thickness of the materials.

205. Welders will be qualified based on their ability to produce good quality weldings at the positions and thicknesses in accordance with Table F.F5.205.1/2/3/4

300. Plating tests

301. The test set for plating will be prepared according to the test specimens indicated in figures F.F5.301.1 and F.F5.301.2, and requirements of table F.F5.301.1 and the following procedures:

a. the test specimens will be fixed in the positions of welding indicated in the figure F.F5.204.1;

b. deviations exceeding the limits of 15^{o} on the variation of the welding position will not be allowed;

c. the joint cover used should be assembled in intimate contact with the test specimen;

d. the test specimen should be welded in such way that the warping caused by the final pass should not exceed 5^{o};

e. each welding pass should be performed with filler metal with the same dimension that is used in the production;

f. the welding reinforcements and joint covers should be grinded or machined until be obtained flat faces with the test specimen;

g. for welding in vertical position welds should be performed in ascending progression.

400. Tubing tests

401. The test set for tubing will be prepared according to the test specimens indicated in figure F.F5.401.1, requirements of table F.F5.301.1 and the following procedures:

a. according to the paragraph 301 above, ítems a), b), c), e), f) e g);

b. When is used built-in ring, the surface of the test specimen should be machined to the depth of the recess, in order to remove the ring, being that the final thickness of the test specimen should conform to specified requirements;

c. to the flat position, the test tube should be rotated with its axis horizontally, so that the filler metal is deposited always on top of the circumference, during welding;

d. to the horizontal position, the test tube should be fixed with its axis vertically, so that the filler metal is deposited always horizontally on the circumference, during welding; and

e. to a multiple position, the test tube should be fixed with its axis horizontally, so that the filler metal is deposited in the positions flat, vertical vertical-downward, overhead and vertical-upward on the circumference, during the welding.

500. Requirements for all the tests

501. The tests for qualification renewal should be considered satisfactory if it met the requirements of topic 800. Of this subchapter, the satisfaction of the surveyor, and met the following requirements:

a. the surface of the welded joint in the specimen tests, examined visually, should be free of cracks, bites, superposition and other surface defects;

b. the test specimens for guided bending, required in the table F.F5.301.1, prepared for each position involved and tested according to requirements of this chapter.

c. alternatively to the tests prescribed in a) and b) above, should be allowed the welders qualification through radiographic examination, being that, to be considered satisfactory, the welded joint should

meet the requirements of NBR-8420 or another entity recognized.

600. Qualification renewal

601. The capacity certificate for welders is valid for a period of 5 years from the date of the tests for qualification.

602. When the welder qualify for welding of stainless steel will be indicated on the certificate the mention "SPECIAL FOR STAINLESS STEEL.

603. The welders who intend to maintain their qualification at the end of the validity of certificate will meet the following requirements:

a. for each certificate of qualification will be prepared a set of tests as requirements of table F.F5.603.1;

b. the set of tests for the plating will consist of butt welding on both sides of the joint, with details of format and dimensions given in table F.F5.603.1;

c. specimens for tests required for the CT type will be prepared for each position involved, sealing with welded plate both ends, welding in fillet with socket, in accordance with the format and dimensions given in table F.F5.603.1, and submitting the test tube to the hydraulic pressure.

700. Test repetition

701. When the initial test result does not meet the prescribed requirements, retest procedure is applied with the same type of tests and the first test conditions.

702. The retest procedure will be carried out for each position that the welder is unable to get qualification, in accordance with the requirements topic 200 of this subchapter.

703. The retest can be done immediately after testing or after the welder have additional training.

704. To renewal of the qualification, when the result of the tests does not meet the prescribed requirements, will be applied the retest procedure of the topic 800 of this subchapter.

800. Requalification

801. The welder will be submitted for requalification in the following cases:

a. change of employer;

b. have reasons to doubt in his ability;

c. changes in the parameters and conditions set forth in the welding procedure;

d. on expiration of the certificate of qualification;

e. remain without welding for more than 3 months; and

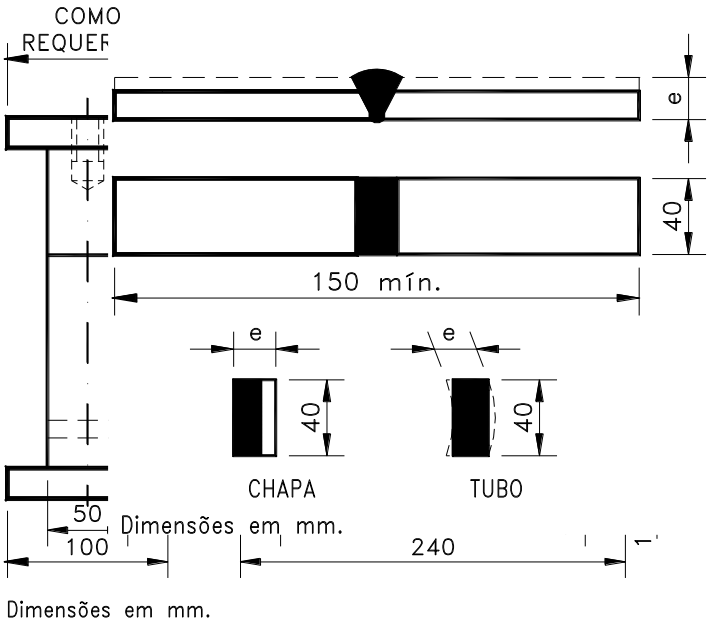
f. perform welds with another process other than qualified for more than 6 months.

802. In case of expiration of the qualification, the welder will be re-qualified in accordance with the following requirements:

a. for qualifying expired more than 12 months, will be applied the requirements of table F.F5.205.1

b. for the qualification expired less than 12 months, will be applied the requirements of table F.F5.201.1

FIGURE F.F5.301.1 - DEVICE
FOR GUIDED BENDING



Notes:
1) The entry guides should be hardened and greased.

2) The entry guides may be replaced by hardened rollers with 40 mm of diameter.

3) Thicknesses of cleaver (ASTM A 307):

Thickness of the plate t (mm)	Thickness of the cleaver t (mm
t ≤ 9,5	38
t > 9,5	4 x t

FIGURE F.F5.302.1 – SPECIMEN TEST FOR CROSS BENDING OF ROOT IN PLATES AND TUBES

NOTES:

1) The weld reinforcement, joint cover and / or built-in ring should be removed until obtaining flat faces with the test specimen.

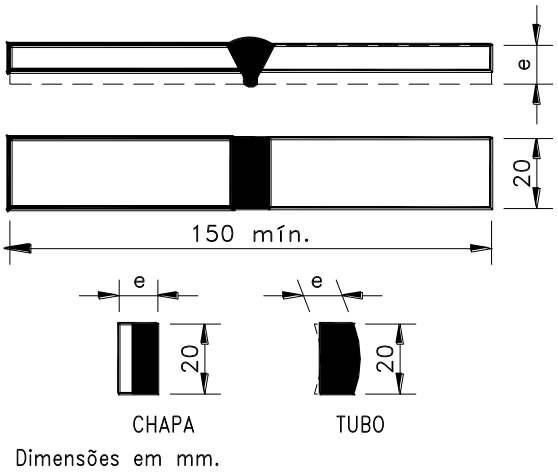
2) Machining the surface of greater width of weld when the thickness "e" of the base metal exceeds 10 mm.

3) The edges of the test specimen should be rounded up to the maximum, with radius of 3 mm.

4) The thickness of the test specimen will be of the same as the material used in the production when "e" does not exceed 10 mm.

5) The thickness of the test specimen will be equal to 10 mm when "e" does not exceed 20 mm.

FIGURE F.F5.302.2 – TEST SPECIMEN FOR CROSS BENDING OF FACE IN PLATES AND TUBES



Notes:
1) The weld reinforcement, joint cover and / or built-in ring should be removed until obtaining flat faces with the test specimen.

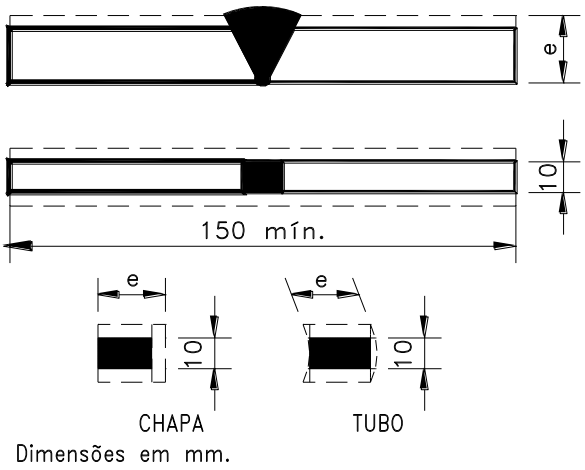
2) Machining the surface of the weld root when the thickness "e" of the base metal exceeds 10 mm.

3) The edges of the test specimen should be rounded, up to the maximum, with radius of 3 mm.

4) The thickness of the test specimen will be of the same as the material used in the production when "e" does not exceed 10 mm.

5) The thickness of the test specimen will be equal to 10 mm when "e" does not exceed 20 mm.

FIGURE F.F5.302.3 - TEST SPECIMEN FOR SIDE CROSS BENDING OF FACE IN PLATES AND



Notes:

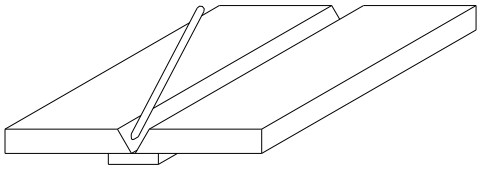
1) The weld reinforcement, joint cover and / or built-in ring should be removed until obtaining flat faces with the test specimen.

2) Machining the surface of greater width of weld when the thickness "e" of the base metal exceeds 40 mm.
3) The edges of the test specimen should be rounded, up to the maximum, with radius of 3 mm.
4) Machining or grinding at least 3 mm of each side of side surfaces of the test specimen when submitted to hot cut.

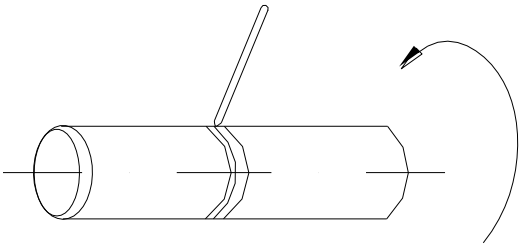
5) The thickness of the test specimen will be the same as the material used in the production when "e" is between 20 mm and 40 mm

6) The thickness of the test specimen will be equal to 40 mm when “e” exceeds 40 mm. same as the material used in the production when "e" is between 20 mm and 40 mm. Alternatively the specimens may be divided in equal parts with height between 20 mm and 40 mm

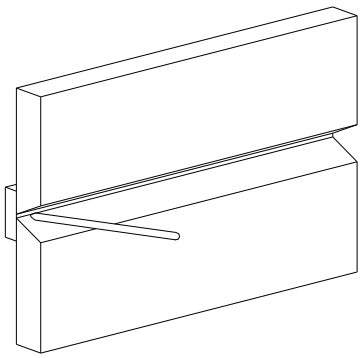
FIGURE F.F5.204.1 – WELDING POSITIONS



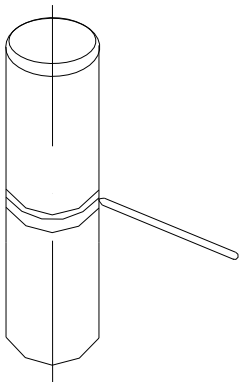
Plana (1G)



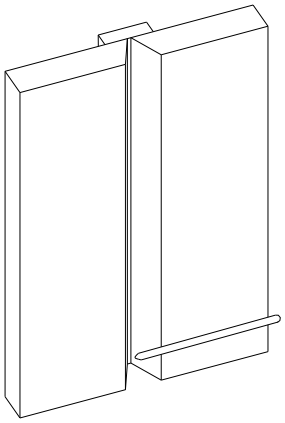
Plana Rotativa (1G)



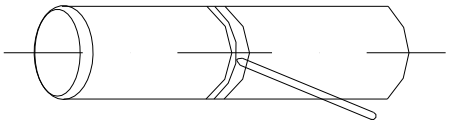
Horizontal (2G)



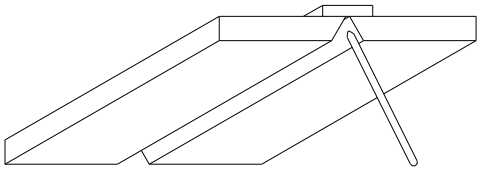
Horizontal Fixa (2G)



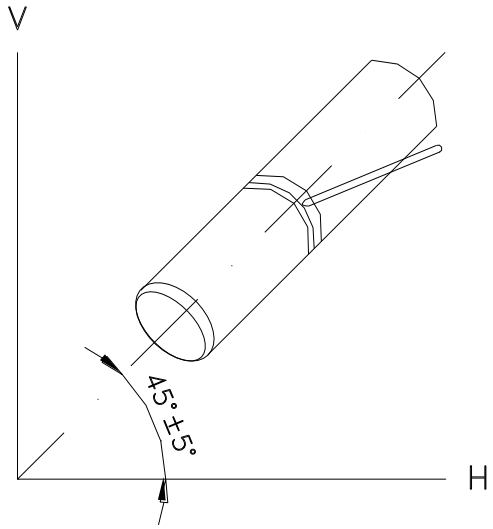
Vertical (3G)



Multipla Fixa (5G)



Sobre Cabeça (4G)



Inclinada Fixa (6G)

TABLE T.F7.205.1 – QUALIFICATION OF WELDERS (PLATING)

QUALIFICATION OF WELDERS					QUALIFICATION TESTS			SET OF TESTS
MATERIAL	CLASS		THICKNESS (mm)	POSITION QUALIFIED	TYPE	POSIITON OF WELDING	THICKNESS (mm)	BENDING GUIDED FOR EACH POSITION INVOLVED
CHAPA	A	I	LIMITLESS	ALL	AC	1 HORIZONTAL 1 VERTICAL 1 OVERHEAD	25 ~ 40	2 BENDINGS LATERAL
		II		FLAT VERTICAL OVERHEAD		1 VERTICAL 1 OVERHEAD		
		III		FLAT HORIZONTAL VERTICAL		1 HORIZONTAL 1 VERTICAL		
		IV		FLAT		1 FLAT		
	B	I	≤ 20	ALL	BC	1 HORIZONTAL 1 VERTICAL 1 OVERHEAD	10	1 BENDING OF FACE 1 BENDING OF ROOT
		II		FLAT VERTICAL OVERHEAD		1 VERTICAL 1 OVERHEAD		
		III		FLAT HORIZONTAL VERTICAL		1 HORIZONTAL 1 VERTICAL		
		IV		FLAT		1 FLAT		
PA	C	I	≤ 10	ALL	CC	1 HORIZONTAL 1 VERTICAL 1 OVERHEAD	3 ~5	1 BENDING OF FACE 1 BENDING OF ROOT
		II		FLAT VERTICAL OVERHEAD		1 VERTICAL 1 OVERHEAD		
		III		FLAT HORIZONTAL VERTICAL		1 HORIZONTAL 1 VERTICAL		
		IV		FLAT		1 FLAT		

TABLE T.F7.205.2 - QUALIFICATION OF WELDERS (TUBES)

QUALIFICATION OF WELDERS					TESTS FOR QUALIFICATION			SET OF TESTS
MATERIAL	CLASS		THICKNESS (mm)	POSITION QUALIFIED	TYPE	POSITION OF WELDING	THICKNESS (mm)	BENDING GUIDED FOR EACH POSITION INVOLVED
TUBE	A	I	LIMITLESS	ALL	AT	1 HORIZONTAL FIXED 1 MULTIPLE	≥ 20 (ϕ nom. ≥ 20mm)	4 BENDINGS SIDE
		II		FLAT		1 FLAT ROTATIONAL		
	B	I	< 20	ALL	BT	1 HORIZONTAL FIXED 1 MULTIPLE	9 ~ 11 (ϕ nom125~ 300mm)	2 BENDINGS OF FACE 2 BENDINGS OF ROOT
		II		FLAT		1 FLAT ROTATIONAL		
	C	I	< 5	ALL	CT	1 HORIZONTAL FIXED 1 MULTIPLE	4 ~ 5 (ϕ nom.80~ 150mm)	1 BENDING OF FACE 1 BENDING OF ROOT
		II		FLAT		1 FLAT ROTATIONAL		

TABLE T.F5.205.3 - RENEWAL OF THE QUALIFICATION OF WELDERS (PLATING)

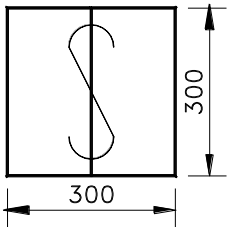
QUALIFICATION OF THE WELDER			TESTS FOR RENEWAL OF THE QUALIFICATION				
			POSITION QUALIFIED	THICKNESS (mm)	DIMENSIONS (mm)		SET OF TESTS
					BEVEL	TEST SPECIMEN	
PLATE	A	I	ALL	≥ 25	SIMPLE V OR DOUBLE V		EXAM VISUAL AND EXAM RADIOGRAPHIC
		II	FLAT VERTICAL OVERHEAD				
		III	FLAT HORIZONTAL VERTICAL				
		IV	FLAT				
	B	I	ALL	≥ 10			
		II	FLAT VERTICAL OVERHEAD				
		III	FLAT HORIZONTAL VERTICAL				
		IV	FLAT				
	C	I	ALL	3 ~ 5	I APPART 0 ~ 3 mm		
		II	FLAT VERTICAL OVERHEAD				
		III	FLAT HORIZONTAL VERTICAL				
		IV	FLAT				

TABLE T.F5.205.4 - RENEWAL OF THE QUALIFICATION OF WELDERS (TUBES)

QUALIFICATION OF THE WELDER			TESTS FOR RENEWAL OF THE QUALIFICATION			
			POSITION QUALIFIED	THICKNESS (mm)	DIMENSIONS (mm) TEST SPECIMEN	SET OF TESTS
TUBE	A	I	ALL	≥ 20 (ϕ nom. ≥ 200mm)	SEE FIGURE F.F7.205.1	EXAM VISUAL AND TEST OF PRESSURE HIDRAULIC STANDARD OF 17 BAR
		II	FLAT			
	B	I	ALL	≥ 9 (ϕ nom. ≥ 125mm)		
		II	FLAT			
	C	I	ALL	≥ 4 (ϕ nom. ≥ 80mm)		
		II	FLAT			

FIGURE F.F5.205.1 – DIMENSIONS FOR THE TEST SPECIMEN

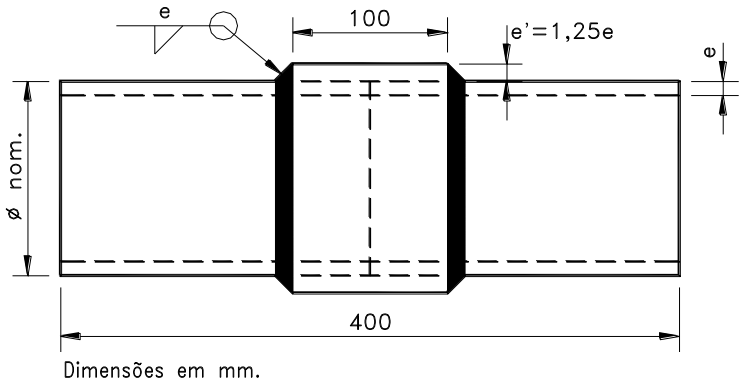
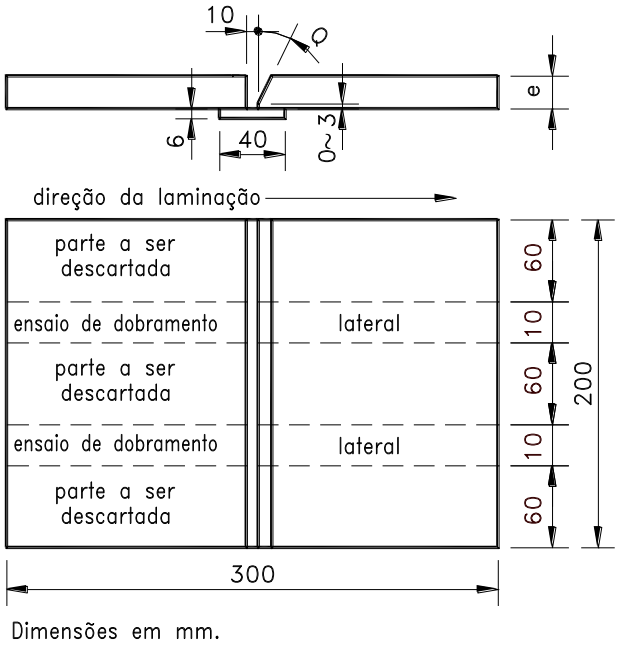


FIGURE F.F5.301.1 – TEST SPECIMEN FOR PLATES AND DETAILS OF THE JOINTS OF THE TYPES AC (“e” > 20 mm)



Notes:

1) The bevel angle will be equal to 25º when the welding test specimen is performed on FLAT or vertical position.

2) The bevel angle will be equal to 35º when the welding of the test specimen is performed in a horizontal position, being the plate without bevel placed at the top of the joint.

FIGURE F.F5.301.2 - TEST SPECIMEN FOR PLATES AND DETAILS OF THE JOINTS OF THE TYPES BC AND CC (“e” ≤ 20 mm)

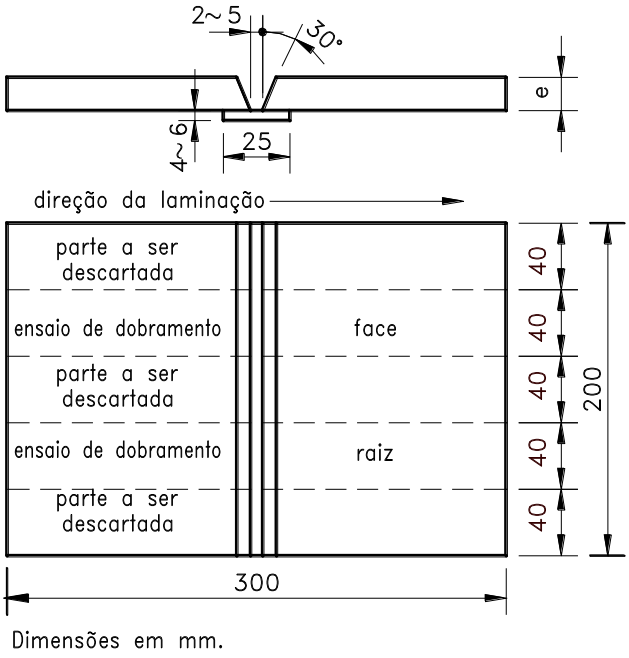
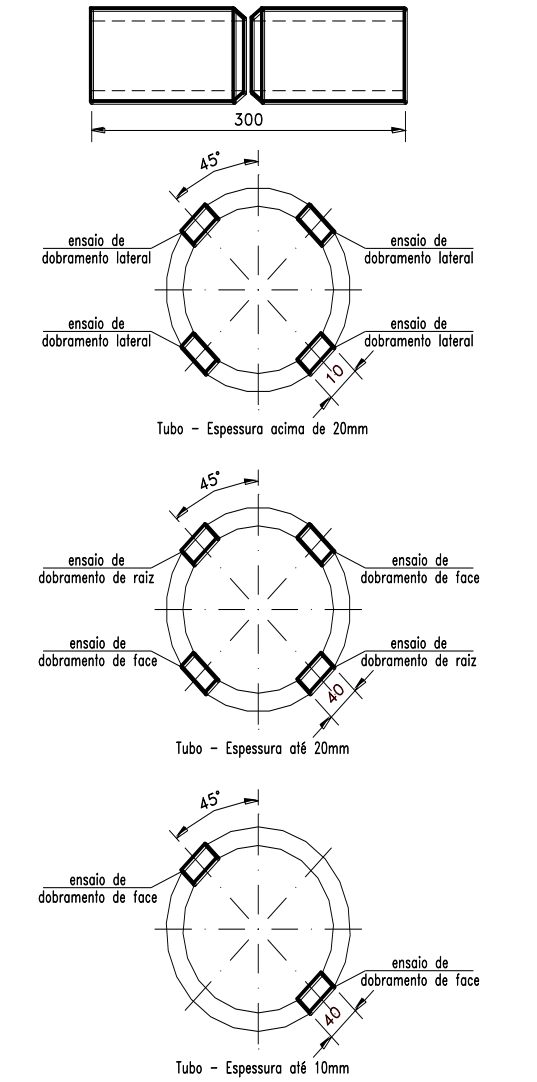
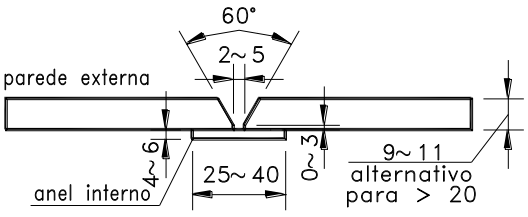
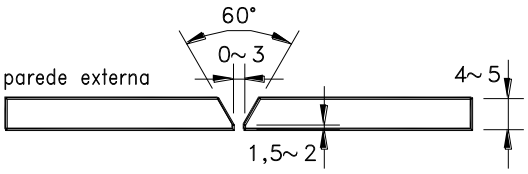


FIGURE F.F5.401.1 – SPECIMEN TESTS FOR TUBES AND DETAILS OF THE JOINTS OF THE TYPES AT, BT AND CT





Detalhe das juntas tipo AT e BT



Detalhe da junta tipo CT

CHAPTER G
ALUMINIUM ALLOYS FOR HULL CONSTRUCTION AND MARINE STRUCTURE [IACS UR W25]

CHAPTER CONTENTS

G1. APPLICATION SCOPE

100. Scope [IACS UR W25.1]

101. The requirements of this chapter apply to wrought aluminium alloys used in the construction of hulls, superstructures and other marine structures. They are not applicable to the use of aluminium alloys at low temperature for cryogenic applications.

102. These requirements are applicable to wrought aluminium alloy products within a thickness range of 3 mm and 50 mm inclusive. The application of aluminium alloys products outside this thickness range requires prior agreement of the RBNA.

103. The numerical designation (grade) of aluminium alloys and the temper designation are based on those of the Aluminium Association.

104. Temper conditions (delivery heat treatment) are defined in the European Standard EN 515 or ANSI H35.1.

105. Consideration may be given to aluminium alloys not specified in these requirements, and to alternative temper conditions, subject to prior agreement with the RBNA further to a detailed study of their properties, including corrosion resistance, and of their conditions of use (in particular welding procedures).

200. Definitions

201. Refer to Guidance for the Survey and Construction of Steel Ships, Subchapter G3, for definition of the codes for aluminium alloys (numerical code such as "*5083*"; temper conditions such as "*O/H112*"; and alloy references such as "*5xxx-alloys in the H116 and H321 tempers*".

G2. APPROVAL [IACS UR W25.2]

100. Approval

101. All materials, including semi finished products, are to be manufactured at works which are approved by the RBNA for the grades of aluminium alloy supplied.

G3. ALUMINIUM ALLOYS AND THEIR TEMPER CONDITIONS [IACS W25-3]

100. Rolled products (sheets, strips and plates)

101. The following aluminium alloys are covered by these requirements: 5083, 5086, 5383, 5059, 5754, 5456, with the hereunder temper conditions: O/H112, H116, H321.

200. Extruded products (sections, shapes, bars and closed profiles)

201. The following aluminium alloys are covered by these Requirements: 5083, 5383, 5059, 5086, with the hereunder temper conditions: O/H111/H112, and: 6005A, 6061, 6082, with the hereunder temper conditions: T5 or T6.

202. The alloy grades 6005A, 6061 of the 6000 series should not be used in direct contact with sea water unless protected by anodes and/or paint system.

G4. CHEMICAL COMPOSITION [IACS UR W25.4]

100. Chemical composition

101. The Manufacturer is to determine the chemical composition of each cast.

102. The chemical composition of aluminium alloys is to comply with the requirements given in Table T.G4.102.1.

103. The Manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyor; in particular, product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

104. When the aluminium alloys are not cast in the same works in which they are manufactured into semi finished products, the RBNA Surveyor shall be given a certificate issued by the works in question which indicates the reference numbers and chemical composition of the heats.

G5. MECHANICAL PROPERTIES [IACS UR W25.5]

101. The mechanical properties are to comply with the requirements given in Tables T.G5.101.1 and .T.G5.101.2.

102. Note: It should be recognized that the mechanical properties of the welded joint are lower for strain hardened or heat treated alloys, when compared with those of the base material, in general. For reference, see the subchapter G15.

TABLE T.G4.102.1 – CHEMICAL COMPOSITION (1)

Grade	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other elements 2)	
									Each	Total
5083	0.40	0.40	0.10	0.40-1.0	4.0-4.9	0.05-0.25	0.25	0.15	0.05	0.15
5383	0.25	0.25	0.20	0.7-1.0	4.0-5.2	0.25	0.40	0.15	0.05 5)	0.15 5)
5059	0.45	0.50	0.25	0.6-1.2	5.0-6.0	0.25	0.40-0.90	0.20	0.05 6)	0.15 6)
5086	0.40	0.50	0.10	0.20-0.7	3.5-4.5	0.05-0.25	0.25	0.15	0.05	0.15
5754	0.40	0.40	0.10	0.50 3)	2.6-3.6	0.30 3)	0.20	0.15	0.05	0.15
5456	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15
6005A	0.50-0.9	0.35	0.30	0.50 4)	0.40-0.7	0.30 4)	0.20	0.10	0.05	0.15
6061	0.40-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15	0.05	0.15
6082	0.7-1.3	0.50	0.10	0.40-1.0	0.6-1.2	0.25	0.20	0.10	0.05	0.15

Notes:
1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Includes Ni, Ga, V and listed elements for which no specific limit is shown. Regular analysis need not be made.
3) Mn + Cr: 0.10-0.60
4) Mn + Cr: 0.12-0.50
5) Zr: maximum 0.20. The total for other elements does not include Zirconium.
6) Zr: 0.05-0.25. The total for other elements does not include Zirconium.

TABLE T.G5.101.1 – MECHANICAL PROPERTIES FOR ROLLED PRODUCTS, 3 mm ≤ t ≤ 50 mm

Grade	Temper condition	Thickness, t	Yield Strength $R_{p0.2}$ min. N/mm^2	Tensile Strength R_m min. or range N/mm^2	Elongation, % min. [1]	
					$A_{50\,mm}$	A_{5d}
5083	O	3 ≤ t ≤ 50 mm	125	275-350	16	14
	H112	3 ≤ t ≤ 50 mm	125	275	12	10
	H116	3 ≤ t ≤ 50 mm	215	305	10	10
	H321	3 ≤ t ≤ 50 mm	215-295	305-385	12	10
5383	O	3 ≤ t ≤ 50 mm	145	290		17
	H116	3 ≤ t ≤ 50 mm	220	305	10	10
	H321	3 ≤ t ≤ 50 mm	220	305	10	10
5059	O	3 ≤ t ≤ 50 mm	160	330		24
	H116	3 ≤ t ≤ 20 mm	270	370	10	10
		20 < t ≤ 50 mm	260	360	10	10
	H321	3 ≤ t ≤ 20 mm	270	370	10	10
		20 < t ≤ 50 mm	260	360	10	10
5086	O	3 ≤ t ≤ 50 mm	95	240-305	16	14
	H112	3 ≤ t ≤ 12.5 mm	125	250	8	
		12.5 < t ≤ 50 mm	105	240		9
	H116	3 ≤ t ≤ 50 mm	195	275	10[2]	9
5754	O	3 ≤ t ≤ 50 mm	80	190-240	18	17
5456	O	3 ≤ t ≤ 6.3 mm	130-205	290-365	16	
		6.3 < t ≤ 50 mm	125-205	285-360	16	14
	H116	3 ≤ t ≤ 30 mm	230	315	10	10
		30 < t ≤ 40 mm	215	305		10
		40 < t ≤ 50 mm	200	285		10
	H321	3 ≤ t ≤ 12.5 mm	230-315	315-405	12	
		12.5 < t ≤ 40 mm	215-305	305-385		10
		40 < t ≤ 50 mm	200-295	285-370		10

Notes:
[1] Elongation in 50 mm apply for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.
[2] 8 % for thicknesses up to and including 6.3 mm.

TABLE T.G5.101.2 - MECHANICAL PROPERTIES FOR EXTRUDED PRODUCTS, 3 mm ≤ t ≤ 50 mm

Grade	Temper	Thickness, t	Yield Strength $R_{p0.2}$ min. N/mm^2	Tensile Strength R_m min. or range N/mm^2	Elongation, % min. [1)2)]	
					$A_{50\,mm}$	A_{5d}
5083	O	3 ≤ t ≤ 50 mm	110	270-350	14	12
	H111	3 ≤ t ≤ 50 mm	165	275	12	10
	H112	3 ≤ t ≤ 50 mm	110	270	12	10
5383	O	3 ≤ t ≤ 50 mm	145	290	17	17
	H111	3 ≤ t ≤ 50 mm	145	290	17	17
	H112	3 ≤ t ≤ 50 mm	190	310		13
5059	H112	3 ≤ t ≤ 50 mm	200	330		10
5086	O	3 ≤ t ≤ 50 mm	95	240-315	14	12
	H111	3 ≤ t ≤ 50 mm	145	250	12	10
	H112	3 ≤ t ≤ 50 mm	95	240	12	10
6005A	T5	3 ≤ t ≤ 50 mm	215	260	9	8
	T6	3 ≤ t ≤ 10 mm	215	260	8	6
		10 < t ≤ 50 mm	200	250	8	6
6061	T6	3 ≤ t ≤ 50 mm	240	260	10	8
6082	T5	3 ≤ t ≤ 50 mm	230	270	8	6
	T6	3 ≤ t ≤ 5 mm	250	290	6	
		5 < t ≤ 50 mm	260	310	10	8

Notes:
1) The values are applicable for longitudinal and transverse tensile test specimens as well.
2) Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

G6. FREEDOM OF DEFECTS [IACS UR W25.6]

100. Fredom from defects

101. The finished material is to have a workmanlike finish and is to be free from internal and surface defects prejudicial to the use of the concerned material for the intended application.

102. Slight surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in subchapter G7.

G7. TOLERANCES [IACS UR W25.7]

100. Tolerances

101. The underthickness tolerances for rolled products given in Table T.G7.101.1 are minimum requirements.

TABLE T.G7.101.1 – UNDERTHICKNESS TOLERANCES FOR ROLLED PRODUCTS

Nominal thickness (t), mm	Thickness tolerances for nominal width (w), mm		
	$w \le 1500$	$1500 < w \le 2000$	$2000 < w \le 3500$
$3.0 \le t < 4.0$	0.10	0.15	0.15
$4.0 \le t < 8.0$	0.20	0.20	0.25
$8.0 \le t < 12.0$	0.25	0.25	0.25
$12.0 \le t < 20.0$	0.35	0.40	0.50
$20.0 \le t < 50.0$	0.45	0.50	0.65

102. The underthickness tolerances for extruded products are to be in accordance with the requirements of recognized international or national standards.

103. Dimensional tolerances other than underthickness tolerances are to comply with a recognized national or international standard.

G8. TESTING AND INSPECTION [IACS UR W25.8]

100. Tensile test

101. The test specimens and procedures are to be in accordance with Part III, Title 61, Secton 2, Chapter A.

200. Non-destructive examination.

201. In general, the non-destructive examination of material is not required for acceptance purposes.

202. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

300. Dimensions

301. It is the manufacturer's responsibility to check the materials for compliance with the tolerances given in Subchapter G7.

400. Verification of proper fusion of press welds for closed profiles

401. The Manufacturer has to demonstrate by macrosection tests or drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

402. Drift expansion tests:

a. Every fifth profile shall be sampled after final heat treatment. Batches of five profiles or less shall be sampled one profile. Profiles with lengths exceeding 6 m shall be sampled every profile in the start of the production. The number of tests may be reduced to every fifth profile if the results from the first 3-5 profiles are found acceptable.

b. Each profile sampled will have two samples cut from the front and back end of the production profile.

c. The test specimens are to be cut with the ends perpendicular to the axis of the profile. The edges of the end may be rounded by filing.

d. The length of the specimen is to be in accordance with Part Iii, Title 61, Secton 2, Chapter A.

e. Testing is to be carried out at ambient temperature and is to consist of expanding the end of the profile by means of a hardened conical steel mandrel having an included angle of at least 60°.

f. The sample is considered to be unacceptable if the sample fails with a clean split along the weld line which confirms lack of fusion.

500. Corrosion testing

501. Rolled 5xxx-alloys of type 5083, 5383, 5059, 5086 and 5456 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

502. The manufacturers shall establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x (*refer to Guidance for the Survey and Construction of Steel Ships, Chapter G3*), shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than 15mg/cm2, when subjected to the test described in ASTM G67. Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by the RBNA. Production practices shall not be changed after approval of the reference micrographs. Other test methods may also be accepted at the discretion of the RBNA.

G9. TEST MATERIALS [IACS UR W25.9]

100. Definition of batches

101. Each batch is made up of products:

a. of the same alloy grade and from the same cast;

b. of the same product form and similar dimensions (for plates, the same thickness);

c. manufactured by the same process;

d. having been submitted simultaneously to the same temper condition.

102. The test samples are to be taken:

a. at one third of the width from a longitudinal edge of rolled products;

b. in the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.

103. Test samples are to be taken so that the orientation of test specimens is as follows:

a. Rolled products: Normally, tests in the transverse direction are required. If the width is insufficient to obtain transverse test specimen, or in the case of strain hardening alloys, tests in the longitudinal direction will be permitted.

b. Extruded products:The extruded products are tested in longitudinal direction.

104. After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

G10. MECHANICAL TEST SPECIMENS [IACS UR W25.10]

100. Type and location of tensile test specimen

101. The type and location of tensile test specimens are to be in accordance with chapter A.

G11. NUMBER OF TEST SPECIMENS [IACS UR W25.11]

100. Tensile test

101. Rolled products: one tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 kg, one extra tensile test specimen is to be taken from every 2000 kg of the product or fraction thereof, in each batch. For single plates or for coils weighting more than 2000 kg each, only one tensile test specimen per plate or coil shall be taken.

102. Extruded products: for the products with a nominal weight of less than 1 kg/m, one tensile test specimen is to be taken from each 1000 kg, or fraction thereof, in each batch. For nominal weights between 1 and 5 kg/m, one tensile test specimen is to be taken from each 2000 kg or fraction hereof, in each batch. I f the nominal weight exceeds 5 kg/m, one tensile test specimen is to be taken for each 3000 kg of the product or fraction thereof, in each batch.

200. Verification of proper fusion of press welds

201. For closed profiles, verification of proper fusion of press welds is to be performed on each batch as indicated in G8.400 above.

300. Corrosion tests

301. For rolled plates of grade 5083, 5383, 5059, 5086 and 5456 delivered in the tempers H116 or H321, one sample is to be tested per batch.

G12. RETEST PROCEDURES [IACS UR W25.12]

100. Retest procedures

101. When the tensile test from the first piece selected in accordance with **G11.100** fails to meet the requirements, two further tensile tests may be made from the same piece. If both of these additional tests are satisfactory, this piece and the remaining pieces from the same batch may be accepted.

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

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

G13. BRANDING [IACS UR W25.13]

100. Branding

101. The manufacturer shall mark each product at least one place with the following details:

a. Manufacturer's mark

b. Abbreviated designation of aluminium alloy according to G3;

c. Abbreviated designation of temper condition according to G3;

d. Tempers that are corrosion tested in accordance with G8.500 are to be marked "M" after the temper condition, e.g. 5083 H321 M.

e. Number of the manufacturing batch enabling the manufacturing process to be traced back.

102. The product is also to bear the RBNA's brand.

103. When extruded products are bundled together or packed in crates for delivery, the specified marking should be affixed by a securely fastened tag or label.

G14. DOCUMENTATION [IACS UR W25.14]

100. Documentation

101. For each tested batch, the manufacturer must supply to the RBNA's Surveyor a test certificate, or a shipping statement containing the following details:

a. Purchaser and order number;

b. Construction project number, when known;

c. Number, dimensions and weight of the product;

d. Designation of the aluminum alloy (grade) and of its temper condition (delivery heat treatment);

e. Chemical composition;

f. Manufacturing batch number or identifying mark;

g. Test results.

G15. REQUIREMENTS FOR WELDING CONSUMABLES FOR ALUMINIUM ALLOYS [IACS UR W26]

100. Scope

101. These requirements give the conditions of approval and inspection of welding consumables to be used for hull construction and marine structure aluminium alloys according to G1 to G14. Where no special requirements are given herein, e.g. for the approval procedure or for the welding of test assemblies and testing, those of Chapter E apply in analogous manner.

102. The welding consumables preferably to be used for the aluminium alloys concerned are divided into two categories as follows:

W = wire electrode - and wire - gas combinations for metal-arc inert gas welding (MIG, 131 acc. to ISO 4063), tungsten inert gas arc welding (TIG, 141) or plasma arc welding (15)

R = rod - gas combinations for tungsten inert gas arc welding (TIG, 141) or plasma arc welding (15)

200. Grading, Designation

201. The consumables concerned are graded as mentioned in **T G15.201.1**, in accordance with the alloy type and strength level of the base materials used for the approval tests.

TABLE T G15.201.1 - CLASSIFICATION OF CONSUMABLES

Consumable quality grade (Symbol)	Base material for the tests	
	Alloy Designation	
	Numerical	Chem. symbol
RA/WA	**5754**	AlMg3
RB/WB	**5086**	AlMg4
RC/WC	**5083**	AlMg4.5Mn0,7
	5383	AlMg4.5Mn0.9
	5456	AlMg5
	5059	-
RD/WD	**6005A**	AlSiMg(A)
	6061	AlMg1SiCu
	6082	AlSi1MgMn
Note: Approval on higher strength AlMg base materials covers also the lower strength AlMg grades and their combination with AlSi grades		

202. Approval of a wire or a rod will be granted in conjunction with a specific shielding gas acc. to **T G15.202.1** or defined in terms of composition and purity of "special" gas to be designated with group sign "S". The composition of the shielding gas is to be reported. The approval of a wire or rod with any particular gas can be applied or transferred to any combination of the same wire or rod and any gas in the same numbered group as defined in **T G15.202.1**, subject to the agreement of the RBNA.

TABLE T G15.202.1 – GAS COMPOSITION

Group	Gas composition (Vol. %) [1]	
	Argon	Helium
I - 1	100	---
I - 2	---	100
I - 3	Rest	> 0 to 33
I - 4	Rest	> 33 to 66
I - 5	Rest	> 66 to 95
S	Special gas, composition to be specified, see 1.2.2	
[1] Gases of other chemical composition (mixed gases) may be considered as „special gases" and covered by a separate test.		

300. Manufacture, testing and approval procedure

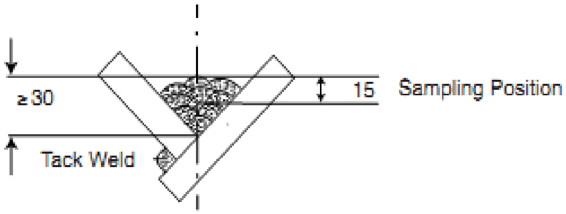
301. Manufacturer's plant, production methods and quality control measures shall be such as to ensure reasonable uniformity in manufacture, see also Chapter E.

302. Testing and approval procedure shall be in accordance with subchapter E2 and E3, and as required in chapter E for the individual categories (types) of welding consumables, shielding gases and their mixtures mentioned in G15.102 above.

400. Testing of the deposited weld metal

401. For the testing of the chemical composition of the deposited weld metal, a test piece according to **FIGURE F G15.401.1** shall be prepared. The size depends on the type of the welding consumable (and on the welding process) and shall give a sufficient amount of pure weld metal for chemical analysis. The base metal used shall be compatible with the weld metal in respect of chemical composition.

FIGURE F.G15.401.1 - DEPOSITED WELD METAL TEST ASSEMBLY



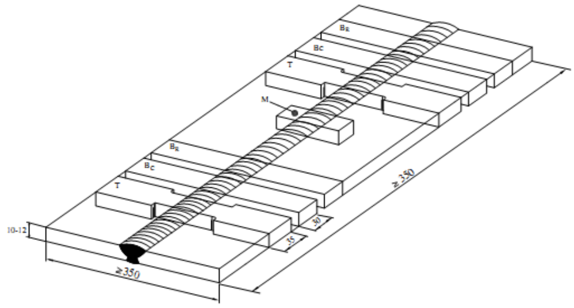
402. The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in subchapter E5.703. The results of the analysis shall not exceed the limit values specified by the manufacturer.

500. TESTING OF BUTT WELD ASSEMBLIES

501. The testing of the welded joints shall be performed on butt-weld test assemblies according to Figure **F G15.502.1** and Figure **F G15.503.1**, made from materials as given in Table **T G15.201.1**, in an analogous manner to subchapter E4.300, E5.705, E5.805 e E5.902.

502. Butt weld test assemblies according to **FIGURE F. G15.502.1** with a thickness of 10 to 12 mm are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position subject to the agreement of the RBNA.

FIGURE F.G15.502.1 - BUTT WELD TEST ASSEMBLY FOR POSITIONAL WELDING



Notes: 1) Edge preparation is to be single V or double V with 70° angle.
2) Back sealing runs are allowed in single V weld assemblies.
3) In case of double V assembly both sides shall be welded in the same welding position.

503. Additionally one test assembly according to **F. G15.503.1** with a thickness of 20 to 25 mm is to be welded in the downhand position only.

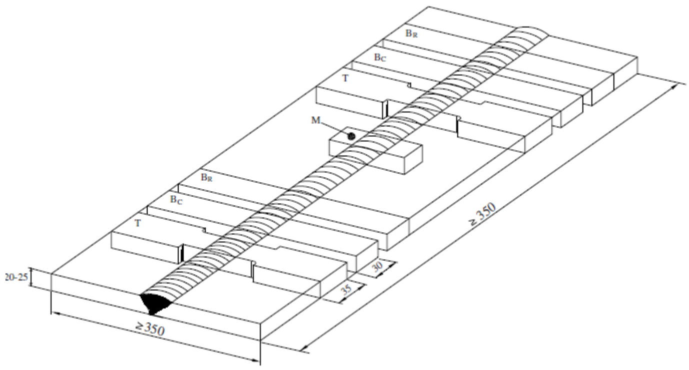
T = Flat tensile test specimen

BC = Face bend test specimen

BR = Root bend test specimen

M = Macrographic section

FIGURE F.G15.503.1 – ADDITIONAL BUTT WELD ASSEMBLY IN DOWNHAND POSITION



Notes:
1) Edge preparation is to be a single V with 70° angle.
2) Back sealing runs are allowed.

504. On completion of welding, assemblies must be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens must not be subjected to any heat treatment. Grade D assemblies should be allowed to naturally ageing for a minimum period of 72 hours from the completion of welding before testing is carried out.

505. The test specimens shown in **FIGURE F.G15.502.1** and **FIGURE F.G15.503.1** and described in

chapter E shall be taken from the butt weld test assemblies.

506. The mechanical properties must meet the requirements stated in TABLE **T G15.506.1**. The provisions of chapter E apply in analogous manner to the performance of the tests, including the requirements regarding the annual repeat tests and retesting. The position of the fractures is to be stated in the report. The macrographic specimen shall be examined for imperfections such as lack of fusion, cavities, inclusions, pores or cracks.

TABLE T G15.506.1 – REQUIREMENTS FOR THE TRANSVERSE TENSILE AND BEND TESTS

Grade	Base material used for the test	Tensile strength R_m [N/mm²] min.	Former diameter	Bending angle[1] [°] min.
RA/WA	5754	190	3t	180
RB/WB	5086	240	6t	
RC/WC	5083	275	6t	
	5383 or 5456	290	6t	
	5059	330	6t	
RD/WD	6061. 6005A or 6082	170	6t	

Note: [1] During testing, the test specimen shall not reveal any one single flaw greater than 3 mm in any direction. Flaws appearing at the corners of a test specimen shall be ignored in the evaluation, unless there is evidence that they result from lack of fusion.

600. Annual repeat tests

601. The annual repeat tests shall entail the preparation and testing of the deposited weld metal test assembly as prescribed under **(FIGURE F.G15.401.1)** and of the downhand butt weld test assembly according to **(FIGURE F.G15.502.1)**.

CHAPTER H
APPROVAL OF WELDING CONSUMABLES FOR HIGH STRENGTH QUENCHED AND TEMPERED STEELS FOR WELDED STRUCTURE [IACS UR W23]

CHAPTER CONTENTS

H1. GENERAL

100 Scope

101. These requirements supplements the chapter E and give the conditions of approval and inspection of welding consumables used for high strength quenched and tempered or TMCP steels for welded structures according to chapter B with yield strength levels from 420 N/mm^2 up to 690 N/mm2 and impact grades A, D, E and F.
Where no special requirements are given, those of chapter E apply in analogous manner.

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

a. covered electrodes for manual welding;

b. wire-flux combinations for multirun submerged arc welding;

c. solid wire-gas combinations for arc welding (including rods for gas tungsten arc welding);

d. flux cored wire with or without gas for arc welding.

103. Wire-flux combinations for single or two-run technique are subject to special consideration of the RBNA.

200 Grading, Designation

201. Based on the yield strength of the weld metal, the welding consumables concerned are divided into six (yield) strength groups :

a. Y42 - for welding steels with minimum yield strength 420 N/mm^2

b. Y46 - for welding steels with minimum yield strength 460 N/mm^2

c. Y50 - for welding steels with minimum yield strength 500 N/mm^2

d. Y55 - for welding steels with minimum yield strength 550 N/mm^2

e. Y62 - for welding steels with minimum yield strength 620 N/mm^2

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

202. Each of the six (yield) strength groups is further divided into three main grades in respect of charpy V-notch impact test requirements (test temperatures):

a. Grade 3, test temperature -20^{oC}

b. Grade 4, test temperature -40^{oC}

c. Grade 5, test temperature -60^{oC}

203. Analagously to the designation scheme used in chapter E the welding consumables for high strength quenched and tempered steels are subject to classification designation and approval as follows:

a. According to G15.102 with the quality grades 3, 4 or 5;

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

c. With the added symbol H10 (HH) or H5 (HHH) for controlled hydrogen content of the weld metal;

d. With the added symbol S (= semi-automatic) for semi-mechanised welding;

e. With the added symbol M designating multirun technique and is applicable only to welding consumables for fully mechanised welding.

204. Each higher quality grade includes the one (or those) below Grade A. and D. steels acc. to subchapter B4 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 T.H1.204.1.

TABLE T.H1.204.1 – GRADE

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

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

206. The RBNA 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.

300. Manufacture, testing and approval procedure

301. Manufacturer's plant, production methods and quality control measures shall be such as to ensure reasonable uniformity in manufacture, see also chapter E.

302. Testing and approval procedure shall be in accordance with subchapter E2 and E3 and as required in chapter E for the individual categories (types) of welding consumables mentioned in H1.102 above.

H2. TESTING OF THE WELD METAL

100. Test of the deposited weld metal

101. For testing the deposited weld metal, test pieces analogous to those called for in subchapter E, E4.200, E5.200, E5.700, E5.800 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.

102. The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in subchapter E, E4.203. 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.

103. Depending on the type of the welding consumables (and according to the welding process), the test specimens prescribed in subchapter E3.100, E4.200, E5.200, E5.700 or E5.800 respectively shall be taken from the weld metal test pieces in a similar manner.

104. The mechanical properties must meet the requirements stated in T.H2.104.1 and T.H2.104.2. The provisions of chapter E 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 T.H2.104.1- 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
4	- 40	
5	- 60	

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

TABLE T.H2.104.2 - REQUIRED STRENGTH PROPERTIES OF THE WELD METAL

Symbols added to quality grade	Minimum yield strength or 0.2% proof stress [N/mm²]	Tensile Strength 1) [N/mm²]	Minimum elongation [%]
Y42	420	530-680	20
Y46	460	570-720	20
Y50	500	610-770	18
Y55	550	670-830	18
Y62	620	720-890	18
Y69	690	770-940	17

1) The tensile strength of the weld metal may be up to 10% below the requirements, provided that the results obtained with the transverse tensile specimens taken from the welded joints meet the minimum tensile strength requirements stated in Table 3. The elongation is to be stated in the test report.

Note:
For welding very large plate thicknesses where the "supporting effect" of the base material on either side of the weld no longer applies and the tensile strength of the weld metal also determines the tensile strength of the welded joint, it may be necessary, when applying footnote 1), to choose welding consumables of the next higher strength category (next higher added Symbol).

H3. TESTING ON WELDED JOINTS

100. Requirements

101. 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 subchapter E, E4.300, E5.200, E5.700, E5.800 or E5.900.

102. Depending on the type of the welding consumables (and according to the welding process), the butt-weld test pieces called for in item 101shall be welded in a manner analogous to that prescribed in Part III, Title 61, Section 2, Chapter E. The base metal used shall be a high-strength fine-grained structural steel with an appropriate minimum yield strength and tensile strength and compatible with the added symbol for which application is made.

103. Depending on the type of the welding consumables (and according to the welding process), the test specimens described in chapter E shall be taken from the butt-weld test pieces.

104. The mechanical properties must meet the requirements stated in Table T.H3.104.1. The provisions of chapter E 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 T.H3.104.1- REQUIRED PROPERTIES OF WELDED JOINTS

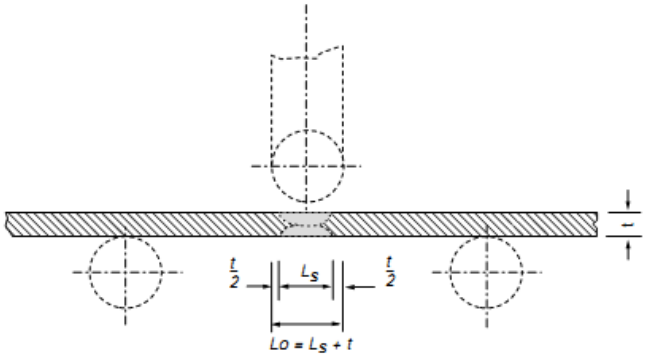
Quality grade	Added symbol	Minimum tensile strength [N/mm^2]	Minimum notch impact energy, test temperature	Minimum bending angle 1)	Bend ratio D/t 2)
3 to 5 accordance with Table 1	Y42	530	Depending on the quality grade & yield strength in accordance Table 1	120º	4
	Y46	570			4
	Y50	610			4
	Y55	670			5
	Y62	720			5
	Y69	770			5

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

2) D = Mandrel diameter, t = specimen thickness

105 Where the bending angle required in Table T.H3.104.1 is not achieved, the specimen may be considered as fulfilling the requirements, if the bending elongation on a gauge length length Lo fulfills the minimum elongation requirements stated in Table T.H2.104.2. The gauge length Lo = Ls + t (Ls = width of weld, t = specimen thickness), see figure F.H3.105.

FIGURE F.H3.105.1- GAUGE LENGTH



H4. HYDROGEN TEST

100. Requirements

101. 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.

102. The diffusible hydrogen content of the weld metal determined in accordance with the provisions of subchapter E, E4.600 shall not exceed the limits given in table T.H4.102.1.

TABLE T.H4.102.1 – Allowable diffusible hydrogen content

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

H5 ANNUAL REPEAT TEST

100. Geral

101. The annual repeat tests specified in Chapter E5 item 500 shall entail the preparation and testing of weld metal test pieces as prescribed under H2. In special cases, the RBNA may require more extensive repeat tests.

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